MORPHOLOGICAL RECONSTRUCTION OF THE KIMBERLEY-ELSBURG SERIES, WITH SPECIAL REFERENCE TO THE KIMBERLEY GROUP OF SEDIMENTS IN THE EAST RAND BASIN.

BY :

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Pectora roborant cultus recti

Thesis submitted for the Degree of Doctor of Science in the University of Stellenbosch - July 1952

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SUMMARY

The ideal geological column of the Kimberley-Elsburg Series in the East Rand Basin is described, with particular reference to the Kimberley group of sediments.

A system of nomenclature has been devised, and it is suggested that it could also be used in other parts of the large structural basin, stretching from Johannesburg in the north to near Theunissen in the south, and from Klerksdorp in the west to Greylingstad in the east.

The stratigraphy of individual areas in the East Rand Basin is described in detail, and it is shown that certain stratigraphic units display a remarkable regularity, maintaining their lithological characteristics over large areas, persisting also into the Greylingstad-Balfour district, the Central Rand, the West and Far West Rand, the Klerksdorp area, and into the Orange Free State gold field.

In the East Rand Basin the May Reef is the principal gold carrier, and is of economic importance in certain mines. In the Orange Free State gold field the lowermost Kimberley reef is also of economic importance.

Three regional unconformities have been recognised in the part of the column extending from below the Kimberley Shales to above the May Reef. The May Reef covers the upper one, and owes its existence to this period of erosion. The history of this reef could be traced back to its parent rocks, in this case, stratigraphically older auriferous gravels. The author believes that the unconformity below the May Reef developed as a result of sub-aqueous erosion. The oldest erosion surface probably developed in the same way. The middle one developed largely on the land, but was subsequently submerged.

It is concluded that the sediments of the Kimberley-Elsburg Series were deposited in the marine neritic environment, i.e. in a sea of substantial but not excessive depth.

A few remarks have been added on the metamorphism of the System. An interesting feature in this connection is the occurrence of ubiquitous authigenic rutile in the form of minute needles and knee-shaped twins. It appears that the rutile developed as a stress mineral, ilmenite having been the original detrital constituent.

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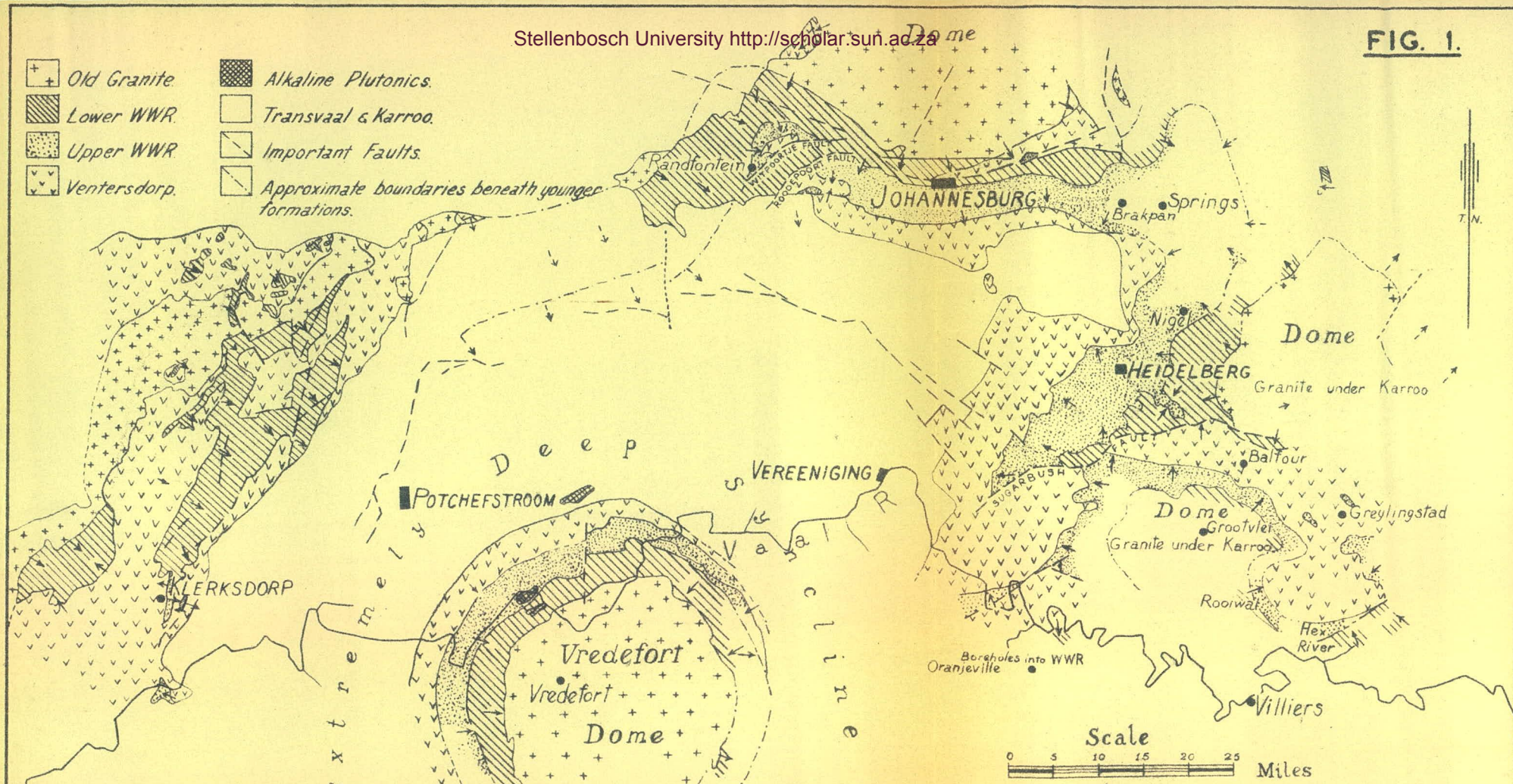
FIG. 1.



DISTRIBUTION OF THE WITWATERSRAND AND VENTERSDORP SYSTEMS TO THE SOUTH OF THE RAND.

After A. L. du Toit. Not all detail shown.

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I. INTRODUCTION.

A. General:

Location of the Area:

The East Rand Basin is part of the Witwatersrand gold field, the centre of the area lying near Dunnottar, some 25 miles to the east of the city of Johannesburg. The area studied in detail (sub-surface geology) measures approximately 22 miles along a north-south line, and about half that distance along an east-west line. The village of Heidelberg is situated near the southern edge of the Basin (figure 1).

The Regional Basin:

The Witwatersrand System with its auriferous deposits in the upper division has now been traced for a distance of some 200 miles to the south of Johannesburg to near Theunissen in the Orange Free State. In the Orange Free State gold field the rocks of the Witwatersrand System are nearly everywhere covered by younger formations.

Along an east-west line this large structural basin is defined by intermittent outcrops from around Klerksdorp in the west to Greylingstad in the east, a distance of approximately 150 miles.

Physical Features of the Witwatersrand:

The general elevation of the Witwatersrand area is considerable, very little of it falling below 5,000 feet above sea level. Some of the highest points lie within the township of Johannesburg itself, reaching nearly 6,000 feet. The Witwatersrand is part of the High Veld of the Southern Transvaal, and forms part of one of the main watersheds of the sub-continent. The northward flowing streams drain ultimately to the Indian Ocean, and the southward flowing streams find their way to the Atlantic. (Mellor (25) and Rogers (34)).

Age of the System:

"The System is not fossiliferous, and is in all probability of Pre-Cambrian age" - Reynecke (33).

B. The Thesis:

The investigation was started in April, 1944, with a view to assess the economic possibilities of the Kimberley group of conglomerates.

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Some of the gold mines on the Rand have been exploiting for many years the principal auriferous reefs at and near the junction of the upper and lower divisions of the System, and are now approaching old age. Some have been forced to close down. During recent years more and more attention has therefore been directed to the so-called "lesser" reefs, notably the Kimberley Reefs and Bird Reefs. A fair amount of success has been achieved in some areas.

As a result of the drilling programmes carried out during the past eight years in the East Rand area, largely under the supervision of New Consolidated Gold Fields, Limited, and as a result of the extensive underground development carried out by various companies, a great amount of information has accumulated. The author also had the opportunity to describe the boreholes drilled on the Marievale and Nigel Mines.

For purposes of description and argument, and based mainly on lithological and economic grounds, the East Rand Basin is divided into two sectors, a western and an eastern (plate XIII). The dividing line runs northward through the middle of the Nigel Mine, through a point not far east of Vogelstruisbult No.3 Shaft, thence through Springs Mines in a north-westerly direction, and then through a point somewhere east of Government Gold Mining Areas. The geological history of the Kimberley-Elsburg Series in the two sectors is however fundamentally the same.

While the East Rand Basin yielded sufficient information for a comprehensive treatise, one has to look further afield for the solution of various aspects of the problem. The investigation was therefore also carried into other areas : the Greylingstad-Balfour district lying to the south-east of Heidelberg, the Central Rand, the West Rand (Randfontein-Krugersdorp), the Far West Rand (i.e. the area around the Blyvooruitzicht Mine), the Klerksdorp area, and the area immediately to the south and south-east of Odendaalsrus in the Orange Free State. For evidence from the West Rand and Klerksdorp areas the author had to depend entirely on the literature.

The results of this regional investigation have exceeded expectations. It can now be stated with confidence that a regional correlation of individual stratigraphic units within the Kimberley-Elsburg Series exists.

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In this endeavour to unravel the depositional history of the Kimberley-Elsburg Series on a regional basis, the results of the investigation in the East Rand Basin are used as a key to the solution of the problem over the entire structural basin. In this connection should be mentioned the pioneering work of Sharpe (36) on Government Gold Mining Areas. In the pages that follow, much attention is therefore paid to a great amount of detailed observation and deduction in the East Rand Basin.

Twenty-one years ago Reynecke (33) stated that a study of the origin of the sediments of the Witwatersrand System appears to be the most useful line along which an investigation into the mode of distribution of the gold in the reefs can proceed. The succeeding years have added force to his opinion, which to-day is universally accepted by stratigraphers and sedimentationists on the Rand.

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II. HISTORICAL REVIEW.

A. Mining and Prospecting of the Kimberley Reefs

(a) Greylingstad-Balfour District:

This area is separated from the East Rand Basin by the Sugarbush Fault, which has a considerable downthrow to the south (figure 1).

In 1936 G. Carleton Jones (22) correlated what appeared at the time to be the only surviving member of the Kimberley conglomerate group in the area south-east of Heidelberg with the highly payable intersection of Kimberley reef in the Daggafontein No. 3 Shaft.

Kimberley reef was mined south of Greylingstad and Balfour since before the Boer War, and following the abandonment of the Gold Standard by the Union in 1932, considerable activity again took place in this district, and several small mining companies, notably the East Nigel Gold Areas, Limited, East Wits Gold Mining Areas, Limited, New Rand Reefs, Limited and South-East Wits Gold Mining Company, Limited, carried out extensive development between 1933 and 1936 on what subsequently proved to be the May Reef. A portion of the former New Rand Reefs and South-East Wits was worked for a short period a few years ago under the name of the Hex River Gold Areas, Limited.

Westwards from the Greylingstad-Balfour sector the Kimberley reefs increase in number and robustness, forming conspicuous outcrops in the Malanskraal-Tweefontein area. Prospect trenches and pits are particularly numerous on Malanskraal, but an economic horizon was apparently not discovered.

(b) The West Rand:

This is the Randfontein-Krugersdorp area lying immediately to the north-west of the Witpoortje Fault.

In 1936 G. Carleton Jones (22) briefly described the Kimberley reefs in this part of the Witwatersrand gold field: Luipaardsvlei Estates was exploiting the Battery Reef, West Rand Consolidated Mines the Pay Band or Battery Pay Band, and Randfontein Estates the Horsham Reef and Lindum Reef. Jones considered the Battery Reef, Battery Pay Band and the Horsham Reef to be one and the same horizon.

(c) The East Rand Basin:

1. Outcrop Areas.

/The Kimberley .....

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The Kimberley reefs make conspicuous outcrops between Nigel and Heidelberg, and have been prospected extensively in the past, the more robust conglomerates having received the most attention.

Nigel Mine has done some prospecting in the outcrop areas during the past few years.

A number of closed-in pits were discovered a few years ago near the May Reef outcrop in the southern portion of the Vogelstruisbult Mine, close to the common boundary with Marievale. On being re-opened it was found that some of them actually intersected the May Reef some 30 to 50 feet below the surface, and that at the bottom of one of the pits a winze followed the reef for a short distance. It appears that this prospecting must have been done many years ago, when the search for the extension of the Main Reef Group was in progress. Dating from about this same period is an old incline shaft in the Draaikraal sector of the Marievale Mine (plate XIII).

2. Mines of the Anglo American Corporation.

The East Rand mines of the Anglo American Corporation (Brakpan in the west to East Daggafontein in the east) started active prospecting of the Kimberley reefs about 1936, and between the years 1937 and 1943 a total distance of some 43,000 feet of boreholes was drilled from surface in this area (Jeppe (21)).

A considerable amount of Kimberley reef development has been done on both Daggafontein and East Daggafontein, which has resulted in the delimitation of important pay shoots on the May Reef. Springs Mines achieved a small amount of success in the north-eastern corner of the property.

3. Government Gold Mining Areas (Johannesburg Consolidated Investment Company).

During the period 1937 to 1943 Government Gold Mining Areas drilled a great many boreholes in exploration of the Kimberley group of conglomerates. They disclosed some very interesting values on the May Reef, and sporadic payable values on a few other bands.

4. Vogelstruisbult Mine (New Consolidated Gold Fields).

Following on the good results on Daggafontein and East Daggafontein Mines, Vogelstruisbult started underground development from their No.1 Shaft early in 1940, and after an initial period of poor results in the

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immediate vicinity of the shaft, decided to advance a haulage eastwards, which resulted in the delimitation of important pay shoots.

Eleven boreholes were subsequently drilled in the outcrop area near the common boundary with the Marievale Mine, and a haulage advanced eastwards from No. 2 Shaft.

5. Nigel and Marievale Mines (the latter belonging to the Union Corporation Group) followed soon, initially by a period of drilling, and subsequently by underground development.

6. The Western East Rand.

During the years 1944 to 1949 a comprehensive drilling programme was carried out in the area from Vlakfontein Mine in the north to Witwatersrand Nigel near Heidelberg in the south, under the supervision of New Consolidated Gold Fields.

A small amount of underground development has been done on Sub Nigel, Vlakfontein and West Vlakfontein.

(d) The Far West Rand:

The May Reef and its characteristic footwall horizons have been recognised in borehole E.9.H near Blyvooruitzicht Mine on the Far West Rand.

B. Literature

(a) Rogers (34) briefly described the geology of the Kimberley-Elsburg Series in the East Rand area, based mainly on field observations.

(b) du Toit (15) remarks on the geology of the Kimberley-Elsburg Series.

(c) In 1943 Sharpe (36) published a paper based on the results of the extensive drilling programme carried out on Government Gold Mining Areas, in which he suggested sub-divisions and a system of nomenclature, which subsequently proved of invaluable service to many of the East Rand mines.

(d) In 1949 Sharpe (37) published another paper, suggesting a mode of deposition for the rocks of the Upper Witwatersrand System, based partly on his observations of the Kimberley-Elsburg Series on Government Gold Mining Areas. Replying to a discussion on his paper by the present author (10), Sharpe produced more interesting information,

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casting light on the origin of the rocks of this System.

(e) In 1950 Whiteside (44) published a paper on the geology of the Kimberley-Elsburg Series in the East Rand mines of the Anglo American Corporation.

(f) Recent publications on the geology of the Upper Witwatersrand System in the Orange Free State and Klerksdorp areas make reference to the Kimberley-Elsburg Series.

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III. BRIEF REVIEW OF THE WITWATERSRAND SYSTEM IN THE EAST RAND BASIN, WITH SPECIAL REFERENCE TO THE UPPER DIVISION.

Broadly the System is divided into an upper and a lower division, based partly on the difference in lithology, and partly on the fact that a period of erosion preceded the deposition of the only surviving member of the Main Reef Group. This reef lies at the junction of the competent quartzites of the upper division, and the incompetent shales of the lower division (plates I and II).

The upper division, which in the areas of maximum development reaches a thickness of little over 5,000 feet in the East Rand Basin, includes one persistent shale zone up to 500 feet thick, and a less persistent chloritoid-bearing shale zone a little higher up in the geological column. It includes also a zone of amygdaloidal lava, varying in positional distance from a few feet to several hundred feet below the Kimberley Shales.

The upper division is divided into the Main-Bird Series and the Kimberley-Elsburg Series, the Elsburg group of conglomerates occurring at the top of the System. In the past, the upper limit of the Main-Bird Series was generally placed at the base of the Kimberley Shales, but in view of the fact that the passage upward into the Kimberley Shales is a gradual one, and because it is considered that the lowermost Kimberley reef lies unconformably on the Kimberley Shale Zone, it appears logical to group the latter with the Main-Bird Series.

The Kimberley-Elsburg Series is therefore initiated by coarse sediments, including one inconstant shale zone (often chloritoid-bearing) as described above. The Series is on the average 3,100 feet thick in the Western East Rand, but in the eastern sector no full measurement is available due to the periods of erosion that preceded the deposition of the rocks of the Transvaal and Karroo Systems (plates I and II).

The Kimberley conglomerate group occurs in the lower third of the Series and has an average thickness of 1,000 feet in the western sector and 800 in the eastern sector.

The Elsburg conglomerate group has an average thickness of 700 feet in the East Rand Basin.

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The System has been metamorphosed regionally, an interesting feature in this connection being the occurrence of ubiquitous authigenic rutile in the form of minute crystals frequently twinned, and in crystal aggregates, generally in greater abundance in the more argillaceous phases.

The Kimberley Economic Zone

The Kimberley Economic Zone is defined as the series of sediments extending from the top of the '80' Foot Marker to the Bottom Reef on the Kimberley Shale Zone. The May Reef is the principal gold carrier in this series, although the top band of the '80' Foot Marker gave sporadic payable values on Government Gold Mining Areas, while the Bottom Reef is of economic importance in parts of the Orange Free State gold field.

The Kimberley Economic Zone embraces the lower half of the Kimberley conglomerate group (plates I and II). The different stratigraphic units display a remarkable regularity, maintaining their lithological characteristics over large areas. The thicknesses of the individual units are, however, often extremely variable. Most of the conglomerate horizons and groups have been recognised both in the western and eastern sectors. Exceptions to these general rules are :

1. One of the most constant footwall conglomerates of the May Reef in the Western East Rand disappears eastwards, and has thus far not been encountered in the eastern sector.
2. The other exception concerns a suite of sediments which displays a very marked change of facies from predominantly coarse to predominantly fine sediments, when traced from west to east across the Basin. This is the suite that includes the chloritoid shales.

The recognition of the individual stratigraphic units depends largely on a knowledge of the pebble types, their sizes and shapes, and their distribution along the vertical column.

The May Reef is the economic horizon in the Kimberley conglomerate group.

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group in the East Rand Basin. Over comparatively large areas in the eastern sector, and in portions of Government Gold Mining Areas in the western sector its gold content is sufficiently high to warrant mining.

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the point where, in 1949, he placed his single "hiatus" in the Kimberley group of sediments.

He subsequently agreed with the author (10) that the U.K.9A Reef corresponds to the May Reef of the eastern sector.

In his second paper (37) he groups the Kimberley Shales and the coarse sediments above, up to, but excluding the May Reef, with the Main-Bird Series. Baines (2) followed the same general pattern of correlation, and suggested the name "Kimberley Stage of the Main-Bird Series" for the Kimberley Shales and associated quartzitic phases. According to this grouping the May Reef rests unconformably on the Main-Bird Series, while the sediments above up to the base of the Ventersdorp Lava are grouped under the name Elsburg Series.

In his contribution to Sharpe's second paper the present author (10) questioned Sharpe's interpretation of a certain suite of sediments as typical channel deposits, and discussed the unconformable relationship between the May Reef and the older gravels. It was realized then that the history of the formation of the May Reef could be traced back to its parent rocks, in this case, stratigraphically older gravels. In stead of Sharpe's symbols a system of descriptive names was suggested. But it must now be admitted that some of the names advanced were not very suitable, and that one at least was a complete misnomer.

In 1950 Whiteside (44) published his paper, describing the subsurface geology of the Kimberley-Elsburg Series in the Brakpan-Springs area. He adheres very closely to Sharpe's original classification and nomenclature. He finds difficulty in defining the May Reef in the western sector as compared to the easily recognisable gold carrier of the eastern sector. This has been a stumbling-block to all investigators, but the detailed stratigraphic study which was possible on the Nigel and Sub Nigel Mines, in the author's opinion, clarified the position.

Whiteside gives a very interesting section through the May Shaft on the boundary between Daggafontein and East Daggafontein Mines. He argues very convincingly for a deep erosion channel below the May Reef in this area, filled with a heterogeneous assemblage of fine and coarse sediments in the lower half, and with fine-grained argillaceous quartzites and shales in the upper half.

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As opposed to Sharpe, he groups the Kimberley Shales with the Kimberley beds.

It is thus evident that for those unacquainted with the problem, the position as regards correlation and nomenclature has become very confusing. A modified system of descriptive nomenclature is thus proposed here, and it is suggested that it could be used over the entire structural basin, possibly in a modified form in some areas. This system of classification and nomenclature is fully set out on the accompanying table of correlation. The Kimberley Shales and associated quartzitic phases are bracketed with the Main-Bird Series, and the Kimberley conglomerate group divided into an upper, middle and lower division, based on the three regional unconformities which have been identified.

Latterly, repeated reference has been made in the literature to interruptions in the sedimentation within the upper division of the Witwatersrand System. Sharpe recognised one such break in the Kimberley beds on Government Gold Mining Areas (below his U.K.9C Reef), but it now appears to be a very local one.

Twenhofel (42) defines an unconformity as "the surface separating two distinct deposits, this surface representing a time during which no deposition took place over the area where the unconformity exists, or, if deposition did take place, the deposits were removed before the deposition of the strata above the unconformity", and again "an unconformity represents a rate of deposition that is zero, or if something is removed, a rate that is less than zero".

As applied to the Kimberley-Elsburg Series, the term unconformity is here being used for a regional surface that represents a rate of deposition that is zero in some areas, and less than zero in adjacent areas.

Within the Kimberley group of sediments there exist, apart from minor local interruptions due to scour, three regional unconformities :

1. the Bottom Reef or "B" Reef covers the lower one.
2. the Big Pebble Conglomerate was deposited on the next higher one, while
3. the May Reef blankets the upper one.

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In some areas we have the cumulative effect of these three surfaces of erosion, when the May Reef comes to rest directly on the Kimberley Shales.

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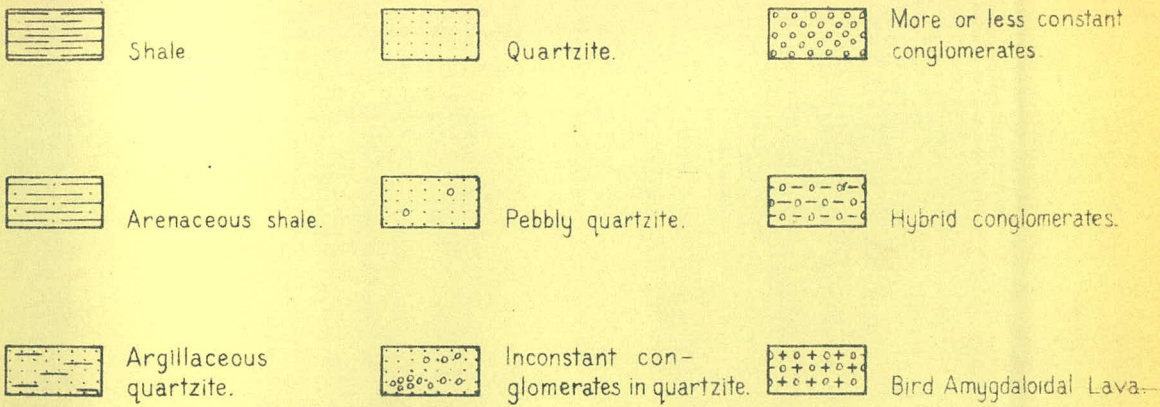

FIG. 2. SYMBOLS PERTAINING TO UNITS OF THE WITWATERSRAND SYSTEM.

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May Reef.
(The economic horizon)

Upper Parent Conglomerate (of the May Reef)
Western East Rand only.

Puddingstone Reef. (A very persistent horizon in the Eastern East Rand.)

Big Pebble Conglomerate Zone. (Individual bands within the zone frequently inconstant.)

FIG. 3. SYMBOLS PERTAINING TO "KEY" HORIZONS IN THE KIMBERLEY GROUP OF SEDIMENTS.

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V. THE KIMBERLEY-ELSBURG SERIES
IDEAL GEOLOGICAL COLUMNS IN THE EAST RAND BASIN.

The complete geological column of the Kimberley-Elsburg Series as constructed from a large number of borehole and shaft sections and observations underground is described here. It has been thought best to consider the eastern and western sectors of the Basin together in this chapter, and to produce, in effect, one column, although there are various differences in the geology of the two sectors. These differences are pointed out in the relevant paragraphs. The ideal geological columns in the two sectors are shown on plates I and II.

Broadly this description is done irrespective of the regional or local interruptions in the sedimentation, which resulted in the elimination of certain horizons and suites of sediments in some areas. Brief reference is, however, made to these geological breaks.

The units are described in ascending sequence, starting with the so-called Kimberley Shale Zone, which is considered as the upper phase of the Main-Bird Series. The borehole columns shown on plates III, IV and V would serve to illustrate the variation along the vertical column, especially in the eastern sector, and the differences in the geology of the two sectors. A system of symbols has been devised indicating the various rock types encountered in the Upper Witwatersrand System and certain "key" horizons in the Kimberley group of sediments. These are shown in figures 2 and 3.

1. The Kimberley Shale Zone:

This dominantly argillaceous zone is very constant in lithological character. Most thin sections for the microscope were made from the upper layers. Chloritoid has never been observed, but rutile and/or leucoxene are always developed. The rutile is decidedly of authigenic origin, occurring as isolated crystals scattered through the groundmass, or in asteriated clusters, and as bundles or sheaves, exactly as they had been shed by the parent titaniferous mineral. A high percentage of the crystals are in the form of geniculate twins.

These shales are easily distinguished from the so-called chloritoid shale a little higher up in the column by virtue of their dark colour (greenish in thin section), parallel banding, absence of

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any interbedded pebble horizons, absence of chloritoid, and always conclusively if the overlying Chert-pebble Quartzite Zone is present.

On Brakpan Mines and Government Gold Mining Areas the upper phase of the zone is a vitreous, fine-grained quartzite up to 80 feet thick. Generally this upper zone is absent from other parts of the East Rand Basin, apparently due to erosion prior to the deposition of the Bottom Reef. Only a few boreholes in the Dunnottar-Heidelberg area intersected it, while it appears to be totally absent from the eastern sector.

The entire Kimberley Shale Zone is absent from the geological column in some areas, due to an interruption in the normal sedimentation process: around the May Shaft on the boundary between Daggafontein and East Daggafontein Mines, and in the central portion of the Marievale Mine. The absence of the Kimberley Shales from these areas is attributed to deep erosion prior to the deposition of the Big Pebble Conglomerate Zone (See Correlation Table).

2. The Bottom Reef, which is the basal member of the Kimberley conglomerate group, rests on the Kimberley Shale Zone. It is an inconstant chert-pebble conglomerate, generally only a few inches thick, and is of no economic importance in the East Rand area.

3. <u>Chert-pebble Quartzite Zone</u>:

This is a zone of pebbly, argillaceous quartzite, with a characteristic greenish colour due to the presence in the matrix of chlorite and rutile.

Pebble types are well rounded quartz and angular chert, the latter predominating. They seldom exceed one inch in diameter. At various horizons in the zone the pebbles may be sufficiently concentrated to form narrow lenticular conglomerates, sometimes carrying small quantities of gold.

The zone has a maximum thickness of nearly 400 feet, but is absent over appreciable areas, when the Big Pebble Conglomerate comes to rest directly on Kimberley Shales.

4. <u>The Big Pebble Conglomerate Zone</u>:

Within the East Rand Basin this generally robust conglomerate zone varies in thickness between 160 feet and less than two inches, in the

/latter .....

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latter case sometimes in the form of a fine-grained vitreous quartzite.

Individual pebble bands in the zone have a tendency to change laterally into quartzite, while locally the zone may include lenticular bodies of chloritoid-rich, rutile-rich shale.

Pebble types comprise quartz and chert. Either of the two types may predominate. As the name implies, the pebbles are sometimes very large; occasional chert members measuring up to 9 inches in longest diameter have been encountered. The bulk of the pebbles are, however, less than 2 inches in diameter.

The sum total of the gold in the zone is sometimes high, but gold is never sufficiently concentrated in any one particular band to make it an economic horizon. There is, however, a tendency for the highest values (and the biggest pebbles) to occur at the base of the zone.

5. The Puddingstone Reef:

The mode of origin of this peculiar conglomerate is not clearly understood. Pebbles of various kinds occur scattered in an argillaceous matrix, the latter sometimes approaching a true shale in composition and texture. The matrix has generally, if not invariably, a characteristic khaki-green colour, which it owes to green chlorite and yellow rutile. It is considered that this conglomerate was originally dark grey in colour due to the deposition with the pebbles of numerous small grains of black ilmenite. As a result of metamorphism the ilmenite yielded rutile, which is yellow and sometimes foxy-red in colour.

Pebble types comprise chert, quartz, occasional quartzite and isolated red jaspers. An occasional altered igneous rock has been observed. The pebbles are generally not more than 1½ inches in diameter, although occasional quartzite boulders up to 18 inches in diameter have been encountered. This quartzite compares well with the upper quartzite phase of the Kimberley Shale Zone on Brakpan Mines and Government Gold Mining Areas. It is therefore considered possible that the boulders have been derived from this horizon, from an area eroded contemporaneously.

The Puddingstone Reef is a characteristic rock in the Eastern East

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Rand, where the overlying rocks are dominantly argillaceous. In this area it apparently represents a transition stage between the Big Pebble Conglomerate below and the "Chloritoid Shale" Marker above. In the Western East Rand where the latter suite of sediments consists dominantly of quartzites and conglomerates, the Puddingstone Reef is seldom recognised in its typical form.

6. The "Chloritoid Shale" Marker:

Interesting about this suite of sediments, which may attain a thickness of several hundred feet, is the very marked change of facies from predominantly coarse quartzites and conglomerates to predominantly argillaceous quartzites and fine-grained shales when traced from west to east across the East Rand Basin.

The conglomerates in the suite are not always readily distinguishable from other conglomerates in the Kimberley group. Hybrid conglomerates resembling the Puddingstone Reef in texture and composition have been observed at intervals within the zone, particularly in the eastern sector. All these conglomerates are as a rule very lenticular in habit.

In the eastern sector flat discoidal shale "pebbles" have been observed amongst the quartz and chert members in the narrow lenticular pebble beds associated with the suite. Locally angular fragments of shale up to two inches long occur as "inclusions" in quartzite and quartzitic shale near the base of the suite. It is obvious that these shale fragments did not travel far, having been derived from a nearby source, apparently from the lower shale phases of their present host.

There is evidence of much scouring and redeposition during this period. In some areas these deposits may therefore be described as "channel-like", but considering their persistence as a suite over large areas, it is thought that they are not erosion channel fillings in a true sense.

Much ilmenite was also deposited during this period, as evidenced by the presence of a great abundance of undoubted secondary rutile in the form of bundles and sheaves of minute needles and geniculate twins, particularly in the more argillaceous phases. The intense khaki-green shale bands are considered to have been black or dark grey ilmenite muds at the time of deposition.

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9. The May Reef:

In the Western East Rand the May Reef comes to rest alternately on the Micaceous-gritty Quartzite and the Upper Parent Conglomerate. The relationship is one of a basal conglomerate blanketing an erosion surface that truncates wide open anticlines and synclines of small amplitude. The angular difference is therefore small, amounting at the most to a few degrees. The coarse and heavy fraction of the eroded portions of the Upper Parent Conglomerate was concentrated, and finally deposited largely on the sub-May Reef synclines (plates XI and XII).

In the western sector the May Reef is generally very thin, seldom exceeding 24 inches, although greater widths up to 5½ feet are known locally. The highest values are generally limited to the upper portion of the reef; most of the gold is frequently concentrated in the uppermost few inches. It is a small-to medium-pebble conglomerate, containing exclusively vein quartz pebbles seldom exceeding one inch in diameter. In this sector the May Reef is of economic importance on Government Gold Mining Areas.

The May Reef is strikingly unconformable to its footwall beds in the Eastern East Rand. The older gravels (i.e. Puddingstone Reef, Big Pebble Conglomerate, etc.) furnished the material, including the gold, for the formation of the May Reef, as a result of pre-May Reef folding and uplift, with consequent erosion to a base level of deposition. The more robust bodies of May Reef are generally found on the sub-May Reef synclines.

In this sector the May Reef varies rapidly from place to place, ranging in width from a mere contact to a robust body up to 10 feet. Pebbles are generally of quartz and chert. The latter may be very large, up to 7 inches in longest measurement.

A feature of great interest and economic importance in the eastern sector is the occurrence near the top of the May Reef of a thin layer of fine-grained material rich in gold, metallic sulphides and other heavy minerals such as chromite and zircon (detrital), and rutile which is clearly secondary in origin. This thin layer is generally indicative

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Chloritoid, well known as a stress mineral, is quite common in the more argillaceous phases of this zone of sediments, not only in the narrow shale bands, but also in the thick zones of a few hundred feet.

Locally the "Chloritoid Shale" Marker rests directly on the Chert-pebble Quartzite Zone, both the Puddingstone Reef and the Big Pebble Conglomerate then being absent from the section.

7. "Upper Parent Conglomerate of the May Reef".

On Government Gold Mining Areas this zone of conglomerates is known as the U.K.9B Reef. Heretofore it was known as the Lower May Reef on the East Rand properties of New Consolidated Gold Fields. The drilling of a large number of boreholes was necessary before this conglomerate zone could be placed with certainty (plate XII b). It is now known to be a footwall conglomerate of the May Reef, in actual fact the principal parent rock of the May Reef in the Western East Rand. It is apparently non-existent in the eastern sector.

The Upper Parent Conglomerate is a zone of conglomerates varying in thickness between 2 feet and, say, 55 feet. Pebbles are almost exclusively of white and dark vein quartz up to 2½ inches in diameter. Individual bands are sometimes well mineralized, but values are generally extremely low. Gold is more or less evenly distributed at an average of about 0.1 to 0.2 dwt. per ton (plate XII b). On Government Gold Mining Areas the zone is slightly richer in gold. Isolated high values have been encountered, but these are very sporadic, and not confined to any particular band. Very high silver values have been recorded on Government Gold Mining Areas, where it was found necessary to have all samples parted for silver in assaying.

Locally an ill-sorted reef, carrying sporadic payable gold values occurs along the base of the zone. This is the U.K.9C Reef of Sharpe (36 and 37).

8. Micaceous-gritty Quartzite:

The Upper Parent Conglomerate is overlain by a peculiar, sometimes highly micaceous quartzite, which also, is only encountered in the Western East Rand. It is up to 20 feet thick, and forms the immediate footwall of the May Reef over large areas.

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In this sector the May Reef varies rapidly from place to place, ranging in width from a mere contact to a robust body up to 10 feet. Pebbles are generally of quartz and chert. The latter may be very large, up to 7 inches in longest measurement.

A feature of great interest and economic importance in the eastern sector is the occurrence near the top of the May Reef of a thin layer of fine-grained material rich in gold, metallic sulphides and other heavy minerals such as chromite and zircon (detrital), and rutile which is clearly secondary in origin. This thin layer is generally indicative

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of high gold values, and in borehole cores it is of great diagnostic value. Sampling frequently shows the highest concentration of gold towards the top of the reef (plate IX c).

10. Siliceous Quartzite Bar:

In the Western East Rand the May Reef is invariably overlain by a pale, vitreous fine-grained quartzite up to 13 feet in thickness. It is a very important marker horizon in this area.

In the eastern sector the bar is usually much thinner, and is absent over appreciable areas. It is frequently bluish-black in colour.

11. The May Reef Hangingwall Leader:

This conglomerate horizon exists from one inch to 13 feet above the May Reef in the eastern sector. It has not been encountered in the western sector.

It varies from a few scattered pebbles in a vitreous quartzite to a robust conglomerate up to 9 feet wide, with vein quartz pebbles of about one inch diameter predominating. It is not a component part of the May Reef, although it may sometimes be extremely difficult to separate the two horizons.

Apart from a fluctuation in thickness, it maintains its characteristic appearance throughout the eastern area, whereas the May Reef immediately below exhibits a marked lateral change as regards pebble types and sizes, and the mineralization of the matrix.

Around the No.2 Shaft on Vogelstruisbult the May Reef Hangingwall Leader has come to rest directly on the "Chloritoid Shale" Marker, i.e. the May Reef does not exist in this area (plate VIII b and plate XIII).

The May Reef Hangingwall Leader generally has a low gold content, a feature which assists in determining the upper contact of the May Reef, when the two conglomerate bands occur close together. However, on East Daggafontein Mine a narrow band carried payable quantities of gold over short distances.

12. Argillaceous Quartzite Bar:

On the Vogelstruisbult Mine a thin film of argillaceous material usually occurs directly above the May Reef Hangingwall Leader. In stoped areas the rocks are seen to part along this plane. Frequently

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it causes trouble during stoping operations, making it difficult to control the stoping width. Locally this thin layer of argillaceous material swells out into an arenaceous shale or argillaceous quartzite up to 15 feet thick. It now contains much chloritoid and rutile, and may be indistinguishable from some of the May Reef footwall rocks. In one instance on Vogelstruisbult, beyond a fault, a haulage was erroneously directed upwards for a short distance in this bed. It is not known in the western sector.

13. Coarse-grained Quartzite (U.K. 8 of Sharpe):

Following above the Argillaceous Quartzite Bar in the Eastern East Rand, and above the Siliceous Quartzite Bar in the Western East Rand, is a zone of coarse-grained quartzite varying in thickness between 30 and 100 feet. Measurement of the true thickness of the zone is seldom possible, because the lower limit of the "80" Foot Marker is usually indefinite.

14. The "80" Foot Marker:

This is a conglomerate zone which varies in thickness from nearly 100 feet on Brakpan Mines to less than 5 feet in portions of the Eastern East Rand. Southwards towards Heidelberg the zone deteriorates so much, that boreholes frequently fail to disclose its existence.

As most of the individual conglomerate bands are short-lived, it is often impossible to measure the thickness of the zone (plates III and IV). The uppermost band is the most persistent, and on Sub Nigel, Vogelstruisbult, Nigel and Marievale Mines, it frequently lies at ± 80 feet vertically above the May Reef. On Government Gold Mining Areas the upper band exists up to 150 feet above the May Reef, and locally contains payable quantities of gold.

Locally, near the sub-outcrop against the Karroo System, the zone contains numerous grains and small pebbles of pyrophyllite, scattered amongst the quartz and chert members. The mineral is very soft and can be scratched by a finger nail. Small pebbles of chlorite, although not as abundant as pyrophyllite, have got wider distribution along this horizon.

15. Groups of quartzites and groups of conglomerates, also belong-

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ing to the Kimberley beds, exist higher up in the column. These conglomerates are of no economic importance.

Towards the northern extremity of the western sector the highest conglomerate band belonging to the Kimberley group occurs at about 800 feet above the May Reef. Eastwards and south-eastwards the section thins appreciably, until in Vogelstruisbult No. 4 Shaft the highest band lies at a distance of 480 feet above the May Reef.

A section from Brakpan Mines to East Daggafontein (Whiteside 1950) shows that this marked thinning is not the result of any interruptions in the sedimentation, but takes place along each individual quartzite and conglomerate zone. In the Dunnottar-Heidelberg area these upper conglomerate clusters are poorly developed, having changed into quartzites near Heidelberg.

16. The Kimberley-Elsburg Intermediate Quartzites:

These are more or less clear quartzites separating the Kimberley group of conglomerates from those of the Elsburg group (plates I and II).

In Sub Nigel No. 3 Shaft the zone has an apparent thickness of 1,388 feet. In this shaft the three major sedimentary groups under consideration have the following apparent thicknesses :

Elsburg conglomerate group	: 700 feet
Kimberley-Elsburg Intermediate Quartzites	: 1,388 "
Kimberley conglomerate group	: 876 "
Total from base of Ventersdorp Lava to Kimberley Shales	: 2,964 feet.

In Vlakfontein No. 1 Shaft the corresponding thicknesses are 625, 1,682, 922 and 3,229 feet.

17. The Elsburg Conglomerate Group:

The average thickness of the group in the East Rand Basin is about 700 feet. Individual conglomerates are often very robust, but generally impersistent. Considered as a whole they appear to be more lenticular in character than most members of the Kimberley group. No economic horizons have been discovered amongst the Elsburg reefs in the East Rand Basin, their gold content being without exception very low.

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VI. THE STRATIGRAPHY OF THE KIMBERLEY GROUP OF SEDIMENTS IN THE EASTERN HALF OF THE BASIN.

This sector includes the eastern half of Springs Mines, Daggafontein Mine, East Daggafontein Mine, the bigger portion of the Vogelstruisbult Mine, Marievale Mine, farm Bloemendal 19 and the eastern half of the Nigel Mine (plate XIII).

The phenomenal variation in the stratigraphic column could be studied in great detail in this area, because of the large number of boreholes drilled from surface, and the extensive underground development carried out on Vogelstruisbult, Daggafontein and East Daggafontein.

The stratigraphy of the Kimberley group of sediments with particular reference to the Kimberley Economic Zone will be described here for the different areas as enumerated above. This cannot be done without reference to the three regional erosion surfaces, namely: immediately below the Bottom Reef, Big Pebble Conglomerate and the May Reef. Evidence will also be produced of local scour at other points along the stratigraphic column in many localities within this area. The measured thicknesses of the major suites of sediments below these erosion surfaces are thus seldom the original depositional thicknesses, although these could also vary within wide limits. An erosion surface is therefore not proved, and not necessarily indicated by the varying thickness of a particular sedimentary suite. Detailed stratigraphic study is necessary in order to determine whether or not any formations have been eliminated.

Differential uplift of the depositional floor and erosion to a base level prior to the deposition of the Bottom Reef apparently took place over a large area, resulting in the elimination of the upper quartzite phase of the Kimberley Shale Zone in such areas of uplift.

Evidence will be produced of a period of erosion that preceded the deposition of the Big Pebble Conglomerate Zone. This erosion surface generally has a low relief, but in some areas there is evidence of scour to some considerable depth, resulting in the elimination of the entire Kimberley Shale Zone (plate V). Renewed deposition appears to have been continuous across these areas of deep scour, resulting in a considerable thickening of the individual units as compared to neighbouring areas (figure 6).

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The floor of the May Reef could be mapped in the mine workings (plate X). This erosion surface is always of low relief.

These three regional unconformities will be described in more detail in succeeding chapters, and their economic and geological significance will be discussed.

As the lithology of the various horizons has been described in fair detail in chapter V, all the details will not be repeated here. Additional information will be given, and the inter-relationships of the various units will be discussed.

Some of the geological sections that accompany this description (plates VI, VII and VIII) have been plotted below a common datum, which is an imaginary plane 6,000 feet above sea level.

A. Eastern Two-thirds of the Vogelstruisbult Mine

The area around No.3 Shaft falls in the western sector.

No.1 and No.2 Shafts penetrated the Kimberley group of sediments and proceeded down to the Main Reef. No.4 Shaft was sunk down to the May Reef only, while 12 boreholes were drilled from surface of which one (V^{o} .1) was stopped in the Kimberley Shales without the May Reef being identified. The other boreholes, $V^{o}3$ to V^{o}.13, drilled in the outcrop area, all intersected the May Reef (plate XIII).

Extensive development on the May Reef has been carried out east of No.1 Shaft to beyond No.4 Shaft. No.2 Shaft is connected up with this development by a single haulage.

Numerous boreholes have been drilled from the underground workings, not only to determine the May Reef position and value beyond faults, but also the inter-relationships of the various horizons, and the nature of the sub-May Reef erosion surface.

(a) In the No.1 Shaft the Kimberley Shale Zone is 356 feet thick, including 65 feet quartzitic shale near the top of the zone.

In No.2 Shaft the zone is only 247 feet thick, the upper 114 feet being a quartzitic shale.

These quartzitic phases are however not the equivalent of the upper vitreous quartzite phase as known in the Brakpan area.

(b) The Chert-pebble Quartzite Zone is a very useful marker in locating

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the May Reef beyond faults in the mine. The thickness of the zone varies between 40 and 120 feet, the thicker developments occurring east of No.1 Shaft. Beyond faults the zone can be confused with a lithologically similar pebbly zone associated with the '80' Foot Marker (plate VIII a and figure 5).

(c) The Big Pebble Conglomerate is of blanket character and a very useful marker. It varies in thickness from a few inches to a maximum of about 18 feet. It is generally a well-packed conglomerate, but locally portions of the body change laterally into quartzite (plate VIII a and photograph No.11). Locally it may also include lenses of chloritoid-rich, rutile-rich shale.

The sum total of the gold in the zone is generally high in the area east of No.1 Shaft. Spectacularly high values have been intersected on the bottom bands, but these values never obtain over long distances. The zone becomes poorer in gold southwards towards No.2 Shaft and the outcrop area.

The chert cobbles are usually of diagnostic value, although locally the May Reef includes similar cobbles.

In some localities the May Reef horizon transgresses on to the Big Pebble Conglomerate. The erosion surface may also cut right through this horizon. In these areas the May Reef usually deteriorates into a pencil-line contact.

Locally the Big Pebble Conglomerate is also absent apparently due to scour prior to the deposition of the Puddingstone Reef or "Chloritoid Shale" Marker.

(d) The Puddingstone Reef is a very persistent horizon in this area, and because of its characteristic and constant lithological character, it is the most useful marker to all those engaged in mining the May Reef. This peculiar hybrid conglomerate with its argillaceous matrix varies in thickness from a few inches to a maximum of about 15 feet. Locally it includes lenses of chloritoid-rich, rutile-rich shale. Its gold content is generally very low, although locally it may contain fair values (plate IX b).

Physically it appears to be a transition phase between the Big Pebble Conglomerate below and the rutile-rich shales above. Locally

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it is absent from the column apparently as the result of erosion prior to the deposition of the "Chloritoid Shale" Marker, and over bigger areas as the result of the period of erosion that gave rise to the formation of the May Reef (plate X).

(e) The "Chloritoid Shale" Marker is perhaps the most interesting suite of sediments in the Kimberley-Elsburg Series, in that the beds exhibit a very marked change of facies regionally, often perceptible over very short distances. There is also evidence of a certain amount of scouring and redeposition during this period.

In the area under review these beds are dominantly argillaceous, locally including quartzite zones indistinguishable from the May Reef hangingwall quartzites. Inconstant conglomerates occur at intervals through the zone (plate VIII b).

On Vogelstruisbult the suite has a maximum thickness of 177 feet in No.2 Shaft, gradually thinning eastwards. East of No.1 Shaft to beyond No.4 Shaft it has a maximum thickness of 50 feet, but is absent over appreciable areas, as a result of the sub-May Reef period of erosion (plates VI, VII, VIII and X).

In No.2 Shaft the suite can be divided into an upper shale division, middle quartzite division and a lower shale division. Eastwards along 2K Haulage (plate VIII b) where a large number of boreholes have been drilled through the zone, this condition still holds in some of the boreholes, but the change is mostly rapid, and possibly abrupt in some instances. The quartzites of the zone intersected by borehole 398 are indistinguishable from the May Reef hangingwall quartzites. Along this haulage an attempt has been made to classify the sediments of the suite into quartzites, argillaceous quartzites, arenaceous shales, shales, pebbly shales (borehole 415), and lenticular conglomerates.

East of No.1 Shaft the same general lithological description would apply, except that the quartzite units are thinner, and that the upper shale phase is apparently everywhere eliminated.

In the outcrop area on Vogelstruisbult (boreholes V° .3 to V°.13) the zone varies in thickness between 20 and 160 feet in a very limited area (plate XIII). In some of these boreholes it is possible to recognise the middle quartzite and the lower shale divisions of No.2 Shaft,

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but in the majority (e.g. V^{o}.11, plate III) the change along the vertical column is very impressive. The different units are however perfectly transitional to one another, sometimes exhibiting also a transitional relationship with the Puddingstone Reef below (e.g. V^{o}.9, plate III).

The angular shale fragments that occur locally as "inclusions" in quartzite and quartzitic shale, have obviously been derived from a nearby source, apparently from the lower shale phase of the suite, and incorporated, without being destroyed, in the succeeding layers. That would indicate a break in the sedimentation near the bottom of the zone in some areas (plate II).

Sharpe (36 and 37) regarded this group of sediments as typical channel deposits, as the infilling of narrow longitudinal hollows cut into the underlying rocks. But that does not seem to be entirely correct, as regionally the basal members of the group appear to have been deposited on a fairly even floor. The marked lateral variation creates the impression that these beds are true channel fillings. They have furthermore very wide distribution, although individual lithological units are frequently highly lenticular. They have been proved to be absent only in some well defined areas in the eastern sector as the result of pre-May Reef folding and uplift, with erosion to a base level of deposition as a sequel, and very locally in the western sector as a result of erosion prior to the deposition of the Upper Parent Conglomerate of the May Reef. Elsewhere their distribution is controlled by the outcrop and sub-outcrop of the bottom surface of the zone.

(f) The May Reef, which apparently is the only economic horizon amongst the Kimberley reefs in the East Rand Basin, has certain characteristic features. Primarily, as mentioned before, it lies unconformably on the older Kimberley beds.

In the area under review the May Reef horizon varies in thickness from a pencil-line contact to a robust body 10 feet wide. It exhibits a marked lateral change. In places it is a narrow small-pebble conglomerate containing smoky quartz pebbles only. In adjacent areas it develops into a robust large-pebbled conglomerate containing large quartz pebbles and cobbles of chert, the latter up to 7 inches long.

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It may consist of several bands, separated by bands of fine-grained vitreous quartzite.

Pebble types in the May Reef comprise black and banded cherts, white vein quartz frequently with dark rims, dark smoky quartz and occasional opalescent blue quartz. In one instance only was the May Reef observed to include a 1¼ inch pebble of khaki-green argillaceous quartzite, lying about two inches above the bottom contact of the reef. At this point, and in the immediate vicinity, the May Reef rests on a similar rock.

The matrix of the reef is as a rule very dark in colour. Characteristic of the highly payable May Reef is its "ashy" matrix, consisting of carbon, pyrite, pyrrhotite, rutile, gold, zircons, chromite, etc. In one instance a ¼-inch layer of brittle carbon traversed by numerous thin veinlets of gold was observed along the bottom contact of a 4-inch reef. The pyrrhotite is usually in the form of thin flakes, frequently in fractures in the pebbles. A member of the Sampling Department found a large crystal of sphalerite on the bottom contact of the reef.

As mentioned in chapter V, a thin layer of fine-grained heavy minerals frequently occurs near the top of the May Reef in rich areas. It includes the bulk of the gold and other heavy minerals found in the May Reef. Under the microscope it was possible to distinguish between the allogenic and authigenic constituents of this thin undoubted sedimentary layer:

1. Primary or Allogenic Constituents:

(i) Chromite

The concentrate is very rich in chromite. Most of the grains are well rounded and up to 0.3 m.m. in diameter.

In thin section the chromite grains become translucent appearing brown by transmitted light. Some of the grains are fractured, apparently in situ, the cracks having afterwards been filled with pyrite.

(ii) Zircon

This mineral appears as well rounded grains, up to 0.3 m.m. in diameter. Although always present, it is not as abundant as chromite.

/(iii) Detrital .....

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(iii) Detrital quartz grains.

(iv) A very high concentration of gold, the bulk of which is apparently now locked up in the pyrite and pyrrhotite.

2. Secondary or Authigenic Constituents:

(i) "Buckshot" pyrite up to 0.5 m.m. in diameter. Numerous crystal faces can be observed in the small bodies. Occasionally the pyrite is surrounded by dark rims, possibly caused by carbon. Around their edges the small pyrite bodies are seen to replace detrital quartz grains.

Stringers of pyrite occur in the matrix and may cut across the quartz grains.

(ii) Very small crystals of rutile are always present, usually in bundles and sheaves. Many of the crystals are twinned. It is believed that the rutile betrays the former presence of detrital ilmenite.

(iii) Chloritoid containing abundant dark inclusions.

(iv) Sericite and chlorite.

The pyrrhotite is generally of macroscopic dimension.

Around No.2 Shaft and eastwards along 2K Haulage for a distance of nearly 6,000 feet, the May Reef Hangingwall Leader comes to rest directly on the "Chloritoid Shale" Marker, possibly eliminating a pre-existing May Reef (plate VIII - b and c, and plate XIII). This condition could be explained by slight post-May Reef warping of the depositional floor, resulting in the May Reef being stripped off from the higher areas and deposited nearby. Alternatively this area might have stood slightly above the general level of deposition of the May Reef.

(g) The '80' Foot Marker consists of a zone of pebbly quartzite 30 feet thick, capped by a well-developed persistent conglomerate band up to 3 feet wide, the latter averaging about 80 feet vertically above the May Reef. The minimum distance is about 60 and the maximum 90 feet.

A feature of this conglomerate cluster is the high percentage of chert pebbles, while some individuals appear to be of chlorite.

The '80' Foot Marker is invaluable in unravelling structural

/problems. .....

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problems. The sub-May Reef geology in the area north of the east-west tear fault (plate X) was largely determined by making use of this cluster as a datum, especially during the initial stages of development in that area. It took a long time before the May Reef horizon was identified in the boreholes drilled from K4. 1B. 2 Winze (figure 5).

B. Marievale Mine

Less than two-thirds of this mine is underlain by the May Reef. The sub-outcrop against the base of the Transvaal or Karroo Systems trends due east-west, with the reef dipping at low angles to the north over the larger portion of the property. But in the western part of the mine the Witwatersrand beds are folded into an asymmetrical anticline, resulting in the sub-outcrop making a sharp horse-shoe bend to the south-east, the reef now dipping at steep angles to the south-west (plate XIII).

Altogether 13 boreholes from surface intersected the May Reef. Two boreholes, UR and UP, drilled not far behind the sub-outcrop of the reef, intersected the lower portion of the Kimberley Economic Zone.

A cross-cut haulage from No.1 Shaft, which is situated behind the sub-outcrop, was begun from a point just below the Main Reef. It intersected the May Reef some 4,000 feet further to the north, after which a drive, advancing both eastwards and westwards, has now nearly crossed the mine.

In the western part of the mine borehole U.T. is the most instructive (plates III and V): the Kimberley Shale Zone is overlain by 54 feet Chert-pebble Quartzite, followed by the Big Pebble Conglomerate. The Puddingstone Reef is absent from the section. The "Chloritoid Shale" Marker is 204 feet thick, being a fine-grained chloritoid-rich shale in the upper half, and a sub-glassy quartzite in the lower half. The two sub-divisions are transitional to each other. The May Reef was intersected very near the sub-outcrop against the base of the Transvaal System. The highest concentration of gold occurs in association with the thin layer of fine-grained heavy minerals near the top of the reef.

The May Reef has the chloritoid-rich shales as footwall over large areas in this mine, but it is possible that it rests directly on

/Kimberley .....

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Kimberley Shales near the common boundary with the farm Bloemendal (boreholes U.X, U.V. and U.J. plate XIII). These boreholes were not drilled deep enough for correlation purposes.

On Bloemendal the May Reef rests on Kimberley Shales in boreholes B.1, B.2 and B.3 (plates III and V). The quartzites above the shales are typical of the May Reef hangingwall, and there can be no possibility of confusing them with the Chert-pebble Quartzite Zone. The shales intersected by these three boreholes are furthermore typical of the Kimberley Shales, having the following diagnostic features:

(1) dark, fine-grained with parallel banding,

(2) absence of any pebbly layers,

(3) chloritoid did not develop,

(4) transitional to the Main-Bird quartzites below.

In the extreme south-western portion of Marievale near the common boundary with the Nigel Mine, borehole U.Y. showed the May Reef to lie directly on the Chert-pebble Quartzite Zone. Around this borehole the sub-May Reef erosion surface has thus eliminated the principal footwall conglomerates of the May Reef (plates III and XIII).

Three boreholes U.A., U.P. and U.R., in the central portion of the mine, deserve special attention because the Kimberley Shales are absent from these sections (plate V).

Borehole U.A.

The May Reef lies on dark, fine-grained chloritoid-rich shale. Including a few thin dykes or sills, the zone has a borehole thickness of 336 feet. Chloritoid developed through-out the zone. Two distinctly different conglomerate beds occur in contact with each other at the base of this shale zone. The upper one, 18 feet thick, is similar in all respects to the Puddingstone Reef as known elsewhere in the East Rand Basin, and the lower horizon, 8 feet thick, looks exactly like the Big Pebble Conglomerate in its typical form. The lower horizon is separated from the Bird Amygdaloid by 50 feet of clear quartzites and thick intrusions.

Borehole U.R.

This borehole was drilled behind the May Reef sub-outcrop (plate V).

/The Black Reef .....

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of the Big Pebble Conglomerate, resulting in the elimination of the entire Kimberley Shale Zone and the upper portions of the Bird Amygdaloid. Renewed deposition appears to have been continuous across this low-lying area, resulting in a marked thickening of the Big Pebble Conglomerate and "Chloritoid Shale" Marker as compared to neighbouring areas (figure 6).

C. Eastern Half of the Nigel Mine

A large number of boreholes have been drilled along the eastern boundary of the mine, and underground development on the May Reef is in progress near the southern extremity of the area under review, so that a fairly comprehensive picture of the geology could be formed (plate XIII).

(a) The Strip along the Eastern Boundary:

Lithologically the average section here compares well with the average column on Vogelstruisbult. Excluding borehole U.Y. on the Marievale side of the boundary (plate XIII), there is no further evidence that the sub-May Reef erosion surface cuts into or through the principal footwall gravels. The Big Pebble Conglomerate, furthermore, occurs very close to or directly on the Kimberley Shales.

The May Reef is generally poorly developed. The small smoky quartz pebbles are a characteristic feature. In some of the boreholes the May Reef is represented by a dark, fine-grained vitreous quartzite.

The "Chloritoid Shale" Marker is represented by arenaceous, micaceous shales, on the average about 100 feet thick. These shales contain virtually no chloritoid, but rutile is a ubiquitous secondary mineral.

The Puddingstone Reef and Big Pebble Conglomerate are generally poorly developed. In borehole K 11.47 the Big Pebble Conglomerate is represented by 7 inches of fine-grained vitreous quartzite. In this borehole the Puddingstone Reef therefore occupies the junction between the two shale zones, which are remarkably similar in this area (plate III).

(b) The Kimberley Workings:

In the southern area near the May Reef sub-outcrop, where underground development on the May Reef is in progress, the "Chloritoid Shale" Marker is up to 180 feet thick, and may consist of alternating phases of

/shale, ...

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shale, arenaceous shale, argillaceous quartzite and quartzite (borehole K 19.49); or a dominantly quartzite zone including narrow more argillaceous layers (borehole K 24.49); or conglomeratic quartzites containing narrow layers of khaki-green, rutile-rich shale (borehole K 25.50). The geological sections of these boreholes are shown on plate III. These shales seldom contain chloritoid.

The Big Pebble Conglomerate Zone is up to 60 feet thick. In hand specimen the rock is indistinguishable from the lenticular conglomerates associated with the "Chloritoid Shale" Marker in this area.

The lateral change of the May Reef is very marked. In places the horizon is represented by a barren plane, developing rapidly into a robust conglomerate in which large angular chert pebbles predominate, or into a zone of grits (6 feet) in which small smoky quartz pebbles predominate, or into a well-packed medium-pebble conglomerate with the thin layer of heavy concentrate near its upper contact. The heavy concentrate in this area contains a great abundance of secondary rutile, and is invariably yellowish in colour.

The May Reef is strikingly unconformable to the older beds, its distance above the Kimberley Shales varying between 50 and 250 feet. In places the erosion surface cuts through the "Chloritoid Shale" Marker into the Big Pebble Conglomerate Zone (plate XIII).

In the eastern half of the Nigel Mine the '80' Foot Marker proved invaluable in estimating a more exact depth for the May Reef when the latter is being approached in a borehole, or in the mine workings in solving structural problems. But it is of the greatest assistance in locating the May Reef on the crests of the truncated anticlines, where the reef horizon is generally represented by a barren plane or an intermittent line of pebbles, sometimes sandwiched in between clear quartzites.

In the case of one borehole the water supply from a pan in the vicinity was exhausted before the May Reef was reached. Based on the recognition of the '80' Foot Marker one tank of water transported by lorry was sufficient to enable completion of the borehole.

This conglomerate zone has some very definite characteristics

/in the area .....

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in the area under review:- The zone is up to 30 feet thick, in the form of a large number of inconstant grit and small-pebble bands, capped by a fairly persistent small-pebble band which lies on the average about 80 feet above the May Reef. The zone includes a white mineral in the form of small pebbles ($\frac{1}{2}$ inch and less), interspersed amongst quartz and chert members of the same average diameter. In other areas, e.g. on Vogelstruisbult, but more commonly in the Western East Rand, a bright green or greenish-black mineral has been observed as small pebbles in the '80' Foot Marker zone. The white mineral is very soft, with a soapy touch, and can be scratched by a finger nail. The green mineral is generally brittle, and is easily scratched by a pen-knife.

As both these rare pebbles are used as markers, their identification became of importance. The Director of the National Building Research Institute, Pretoria, kindly undertook to have these minerals subjected to an X-ray analysis. He identified the white mineral as pyrophyllite and the green one as chlorite. His reports are as follows:-

(a) The White Mineral:

"The white mineral occurring in the Kimberley quartzites which was suspected to be montmorillonite was subjected to X-ray analysis and found to be pyrophyllite. Pyrophyllite has essentially the same molecular lattice structure as montmorillonite, and some varieties are known to possess considerable swelling characteristics".

(b) The Green Mineral:

"Unfortunately the large quantities of quartz in the specimen masked the peak of the other mineral to some extent, and all that could be ascertained was that the mineral belongs to the chlorite group".

The chlorite and pyrophyllite pebbles were probably derived from large crystals in the ancient schists, the parent rocks of some of the sediments of the Witwatersrand System. It is, however, also possible for the pyrophyllite to be an alteration product of some other type of pebble, possibly chlorite. They both occur most abundantly along the same stratigraphic horizon, although seldom together in the same

/locality. .....

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locality. Pyrophyllite has furthermore been observed in greatest abundance near the sub-outcrop against the Karroo rocks along the eastern and southern boundaries of the Nigel Mine.

Underground boreholes drilled through the '80' Foot Marker on Vogelstruisbult almost invariably intersected a few chlorite pebbles, some of them measuring up to $\frac{3}{4}$ inch in diameter.

One-inch pebbles of pyrophyllite have occasionally been observed in the Big Pebble Conglomerate Zone in boreholes drilled in the outcrop areas on the Nigel and Vogelstruisbult Mines.

D. <u>The Area immediately to the North of Vogelstruisbult</u>

This area includes Daggafontein, East Daggafontein, and the eastern half of Springs Mines.

In his discussion of Sharpe's paper (36) Bancroft (3) described what he considered to be an infilled erosion channel immediately below the May Reef around the May Shaft on the boundary between Daggafontein and East Daggafontein Mines. He writes: "An exceptional feature of

> interest and economic importance relates to the presence of a stream channel at the base of the Kimberley Series in the vicinity of the May Shaft on the boundary between Daggafontein and East Daggafontein. At the May Shaft this ancient stream channel is apparently 600 ft. to 700 ft. deep and is filled with conglomerates towards its base with quartzites and shales and is capped by a Black Bar type of deposit, in the form of chloritoid-rich shales and argillaceous quartzites, that varies from 50 ft. to 150 ft. or more in thickness. The stream channel is so deep that in its central portion the lowest reef zone of the normal Kimberley sequence and the 120 ft. thickness of quartzites with scattered chert and quartz pebbles, that in adjacent areas lies between the lowest reef zone and the top of the Kimberley shales, and also at least most of the Kimberley shales themselves have been scoured out by the stream in the development of its valley.
>
> For some time the Black Bar type of deposit that caps this valley was considered to be the Kimberley shales and only

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correspondence appear to be:

(1) Non-existence of the Upper Parent Conglomerate.

(2) Striking unconformity between the May Reef and the older Kimberley beds.

(3) The existence of an erosion surface immediately below the Big Pebble Conglomerate. The Chert-pebble Quartzite Zone is up to 200 feet thick, but in some areas the Big Pebble Conglomerate lies directly on the Kimberley Shales.

(4) The "Chloritoid Shale" Marker changes eastwards into a dominantly argillaceous zone. In the eastern half of Springs Mines the zone is largely represented by quartzites.

(5) The Puddingstone Reef appears to be of blanket character.

(6) The Big Pebble Conglomerate was again the principal contributor of gold to the May Reef.

(7) Absence of the upper quartzite phase of the Kimberley Shales.

(8) Lithologically the different phases of the May Reef correspond closely to the variations known on Vogelstruisbult.

(9) The uppermost Kimberley reef occurs on the average about 500 feet above the May Reef.

The May Shaft and Environs:

Whiteside does not show his May Shaft erosion channel as an entire separate unit on his map of the May Reef floor (plate XLIII of his paper).

There is little doubt that the May Shaft intersected a similar, if not the same feature as disclosed by boreholes U.R., U.A., and U.P. on Marievale (plate V).

Comparing these two areas, it appears probable that the upper sediments in the postulated May Shaft erosion channel could also be looked upon as a continuation of the "Chloritoid Shale" Marker of surrounding areas. The conglomerates towards the base of the depression are probably the Puddingstone Reef and Big Pebble Conglomerate, much

/thicker .....

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thicker here than in surrounding areas, because of the depth of the floor below the general level of deposition (Whiteside (44) plate XLI).

By analogy with the interpretation given to the geological sections of boreholes U.R., U.A. and U.P. on the Marievale Mine, the author therefore prefers to date the deep scouring in the May Shaft area as immediately pre-Big Pebble Conglomerate.

The scour depression on Marievale has considerable depth, but also phenomenal width. The slope of the floor on which the Big Pebble Conglomerate was deposited, was thus apparently very gentle (figure 6).

The scour depression in the May Shaft area has got steeper sides. Noteworthy is the conglomerate (or conglomerate zone) that covers the base and sides of the May Shaft depression. The zone attains a maximum thickness at the deepest point of the depression (Whiteside (44) plate XLI).

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VII. THE STRATIGRAPHY OF THE KIMBERLEY GROUP OF SEDIMENTS IN THE WESTERN HALF OF THE BASIN

The area includes from north to south: Government Gold Mining Areas, Brakpan Mines, the S.A. Land and Exploration Company (Sallies), the western half of Springs Mines, the extreme western portion of Vogelstruisbult, Vlakfontein, Sub Nigel, the western half of the Nigel Mine, West Vlakfontein, Spaarwater, West Spaarwater, the northern portion of Witwatersrand Nigel, the Heidelberg Townlands, and portions of the farms Klippoortje 10 and Maraisdrift 4 between Nigel and Heidelberg (plate XIII).

The May Reef generally occurs from 250 to 400 feet above the Kimberley Shale Zone in the Western East Rand, except in borehole T.L. 3 on the Heidelberg Townlands where the distance is 606 feet, and in the south-eastern portion of the Sub Nigel Mine where a minimum distance of 72 feet is known (See also plate IV).

(a) The Kimberley Shale Zone has a maximum thickness of about 500 feet in this area, including the upper and lower quartzitic phases. The upper quartzite phase is known only in a few isolated places outside Brakpan Mines and Government Gold Mining Areas.

(b) The Chert-pebble Quartzite zone attains a maximum thickness of 400 feet in the northern portion of the area under review. The zone is up to 290 feet thick in the Heidelberg area, generally between 150 and 200 in the Sub Nigel - Spaarwater - Vlakfontein area, but in the south-eastern portion of Sub Nigel and the adjoining portion of the Nigel Mine the zone is only a few feet thick.

(c) The Big Pebble Conglomerate, often in the form of a zone of conglomerates, is very seldom absent from the geological column in the Western East Rand. Locally in the southern portion of the Sub Nigel Mine it has been eliminated apparently as the result of scour prior to the deposition of the Puddingstone Reef, which becomes abnormally thick in such sections.

The zone is up to 160 feet thick on Government Gold Mining Areas, but thins southwards, in places represented by a few inches of fine-grained vitreous quartzite. Great individual thicknesses are, however, still met with, e.g. 122 feet in borehole T.L.3 on the Heidelberg

/Townlands .....

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Townlands and nearly 100 in some boreholes drilled in the western half of the Nigel Mine. The change in thickness often takes place rapidly. The individual conglomerate layers show furthermore a tendency to change laterally into quartzite.

In the Vlakfontein - West Vlakfontein - Spaarwater area the bottom band occasionally carries payable quantities of gold.

(d) The Puddingstone Reef is of local occurrence in the western sector. It is fairly well developed in the Heidelberg area, where it forms a very characteristic rock on the surface. It has also been intersected in the southern portion of the Sub Nigel Mine, where its thickness fluctuates between 2 inches and 38 feet. It contains very little gold.

(e) <u>The "Chloritoid Shale" Marker</u>:

This suite of sediments consists largely of coarse-grained quartzites and lenticular conglomerates in the Western East Rand. Locally it includes inconstant layers of shale up to 30 feet in thickness, and narrow hybrid conglomerates resembling the Puddingstone Reef in appearance. These shale lenses are known on Government Gold Mining Areas, have been encountered in the Vlakfontein - West Vlakfontein - Spaarwater area, but are more pronounced around Heidelberg and in the southern portion of the Sub Nigel Mine.

As a general rule it can be stated that the zone becomes finer grained and more argillaceous eastwards. This feature applies to all east-west sections across the Basin. The shales often contain chloritoid, and invariably abundant secondary rutile.

The thickness of the zone in the western sector varies between 40 and 100 feet. Locally it is only 20 feet thick, while on the other extreme, measurements up to 170 feet have been recorded.

The zone is non-existent locally, e.g. in the northern portion of Brakpan Mines, where the Upper Parent Conglomerate comes to rest directly on the Big Pebble Conglomerate.

The conglomerates associated with the zone occasionally contain traces of gold.

(f) <u>The Upper Parent Conglomerate of the May Reef</u>:

A feature of this conglomerate zone, which attains a maximum thickness of over 50 feet, is the prevalence of white and dark-edged

/vein quartz .....

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locality. Pyrophyllite has furthermore been observed in greatest abundance near the sub-outcrop against the Karroo rocks along the eastern and southern boundaries of the Nigel Mine.

Underground boreholes drilled through the '80' Foot Marker on Vogelstruisbult almost invariably intersected a few chlorite pebbles, some of them measuring up to $\frac{3}{4}$ inch in diameter.

One-inch pebbles of pyrophyllite have occasionally been observed in the Big Pebble Conglomerate Zone in boreholes drilled in the outcrop areas on the Nigel and Vogelstruisbult Mines.

D. The Area immediately to the North of Vogelstruisbult

This area includes Daggafontein, East Daggafontein, and the eastern half of Springs Mines.

In his discussion of Sharpe's paper (36) Bancroft (3) described what he considered to be an infilled erosion channel immediately below the May Reef around the May Shaft on the boundary between Daggafontein and East Daggafontein Mines. He writes: "An exceptional feature of interest and economic importance relates to the presence of a stream channel at the base of the Kimberley Series in the vicinity of the May Shaft on the boundary between Daggafontein and East Daggafontein. At the May Shaft this ancient stream channel is apparently 600 ft. to 700 ft. deep and is filled with conglomerates towards its base with quartzites and shales and is capped by a Black Bar type of deposit, in the form of chloritoid-rich shales and argillaceous quartzites, that varies from 50 ft. to 150 ft. or more in thickness. The stream channel is so deep that in its central portion the lowest reef zone of the normal Kimberley sequence and the 120 ft. thickness of quartzites with scattered chert and quartz pebbles, that in adjacent areas lies between the lowest reef zone and the top of the Kimberley shales, and also at least most of the Kimberley shales themselves have been scoured out by the stream in the development of its valley.

For some time the Black Bar type of deposit that caps this valley was considered to be the Kimberley shales and only

/diamond .....

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diamond drilling and stratigraphic study have determined its true relationship.

The payable 'Kimberley May' reef which is being worked on East Daggafontein and has been developed to some degree on Daggafontein has these chloritoid shales and argillaceous quartzites as its footwall for variable distances on either side of the stream channel".

In 1950 Whiteside published his paper (44) on the geology of the Kimberley-Elsburg Series in the Brakpan-East Daggafontein area: In the western part of this area, according to his plans and sections, he regards the Upper Parent Conglomerate (U.K. 9B) as a component part of the May Reef, and he does not distinguish between the May Reef and its hangingwall leader in the eastern sector. In one place he does state that Sharpe's U.K. 9A Reef is the equivalent of the May Reef of the eastern sector and that the U.K. 9B Reef (Upper Parent Conglomerate) disappears eastwards, which is in agreement with the author's conclusions as set out the previous year (10). But his map of the May Reef floor does not conform with this conclusion.

He gives a very interesting section through the May Shaft, previously described by Bancroft.

He interprets the M.K. 1 suite of sediments ("Chloritoid Shale" Marker) as beds which have filled erosion channels. He agrees, however, that these deposits could not everywhere be classed as the infilling of channels cut into the underlying sediments. On page 249 he writes:

"At first it was thought that they were all deposited in channels cut into the underlying rocks but many of the smaller channel shaped deposits are better explained as remnants of truncated synclinal folds. However, there does appear to be at least one deep erosion channel, first noted in the vicinity of May Shaft, East Daggafontein".

A study of Whiteside's paper, and particularly of the very instructive plans and sections accompanying it, leads one to the conclusion that, apart from the May Shaft area, the stratigraphy of the Kimberley group of sediments in the area under review duplicates the stratigraphy of these beds on Vogelstruisbult. Important points of

/correspondence .....

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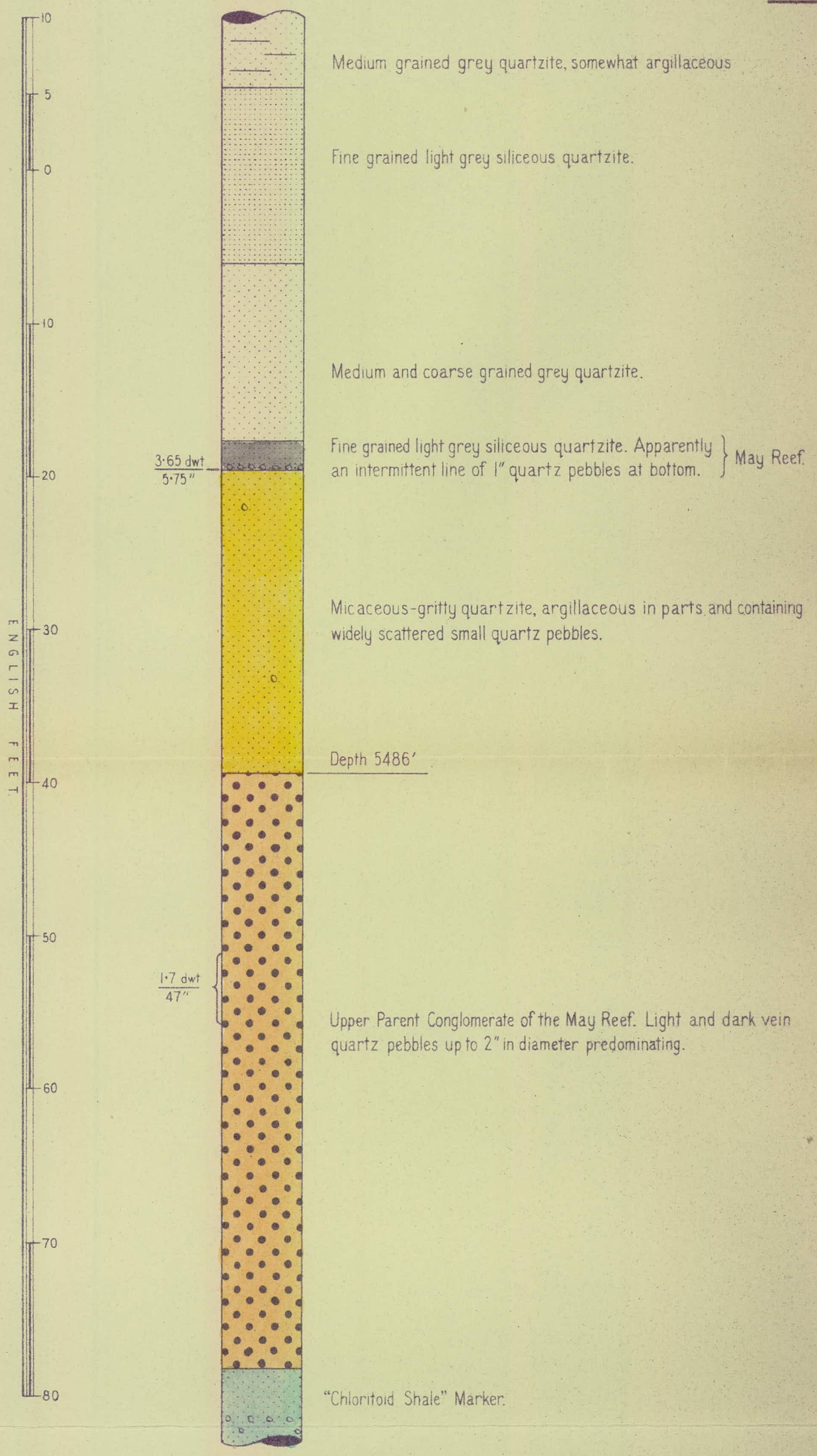
FIG. 4.



$$\frac{3{\cdot}65 \text{ dwt}}{5{\cdot}75} = \frac{\text{gold content in dwt. per ton.}}{\text{sample width.}}$$

VLAKFONTEIN MINE
WESTERN EAST RAND

BOREHOLE V4 - DETAIL IN THE VICINITY OF THE MAY REEF

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vein quartz pebbles up to 2½ inches in diameter. Its gold content is generally very low.

When it lies directly on the Big Pebble Conglomerate, for instance in the northern portion of Brakpan Mines, the two horizons are distinguishable by means of the chert pebbles in the lower horizon.

An intermittently payable horizon exists along the bottom of the zone on Government Gold Mining Areas. This is the ill-sorted U.K. 9C Reef of Sharpe, which he at one stage correlated with the May Reef of the eastern sector.

(g) The Micaceous-gritty Quartzite is up to 20 feet thick in this sector, where it forms the immediate footwall of the May Reef over large areas.

The sub-May Reef erosion surface truncates the beds below to the extent that this unit and portions of the Upper Parent Conglomerate have been eliminated in some areas (plate IV, borehole K 16. 48).

(h) <u>The May Reef</u>:

The May Reef is seldom more than 24 inches wide, although locally widths up to 5½ feet are known. A feature of the May Reef in the western sector is the predominance of smoky and dark-edged quartz pebbles, seldom exceeding one inch in diameter. It is of economic importance on Government Gold Mining Areas, where the gold is almost invariably concentrated in the upper half of the reef, frequently in the uppermost few inches.

It rests unconformably on its footwall beds, and there is no doubt that the eroded portions of the Upper Parent Conglomerate were concentrated and spread out on the erosion surface to form the May Reef. The erosion surface apparently never cuts right through the Upper Parent Conglomerate (plates XI, XII and XIII).

(j) As mentioned before, the upper Kimberley conglomerate clusters gradually fade when traced from Government Gold Mining Areas in the north to Heidelberg in the south. In the latter area they have changed into quartzites.

A feature in the western sector is the occurrence of small chlorite pebbles in the '80' Foot Marker (plate I).

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VIII. CONTINUITY OF HORIZONS IN THE EAST RAND BASIN - SUMMARY.

When studying the sediments of the Kimberley-Elsburg Series, two things become apparent, namely

1. The phenomenal persistence of certain horizons and suites of sediments as regards both lateral extent and lithological character. The May Reef and Big Pebble Conglomerate, as well as some of the thicker zones, notably the Chert-pebble Quartzite Zone, are of very wide-spread occurrence. The Big Pebble Conglomerate is particularly constant in lithological character. These horizons have been identified to far beyond the limits of the East Rand Basin.

As a general rule, it appears that the absence of the thicker zones of sediments from a particular area should be attributed to removal after deposition, possibly in rare instances to non-deposition. Post-Witwatersrand erosion is not considered here.

2. In contrast to the above we have the marked lateral variation or change of facies along certain horizons as described in the preceding pages:

(i) Individual bands of the Big Pebble Conglomerate and Upper Parent Conglomerate change laterally into quartzite locally.

Locally the Big Pebble Conglomerate Zone also includes lenses of chloritoid - and rutile - rich shale up to 35 feet in thickness. Thin lenses of shale have been observed to occur at intervals right through a 50 feet body of Big Pebble Conglomerate.

(ii) Locally the May Reef degenerates into a dark, fine-grained vitreous quartzite, notably in the eastern half of the Nigel Mine.

(iii) The suite of sediments designated the "Chloritoid Shale" Marker changes from predominantly coarse arenaceous and rudaceous sediments in the Western East Rand, to predominantly fine-grained argillaceous rocks in the eastern sector. The basal members of the zone have been deposited on a fairly even floor (plates I and II).

/(iv) The upper .....

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(iv) The upper Kimberley conglomerate clusters (i.e. above the May Reef) gradually fade when traced from Government Gold Mining Areas in the north to Heidelberg in the south, in the latter area having dwindled to insignificance. Of interest in this connection is the behaviour of the '80' Foot Marker, in that individual pebble bands are frequently short-lived to the extent that the entire zone could be represented by clear quartzites (plates III and IV). Some boreholes intersected only one pebble in the zone.

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IX. NOTES ON THE METAMORPHISM OF THE SYSTEM, WITH PARTICULAR REFERENCE TO THE KIMBERLEY-ELSBURG SERIES.

The System has been metamorphosed regionally. The arenaceous types have been converted into quartzites and the once incoherent gravels into conglomerates, while sericitic mica and abundant chlorite have developed in the slaty types.

There are, however, two secondary minerals which deserve special attention. They are chloritoid and rutile, the latter of universal occurrence along the vertical column, to the extent that only the thin sections made from the pure quartzites (e.g. the Siliceous Quartzite Bar above the May Reef) failed to disclose the presence of rutile.

(a) Chloritoid:

Young (45) came to the conclusion that the mineral is chloritoid and not ottrelite. He writes, page 43:

> "When the chloritoid is cut approximately parallel to the base, it shows cleavages intersecting each other at about 60°. The presence of these is sufficient to distinguish the mineral from ottrelite".

A detailed study of the distribution of this mineral in the Kimberley-Elsburg Series has been carried out. It was observed in the following horizons:

1. In the lenticular shale bodies associated with the Big Pebble Conglomerate Zone. These are up to 35 feet thick, sandwiched in between the competent conglomerate layers.

2. The matrix of the Puddingstone Reef often contains chloritoid.

3. The "Chloritoid Shale" Marker: Chloritoid is sometimes very abundant in the argillaceous phases of this suite, not only in the narrow shale bands, but also in the thick bodies of shale. Borehole U.A. on Marievale is of particular interest in this respect. In this borehole chloritoid developed throughout 300 feet of shale. A thin section was prepared from specimens collected every 10 feet.

In some sectors, notably in the eastern half of the Nigel Mine, the argillaceous phases of this suite contain virtually no chloritoid.

4. Chloritoid has been observed in the matrix of the May Reef, especially in the thin layer of heavy concentrate near the top of the reef.

/ 5. The Argillaceous .....

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5. The Argillaceous Quartzite Bar above the May Reef often contains chloritoid.

All these sediments have been folded, faulted and tilted, so that the stress conditions requisite for the formation of chloritoid could have existed. Note the compression fold in K 4. 2E Haulage (plate VIII c.).

Severe shearing parallel to the plane of the May Reef is evident in some areas. On East Daggafontein the shear plane locally coincides with the May Reef, crushing it, and displacing vertical structures such as dykes for distances up to 80 feet. Generally, however, the shear zone can be seen a few inches to a few feet below the reef if the latter rests on shale, and a few feet above it, if the immediate footwall happens to be a more competent rock such as hard quartzites or conglomerates.

The shear zone is particularly well developed in the eastern half of the Nigel Mine. Chloritoid is, however, virtually absent from the "Chloritoid Shale" Marker in this area.

The mineral has not been observed in the Kimberley Shales, not even on Bloemendal 19, where the May Reef transgresses on to this argillaceous zone.

(b) Rutile:

In the East Rand Basin this mineral occurs in all the argillaceous zones and impure quartzites of the Upper Witwatersrand System, and abundantly in the Jeppestown Shales immediately below the Main Reef. It has also been observed in the conglomerates, notably in the thin heavy concentrate near the top of the May Reef.

The shale phases of the "Chloritoid Shale" Marker are particularly rich in rutile.

Numerous thin, lenticular, rutile-rich layers are associated with the Elsburg conglomerates near the top of the System.

Under the microscope the individual crystals and crystal aggregates can usually only be seen under a very high magnification. But the distribution of this mineral in the slide is always easily determined by reflected light. A high percentage of the crystals are in the form of geniculate twins. Others are fine tetragonal crystals. The crystals are frequently in the form of very slender needles, the so-called "clay-slate" needles, particularly in the Kimberley Shales.

/The rutile .....

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The rutile may lie scattered through the groundmass, or may be grouped in asteriated clusters, in bundles or sheaves, exactly as they had been shed by the parent titaniferous mineral.

Leucoxene has also been observed in the sediments of the Kimberley-Elsburg Series. The mineral is easily singled out if viewed by reflected light. It occurs as irregular grains 0.2 to 0.3 m.m. in diameter. It presents a whitish or light grey surface in reflected light. It is considered to be an alteration product of ilmenite. Rutile is frequently seen to "grow" on leucoxene.

Ilmenite has not been observed in the sediments of the Kimberley-Elsburg Series, but below the Main Reef, in the Jeppestown Shales, abundant ilmenite is present, usually showing an incipient alteration to leucoxene.

The three titanium minerals described above follow a very definite pattern of distribution in the Jeppestown Shales for the first 10 feet or so below the Main Reef: The shales are generally khaki-green or khaki-yellow in colour for the first few feet below the reef, gradually becoming darker, until at a distance of 8 to 10 feet below the reef they are dark greenish-grey in colour (bright green in thin section). Within this 10 feet the distribution of the three minerals under consideration is as follows:

1. The authigenic rutile crystals abound in the upper khaki-coloured zone, while an occasional whitish grain of leucoxene can be observed. Some of these grains have the characteristic yellow colour of rutile.

2. The rutile-rich zone is preceded by the darker zone in which leucoxene predominates. In this zone the rutile is frequently observed to "grow" on leucoxene.

3. Ilmenite and leucoxene occur in more or less equal proportions in the dark, greenish-grey zone at the bottom, while a little rutile may still be present. The ilmenite almost invariably shows an incipient alteration to leucoxene.

A partial chemical analysis of the khaki-shale from the Jeppestown Series gave 4 per cent TiO_2.

We are here at the junction of the competent upper Witwatersrand

/quartzites .....

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quartzites and the incompetent shales of the lower division. A certain amount of differential movement has taken place along this junction. It is therefore tentatively considered that the leucoxene and rutile developed as stress minerals from the parent detrital mineral ilmenite, rutile being the end-product. Chloritoid did not develop in these Jeppestown Shales.

As ilmenite has not been observed in the beds of the Kimberley-Elsburg Series, it would appear that the general grade of metamorphism reached in these beds is somewhat more advanced than the grade reached in the Jeppestown Series. Apparently contradicting this tentative conclusion is the fact that, regionally, the incompetent lower division suffered greater deformation than the resistant upper division.

In 1917 Young (45) considered the bulk of the rutile which he observed in the banket to be of authigenic origin, and concluded that titaniferous iron ore appears to have been deposited along certain horizons in the Witwatersrand System, and that the rutile was afterwards derived from that mineral.

In 1939 du Toit (15) mentioned the presence of minute rutile needles in the Kimberley Shales. He considered rutile as a secondary constituent of the banket, and concluded that it indicates the former presence of ilmenite.

H.B. Milner (27) described "compound ilmenite-rutile" grains, the rutile being a secondary product.

He considers rutile to be a possible stress mineral in some of the world occurrences.

Harker (19) considers the great number of minute rutile needles in cleaved slates as having been derived from the decomposition of biotite.

Considering, however, the mode of occurrence and distribution of ilmenite, leucoxene and rutile in the sediments of the Witwatersrand System, there is little doubt that ilmenite was the parent detrital grain, and that leucoxene and rutile are authigenic constituents formed from that mineral.

Ilmenite must have existed as an important accessory constituent in the parent rocks of the sediments of the Witwatersrand System, concentrated during the lengthy period of transportation to the site of

/permanent .....

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permanent deposition. At times extensive ilmenite-sand beaches must have existed.

Of interest and having a bearing on the genesis of rutile in the metamorphosed rocks of the Witwatersrand System, is the occurrence of rutile, leucoxene and ilmenite in certain dykes intrusive into the System: Abundant leucoxene and rutile occur in the so-called Ilmenite Diabase Dykes, which are younger than the Ventersdorp Intrusives and older than the Karroo. The Ilmenite Diabases are often very much sheared. Leucoxene with unaltered ilmenite cores have been observed, but if shearing has been severe, there is usually no trace of the original accessory constituent ilmenite, but rutile abounds, occurring in bundles and sheaves and in asteriated clusters. Under the microscope these highly altered rutile-rich dykes are not always readily distinguishable from the rutile-rich metamorphosed argillaceous sediments of the Witwatersrand System.

On West Vlakfontein borehole W.V.4 recently intersected a near vertical dyke, which contains a great abundance of fresh ilmenite. The other mineral constituents are also unaltered. This dyke is presumably of late Karroo age.

Rutile and leucoxene, although not plentiful, have also been observed in the Ventersdorp Intrusives.

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X. SUMMARY OF EVIDENCE FOR AN EROSION SURFACE IMMEDIATELY BELOW THE BOTTOM REEF IN THE EAST RAND BASIN.

du Toit (15) considered that the Kimberley Shales are transitional to the quartzites above and below. On Brakpan Mines and Government Gold Mining Areas one does get the impression of a gradual coarsening upwards into the Kimberley conglomerate group. But the Upper Quartzite Phase of the Kimberley Shales (a fine-grained vitreous quartzite) is generally absent away from that area, having been found only in isolated patches in the Dunnottar-Heidelberg area, while it appears to be non-existent everywhere in the eastern sector (See plates I, II, III and IV).

This fine-grained vitreous quartzite forms conspicuous outcrops in portions of the Greylingstad - Balfour district. No pebbles were observed in the zone, both there and in the East Rand Basin.

The coarse Chert-pebble Quartzite Zone, with the inconstant "B" Reef at the base, is always abruptly defined, irrespective of whether the Upper Quartzite Phase of the Kimberley Shales is developed or not.

The "B" Reef is strikingly unconformable to its footwall beds in parts of the Orange Free State gold field. It is not of economic importance in the East Rand Basin, but in parts of the Orange Free State gold field it is an important gold carrier. In the latter area the erosion surface sometimes cuts through the Kimberley Shales (Upper Shale Marker), eliminating also some of the Upper Bird Reefs.

While this erosion surface could not be studied in the mine workings, so that its true nature is not known, the author considers that it satisfies Twenhofel's definition of unconformity, as quoted in Chapter IV. It appears to be a regional surface representing a rate of deposition that is zero in some areas, and less than zero in adjacent areas. The absence of the Upper Quartzite Phase of the Kimberley Shales from certain areas is attributed to removal after deposition.

The constituent materials of the Bottom Reef in the East Rand Basin have not been derived from the floor on which it rests.

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XI. SUMMARY OF EVIDENCE FOR AN EROSION SURFACE IMMEDIATELY BELOW THE BIG PEBBLE CONGLOMERATE IN THE EAST RAND BASIN.

On Brakpan Mines and Government Gold Mining Areas the Big Pebble Conglomerate Zone occurs up to 400 feet above the Kimberley Shale Zone. The distance is generally less than 200 feet in the Sub Nigel - Spaarwater - Vlakfontein area, up to 290 feet in the vicinity of Heidelberg, from 3 to 30 feet in the south-eastern portion of the Sub Nigel Mine, and from 40 to 120 feet on Vogelstruisbult (See plates III and IV).

Along the eastern boundary of the Nigel Mine the Big Pebble Conglomerate generally rests directly on Kimberley Shales, but on the Marievale side of the boundary, in borehole U.Y., the Chert-pebble Quartzite Zone is again 157 feet thick (See plate XIII for position of boreholes).

It appears furthermore that deep scouring took place in portions of Marievale, Daggafontein and East Daggafontein prior to the deposition of the Big Pebble Conglomerate Zone, which resulted in the elimination of the entire Chert-pebble Quartzite Zone, the entire Kimberley Shale Zone, and even portions of the Bird Amygdaloid (plate V).

The constituent materials of the Big Pebble Conglomerate were not obtained from the floor on which it rests.

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XII. THE UNCONFORMITY IMMEDIATELY BELOW THE MAY REEF IN THE EAST RAND BASIN.

A. The Eastern East Rand

This erosion surface could be studied in great detail in the mine workings. It was recognised early on in this investigation because of the large number of characteristic marker horizons in the footwall of the May Reef. However, the differences between certain footwall horizons are often very slight, so that if mapping is not accomplished while the exposures underground are still clean and fresh, it soon becomes an impossible task.

The unconformity is more pronounced in some sectors than in others, due to different degrees of pre-May Reef tectonic disturbances in different areas. Over comparatively large areas it is frequently not possible to recognise the unconformable relationship, but that does not detract from the regional conception.

(a) Vogelstruisbult:

For the purpose of description, an "eroded feature" would imply an area in which the sub-May Reef erosion surface has cut into or through the Puddingstone Reef and Big Pebble Conglomerate.

1. The Area East of No.1 Shaft

The relationship here is one of an erosion surface truncating well-defined anticlines and synclines, which generally trend in a direction N30° W. S 30° E. But at least one large eroded feature trends in a NE-SW direction (plates X and XIII).

The angular difference between the May Reef and the older gravels is usually small, although locally, measurements up to 47° were recorded. These large angles do not persist in depth, however, as clearly illustrated by the geological section along K 5.5 Haulage (plate VII).

Locally the May Reef footwall sediments were folded very intricately, in one case giving rise to a complex, now truncated, dome (plate X, K 4.1B Drive).

It is not possible to calculate or estimate the amplitudes of these eroded anticlines to any degree of accuracy, as the folding appears to have been accompanied by a general but extremely gradual uplift of the entire depositional floor. The structurally high areas were planed down

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more or less flush with the adjacent structurally low areas. The coarse and heavy fractions of the detritus thus produced, including the gold and other heavy minerals shed by the older gravels, were deposited on the flanks of the truncated anticlines, but largely on the sub-May Reef synclines (plates VI, VII and X). Occasionally a thin veneer of "lag gravel" found permanent deposition on the crests of the eroded anticlines (plate IX, a and b).

It therefore appears that from a certain stage in the process the floor coinciding with the sub-May Reef synclines stood at a slightly lower elevation than the eroded crests of the anticlines, allowing a thickness of May Reef equal to the distance between wave base and floor. This distance varied between a fraction of an inch and 10 feet.

Some of these eroded features and the distribution of the gold in the May Reef relative to them are shown on plate X.

The following conglomerate horizons contributed to the mineral content of the May Reef in this area:

(i) Lenticular conglomerates associated with the "Chloritoid Shale" Marker.

(ii) The Puddingstone Reef.

(iii) The Big Pebble Conglomerate, which was the principal contributor of gold.

(iv) Lenticular conglomerates in the Chert-pebble Quartzite Zone.

It is not known whether the Upper Parent Conglomerate of the western sector ever existed in the area under review (plate I).

Notes on Individual Eroded Anticlines - plate X.

Eroded Anticline No.1:

Erosion apparently did not penetrate the Big Pebble Conglomerate. The Puddingstone Reef therefore appears to have been the principal source gravel in this area, but because of its general low gold content, a payable May Reef could not have formed over extensive areas. The small payable areas that are arranged on the north-eastern limb of this truncated anticline are considered to be related to it.

Eroded Anticline No.2:

Geological sections measured across portions of this eroded feature

/are shown .....

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are shown on plates VI and IX.

The May Reef has a low gold content immediately on and along the south-western limb of this feature. The reef is, however, more than two feet wide in places, and locally includes a high percentage of large chert pebbles, as for instance near the start of K 4.2B Haulage (plate VI b). These were obtained from the Big Pebble Conglomerate in the immediate vicinity.

As a general rule very little May Reef was deposited on the flat crest of this truncated anticline. It is often very difficult to follow this barren plane successfully, particularly if a robust May Reef Hangingwall Leader occurs immediately above the Big Pebble Conglomerate. If the former also includes a few large chert pebbles as sometimes happens, the May Reef horizon cannot be singled out (photograph No. 10).

The complex eroded dome at the north-western extremity of the feature under review is covered by a thin veneer of May Reef, very rich in gold and containing a great amount of soft carbon. For distances of 3 feet or more the reef does not include a single pebble, but is in the form of a thin veneer of sulphides, carbon, quartz grains, and containing the heavy minerals gold, zircon, rutile, chromite, etc. The crests of the eroded anticlines, although generally areas of non-deposition, are therefore never eliminated beforehand as being of no interest.

The richest May Reef which appears to be related to the No.2 eroded anticline occurs on and along its north-eastern limb, and extends for some 600 feet on to the associated syncline (plate X b). The highest gold values are generally confined to the uppermost few inches (plate IX c), and are associated with a thin layer of fine-grained heavy minerals, which exists in sedimentary continuity with the thin veneer of rich May Reef on the eroded dome.

Eroded Anticline No.3:

Along K 4.3 Haulage the pay shoots are confined to the sub-May Reef synclines. The richest May Reef existing in the mine has been found here.

Eroded Anticline No.4 (North of the tear fault):

Considerable difficulty was experienced in locating the May Reef horizon in this area. Two years elapsed before it was discovered that

/the areas .....

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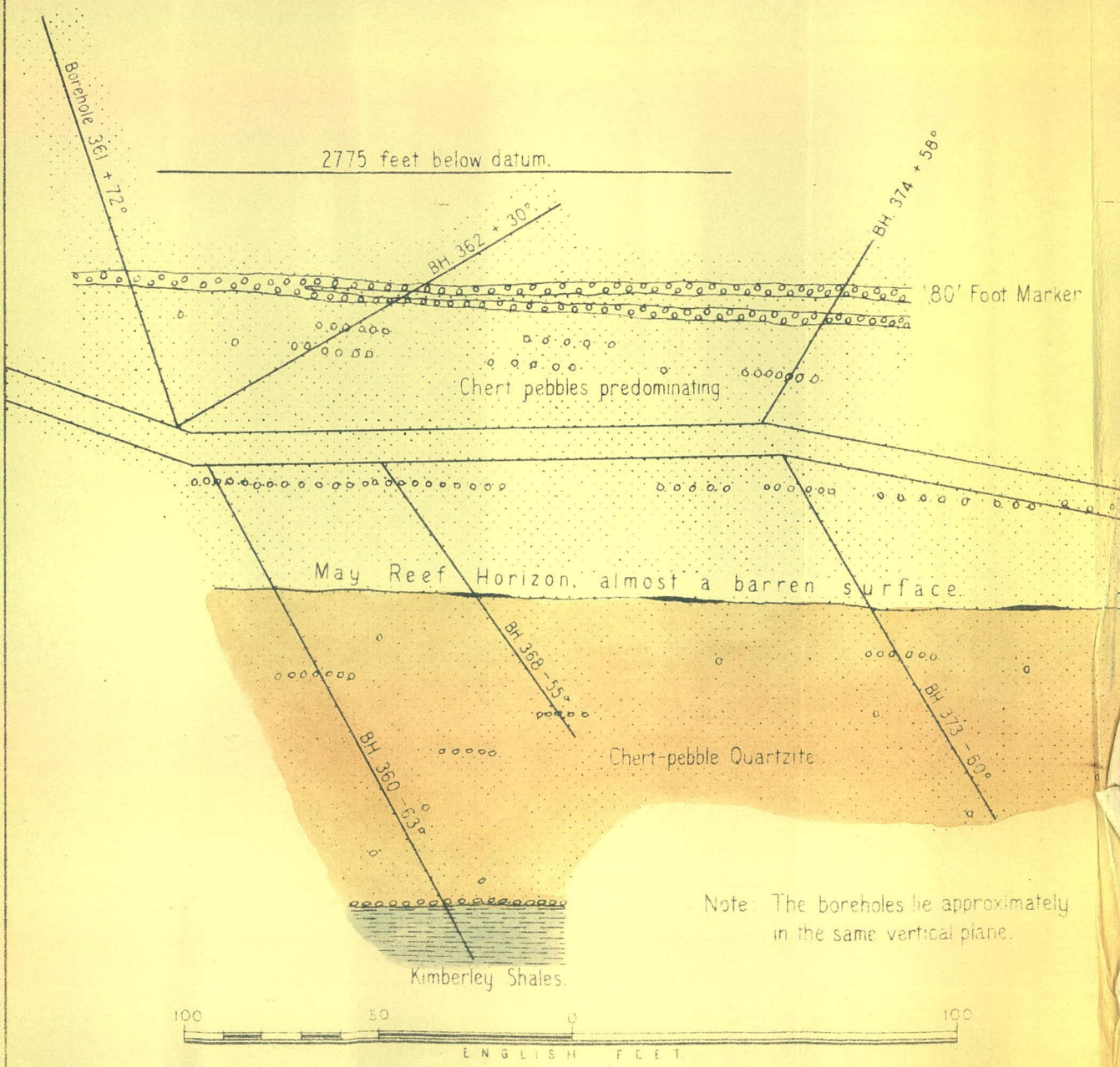
FIG. 5.

VOGELSTRUISBULT MINE

EASTERN EAST RAND

SECTION DETERMINED BY DRILLING ALONG PART OF K4LB.2. WINZE



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the areas to the north and south of the fault were not in sedimentary continuity (plate X). The geological section of K 4.1B.2 Winze (figure 5) illustrates the problem encountered here. Boreholes were drilled upwards and downwards from this winze in search of a known marker horizon. A tentative interpretation was given at the completion of boreholes 373 and 374. The end was then directed downwards and eventually intersected the May Reef horizon on the Big Pebble Conglomerate near the common boundary with East Daggafontein Mine.

It was thus realized that K4.1B. 2 Winze had entered on to an eroded feature of comparatively large amplitude. K.5 Haulage (plate VIII a) thereafter experienced no difficulty, and eventually K5.5 Haulage (plate VII) exposed payable May Reef on the easily recognisable chloritoid shale. More than half a million tons of ore reserve have subsequently been blocked out westwards from this eroded feature.

We have thus in this area striking examples of the provenance of the May Reef, i.e. stratigraphically older auriferous gravels. Due to the small difference in angle of deposition between the May Reef and the older gravels, and the consequent sheet erosion effect, an enormous supply of gravelly material was made available for concentration.

Several more eroded features have been exposed in the mine workings south-east and south-west of No.4 Shaft. The general rule also applies that the structurally high areas were areas of non-deposition as far as the May Reef is concerned, except in one comparatively large area south-west of No.4 Shaft where a wide robust May Reef found permanent deposition on the crest of an eroded anticline (photograph No.6). In such instances the May Reef is distinguished from the Big Pebble Conglomerate by its higher gold content, and visually by the fact that chert pebbles may be more prevalent in the lower horizon. The condition described above could be explained in one of two ways: (i) either the material derived and transported from this terrane was returned or (ii) derived from another eroded area in the vicinity.

The distribution of chert pebbles in the May Reef follows a definite pattern in the area east of Vogelstruisbult No.1 Shaft: on and near the eroded features chert pebbles and cobbles are common, at times predominating over the quartz members (photographs Nos. 2 and 8). With

/increasing ....

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increasing distance from the eroded areas the chert pebbles become inconspicuous, i.e. smaller and often absent (photographs Nos. 1 and 7). The chert pebbles in the footwall gravels are generally large, so that their disappearance from the May Reef in a given direction from an eroded feature could be the result of sorting of the pebbles according to size.

2. No.2 Shaft and the Outcrop Area

No eroded features have been discovered south-westwards towards No.2 Shaft or in the outcrop area. The phenomenal variation in the thickness of the "Chloritoid Shale" Marker in the outcrop area is attributed in part to the unconformity under review.

Eroded features might have existed behind the line of outcrop or sub-outcrop of the May Reef, subsequently obliterated by pre-Transvaal or pre-Karroo erosion (plate XIII).

(b) Marievale Mine:

In the Draaikraal sector adjoining the Nigel Mine, borehole U.Y. intersected an eroded anticline of comparatively large amplitude (plate XIII).

Drilling on Bloemendal showed the May Reef to lie on Kimberley Shales. It is therefore possible that the May Reef also lies on Kimberley Shales in the adjoining portion of Marievale (plate XIII).

Elsewhere on Marievale the May Reef rests on the chloritoid-bearing shales over large areas. Note the thickness of the "Chloritoid Shale" Marker in boreholes U.R., U.P., U.T. and U.A. (plate V).

(c) The Nigel Mine:

In the southern portion of the mine, where underground development is in progress, the May Reef is strikingly unconformable to its footwall beds. The robust lenticular conglomerates associated with the "Chloritoid Shale" Marker are considered to have been the principal parent gravels in this area, although locally the erosion surface cuts into the Big Pebble Conglomerate Zone. Seeing that we are here very near the line of demarcation between the western and eastern sectors of the Basin, the Upper Parent Conglomerate of the western sector might have been an important contributor to the mineral content of the May Reef in the area under review (plate XIII).

(d) The Area to the North of Vogelstruisbult:

/This area .....

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This area includes Daggafontein, East Daggafontein and the eastern half of Springs Mines.

The sub-May Reef erosion surface has cut into and through the Puddingstone Reef and Big Pebble Conglomerate over fairly large areas in this sector. There can be no doubt that these two horizons were the principal parent gravels, the Big Pebble Conglomerate having been the most important contributor of gold to the May Reef. It is not possible to relate a particular payable area on the May Reef to a specific eroded feature. The coarse and heavy fractions of the material obtained from the footwall rocks were deposited along narrow well-defined zones, trending in a north-west south-east direction (Whiteside (44), plates XLIII and XLV).

B. The Western East Rand

In the eastern sector the "Chloritoid Shale" Marker is the stratigraphically highest footwall series below the May Reef (plate II).

In the western sector the Upper Parent Conglomerate and the Micaceous-gritty Quartzite intervene between the "Chloritoid Shale" Marker and the May Reef (plate I). The May Reef has the characteristic Micaceous-gritty Quartzite as its immediate footwall over large areas in this sector. In places the reef transgresses on to the Upper Parent Conglomerate. The unconformable relationship is thus established (plate XIII).

The Upper Parent Conglomerate disappears eastwards along the dividing line between the two sectors. It is not known to what extent it existed in the eastern sector.

The relationship between the May Reef and its floor in the western sector is one of a basal conglomerate blanketing an erosion surface that truncates shallow flexures. The angular difference is therefore small, amounting at the most to a few degrees. On the structurally high areas the erosion surface cuts well into, but apparently never right through the Upper Parent Conglomerate. The second generation pebbles of the May Reef have suffered a reduction in diameter of more than 50 per cent.

"Windows" of the Upper Parent Conglomerate have been located in the following areas:

(a) Around Sub Nigel No.3 Shaft:

/A drive .....

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A drive on May Reef intersected two large eroded features. The erosion surface cuts well into, but never through the Upper Parent Conglomerate (plates XI and XIII).

(b) An extensive eroded area exists in the southern portion of the Sub Nigel Mine, extending also into the Nigel Mine, as indicated by boreholes S.N.6 to S.N.19 (plate XII b and plate XIII). The geological sections of these boreholes indicate the following sequence of events that led to the formation of the May Reef:

1. Uplift of the depositional floor and warping of parts thereof, to above a base level of deposition.

2. Concomitant erosion to near that level, which resulted in the concentration of the gravelly material obtained from the slightly auriferous Upper Parent Conglomerate.

The second generation pebbles suffered a reduction in diameter of more than 50 per cent.

3. Permanent deposition of the concentrate in an adjacent slightly lower-lying area.

Note the gold content of the May Reef in boreholes S.N.17, S.N.18 and S.N.19 (plate XII b).

(c) Around the C.V. Shaft of the Sub Nigel Mine the May Reef horizon is represented by a barren plane, sometimes on the Micaceous-gritty Quartzite and sometimes on the Upper Parent Conglomerate (plate XII a and plate XIII).

(d) Along the outcrops between Nigel and Heidelberg, the floor of the May Reef could be studied at intervals:

An extensive eroded feature was recognised in the southern portion of Spaarwater Mine. The May Reef is apparently not developed in this area.

Further south, on Maraisdrift 4, the May Reef is again well developed, on the Micaceous-gritty Quartzite as footwall (plate XIII).

(e) Most of the deep boreholes drilled in the Heidelberg-Dunnottar area showed the May Reef lying on the Micaceous-gritty Quartzite. Borehole T.L.3 on the Heidelberg Townlands intersected an eroded feature. The May Reef is not developed in this borehole.

/ (f) A study .....

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(f) A study of the literature strongly suggests that in the area to the north of Vlakfontein (Sallies to Government Gold Mining Areas), the May Reef owes its existence to the same sequence of events as described above.

Note: The author is of the opinion that many more eroded features exist in the Western East Rand.

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XIII. THE KIMBERLEY-ELSBURG SERIES IN OTHER AREAS, WITH SPECIAL REFERENCE TO THE KIMBERLEY GROUP OF SEDIMENTS.

A. Greylingstad-Balfour District, i.e. The Area to the South of the Sugarbush Fault (Figure 1).

The area under review stretches from Modderfontein 56 in the west to the old Heidelberg-Roodepoort Mine in the east. This mine is also known under the name of East Nigel Gold Areas.

For descriptive purposes this outcrop area is divided into three parts, a western, central and eastern sector. From a geological point of view the area could probably best be divided into two sectors, as in the case of the East Rand Basin.

(a) The Western Sector:

This sector includes the outcrop area on Modderfontein 56, Malanskraal 73, Driefontein 280, and Tweefontein 98 (geological map by Rogers (34)).

This area has not been examined, so that nothing concrete about it is known, except that exposures are good, and that there are numerous prospect trenches and pits, particularly on Malanskraal.

(b) The Central Sector:

This sector includes the outcrops on Rietfontein 244 and Daspoort 120. The old Balfour Gold Mine is situated on the latter farm (geological map by Rogers (34)).

1. Rietfontein 244

The Kimberley reef outcrops are located about 3 miles south-west of Balfour railway station. The following stratigraphic units of the Kimberley group of sediments have been recognised, striking east-west and dipping to the north at fairly steep angles :

(i) The Kimberley Shales proper, immediately to the south of a prominent quartzite ridge.

(ii) The quartzite ridge mentioned above is formed by the Upper Quartzite Phase of the Kimberley Shale Zone. These quartzites are also known on Brakpan Mines and Government Gold Mining Areas.

(iii) The Chert-pebble Quartzite Zone: These beds do not form good outcrops, but positive proof was obtained from an old excavation

/immediately .....

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immediately to the south of the railway line. From the rock dumps at the sites of the inclined shafts immediately to the north of the railway line fresh specimens were obtained.

(iv) The Big Pebble Conglomerate:

This robust conglomerate is composed almost entirely of large discoidal and angular chert pebbles, exhibiting a complete lack of imbrication. It is very similar in appearance to the intersection of the Big Pebble Conglomerate by borehole E.9H on the Far West Rand.

(v) The Puddingstone Reef occurs a short distance above the Big Pebble Conglomerate and forms a very good outcrop. In the weathered state the rock is reddish-brown in appearance, studded by the various coloured pebbles. Outcrops of the Puddingstone Reef were first studied on the Heidelberg Townlands.

(vi) The May Reef which is a small-pebble reef up to 12 inches wide rests on the Puddingstone Reef.

2. Daspoort 120 - the Old Balfour Gold Mine

Judging by the rock dumps at the shaft site it would appear that the bulk of the underground work had been carried out on the May Reef.

Very fine outcrops could be studied, and a few old winzes on the May Reef were accessible for short distances.

The following horizons were recognised :

(i) The Chert-pebble Quartzite Zone.

(ii) The Big Pebble Conglomerate.

(iii) The Puddingstone Reef. Very typical specimens were obtained from the rock dumps.

(iv) A fine-grained, khaki-green, rutile-rich shale, which is a phase of the "Chloritoid Shale" Marker. A similar rock occurs in the same stratigraphic position in borehole E.9H on the Far West Rand.

(v) The May Reef which rests alternately on the khaki shales and the Puddingstone Reef.

The May Reef is up to 3 feet in thickness and includes fairly wide bands of a dark, vitreous quartzite. The majority of the pebbles are dark, smoky quartz.

The May Reef on Daspoort 120 is similar in all respects to the May Reef intersected by boreholes $V^{o}.3$ to $V^{o}.13$ in the outcrop area on

/Vogelstruisbult Mine .....

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Vogelstruisbult Mine. The former area lies due south of the latter.

(c) The Eastern Sector:

This sector covers the area to the south and south-west of Greylingstad up to a distance of 13 miles from the village (figure 1).

It includes -

1. East Nigel Gold Areas (The old Heidelberg-Roodepoort Mine).
2. East Wits Gold Mining Areas, on the farm Rooiwal 295.
3. New Rand Reefs, and South-East Wits Gold Mining Company.

A portion of this area was recently worked under the name of Hex River Gold Areas.

1. East Nigel Gold Areas

The outcrops are located 2½ miles due south of Greylingstad. The beds strike roughly north-south, dipping to the west at angles varying between 20° and 35°.

The reef on the Kimberley Shales is beyond any doubt the May Reef. The identification of the Kimberley Shales is confirmed by outcrops of the Bird Amygdaloid in the vicinity.

The May Reef is up to 3 feet wide. The bulk of the pebbles are of the dark, smoky quartz variety, with very occasional chert members. They do not exceed one inch in diameter, and are generally much smaller. The reef body includes fairly wide bands of dark, fine-grained, vitreous quartzite. Texturally the reef compares well with the May Reef in certain parts of the East Rand Basin, notably on Marievale, portions of Vogelstruisbult and East Daggafontein, and the eastern half of the Nigel Mine.

2. East Wits Gold Mining Areas on the farm Rooiwal 295 (figure 1).

The outcrops occur due south-west of Greylingstad, at a distance of about 13 miles from the village. The beds strike in a direction N 22° W - S 22° E, and dip at very steep angles to the north-east.

The reef on the Kimberley Shales is undoubtedly the May Reef.

A second shale horizon, which appears to be the Jeppestown Shale, outcrops further updip.

The Bird Amygdaloid was not identified.

A number of winzes were sunk on the reef to depths of about 50 feet, and about 1,000 feet of lateral driving accomplished.

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The quartzites above the reef horizon leading up to the Ventersdorp Lava compare well with the May Reef hangingwall as known in the Heidelberg area.

The May Reef has a very constant thickness of about 3 feet. It is a well-packed conglomerate bed, with a minimum of internal "waste". The bulk of the pebbles are of smoky quartz, seldom exceeding one inch in diameter. The occasional chert members are easily overlooked in the dark matrix of the reef.

3. Hex River Gold Areas (figure 1).

The outcrops are located 12 miles from Greylingstad, in a direction slightly west of south. An old winze near the Greylingstad-Villiers road was examined. A poorly developed reef, 3 feet wide, lies on a weathered shale. Correlation with the May Reef is suggested by a fine-grained, vitreous quartzite occurring immediately above the reef. It is responsible for a low, but well-defined ridge on the surface. Considering the neighbouring areas described above, there remains but little doubt that we are dealing with the May Reef, again lying on Kimberley Shales.

It is interesting to note that geologically, the eastern portion of the Greylingstad-Balfour sector corresponds very closely to the farm Bloemendal 19 and the adjoining portion of the Marievale Mine north of the Sugarbush Fault.

B. Rose Deep Mine to East Rand Proprietary Mines (Between Germiston and Brakpan).

No information could be obtained for this section of the Witwatersrand gold field as regards the Kimberley-Elsburg Series.

C. The Simmer and Jack Mines to the Witpoortje Break.

This section embraces most of the Central Rand proper.

G. Carleton Jones (22) writes about this sector :

"The base of the Kimberley Reef zone is variously given as from 3,200 to 4,000 feet or more above the Main Reef. The group has not been properly delimited in this area and the reef zone is variously reported as being anywhere from 520 to 800 feet in thickness and to include as many as 13 or even 17 individual reefs, with widths ranging from 18 inches to 11

/feet, ...

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feet, and with pebbles up to six inches and more in size and frequently accompanied by much pyrite. These reefs were worked in the past in the old Great Britain Mine and in the Consolidated Main Reef. A certain amount of development work, mostly on the surface, has been done on the Kimberley Reef in other mines, but results have not been encouraging".

The South Deep Shaft on the Simmer and Jack Mines was recently examined. But due to the awkward working conditions in the shaft, its age and consequent condition of the walls, the examination was not very satisfactory.

However, a certain amount of positive information was obtained (plate XIV):

1. The Kimberley Shales are transitional upward into quartzite. To all intents and purposes there could be a gradual coarsening upward into the Kimberley conglomerate group.

2. A 5 foot band of fine-grained, khaki-green, rutile-rich shale, also containing chloritoid, occurs at a depth of 1,111 feet.

3. The reef at 945 feet is tentatively considered to be the May Reef. It gave the highest individual value of the Kimberley reefs intersected by the shaft. The reef is 90 inches wide, with the highest values limited to the upper band. It is a well-packed quartz-pebble conglomerate, the bulk of the pebbles being up to 1½ inches in diameter.

4. Above the 945 foot reef the sediments could be resolved into quartzite zones and conglomerate clusters, corresponding to Sharpe's sub-divisions on Government Gold Mining Areas.

Note: A borehole from surface just completed confirmed the above analysis.

D. The Far West Rand

Strictly speaking the West Rand should now be considered, but because a solution was first found for the Far West Rand, it will be discussed first. The correlation in the West Rand area is based to a great extent on the geological section of borehole E.9H near Blyvooruitzicht Mine. An examination of this borehole, situated on the farm Kleinfontein

/No.36, showed .....

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No.36, showed that the Kimberley group of sediments on the Far West Rand could be resolved into the same sub-divisions as in the East Rand Basin (plate XIV). That establishes correlation.

The individual units that were recognised are as follows :-

1. The Kimberley Shale Zone with its upper and lower quartzite phases between depths of 4,990 and 5,594 feet, a total borehole thickness of 604 feet.

2. The horizon of the Bottom Reef at 4,990 feet.

3. The Chert-pebble Quartzite Zone between depths of 4,761 and 4,990 feet.

4. The Big Pebble Conglomerate (3 feet wide) at 4,761 feet.

5. The "Chloritoid Shale" Marker between depths of 4,603 and 4,758 feet, a total borehole thickness of 155 feet.

Lithologically the suite varies rapidly along the vertical column, and most probably also laterally. Many of the contacts between individual units are sharp. The different phases which could be recognised are :

(i) Fine-grained khaki-green rutile-rich shale between depths of 4,650 and 4,660 feet.

(ii) Narrow chert-pebble bands, probably lenticular.

(iii) Widely scattered chert pebbles (½ inch) in a greenish somewhat argillaceous quartzite.

(iv) Concentrations of black chert fragments in quartzite.

(v) Coarse-grained khaki-green quartzite, with matrix consisting mostly of chlorite, rutile and a little sericite.

(vi) Numerous narrow layers of fine-grained, whitish, vitreous quartzite, having sharp contacts. Under the microscope it is seen to be a nearly pure quartzite, the quartz grains forming a very close mosaic.

6. The May Reef occurs at a depth of 4,603 feet.

7. The '80' Foot Marker is represented by a 6 inch pyritic pebbly grit at 4,487 feet.

E. The West Rand Area

Luipaardsvlei Estates, West Rand Consolidated Mines and Randfontein Estates are discussed under this heading (Jones (22) plan B).

/Facts .....

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Facts and ideas were obtained from the Presidential address to the Geological Society of South Africa by G. Carleton Jones (22). Additional information was obtained from publications by C.S. McLean (24) and C.W. Pegg (29).

(a) Luipaardsvlei Estates:

Considering the geological section of borehole E.9H on the Far West Rand, there is very little doubt that the Boulder Reef of Luipaardsvlei Estates correlates with the Big Pebble Conglomerate of the areas described thus far. It occurs only a short distance above the Kimberley Shales. On this basis the Battery Reef which is being mined on Luipaardsvlei Estates should correlate with the May Reef. The Battery Reef occurs only a few inches, or at the most a few feet above the Boulder Reef.

In the Battery Reef the pebbles are up to 3 inches in diameter, while 12-inch boulders have been encountered in the Boulder Reef. The Battery Reef may thus well represent a "re-worked portion" of the Boulder Reef.

(b) West Rand Consolidated Mines:

The Boulder Reef of this mine is considered to be the equivalent of the Big Pebble Conglomerate. Cobbles in the Boulder Reef are up to 6 inches in diameter.

The economic horizon called the Pay Band or Battery Pay Band is considered to be the equivalent of the May Reef. It lies from 250 to 500 feet above the Kimberley Shales. It is a well mineralized reef up to 15 feet in thickness, and contains large pebbles, often 3 inches in diameter. The highest values usually occur in the bottom band which is associated with a carbon seam. It is therefore possible that the upper portion of the socalled Battery Pay Band actually corresponds to the May Reef Hangingwall Leader of the Eastern East Rand.

Near the common boundary with Luipaardsvlei Estates the Battery Pay Band occurs only about 2 feet above the Boulder Reef. In a westerly direction the two reefs diverge more and more until they are 60 to 70 feet apart in the south-western corner of West Rand Consolidated Mines.

The geological section of West Rand Consolidated South Shaft (plate XIV) illustrates the close correspondence between the West Rand and East Rand columns. In ascending sequence it appears that the

/following .....

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following stratigraphic units can be recognised in this shaft: Bottom Reef, Chert-pebble Quartzite, Big Pebble Conglomerate, "Chloritoid Shale" Marker, May Reef and the '80' Foot Marker.

Pegg (29) mentioned the presence of small chert pebbles in the quartzites above the Kimberley Shales in this area.

(c) Randfontein Estates:

The Big Pebble Conglomerate is represented on this mine by the Lindum Reef. Actually the Lindum Reef is the bottom band of a wide conglomerate zone.

The Horsham Reef, considered to be the equivalent of the May Reef, lies at 110 to 125 feet above the Lindum Reef. It has an immediate footwall of either thin shale or soft grit, which presumably correspond to the "Chloritoid Shale" Marker of other areas. The stoped section of the Horsham Reef lies at the base of a 25 foot zone of conglomerates. The upper portion of the reef body is therefore considered to be the equivalent of the May Reef Hangingwall Leader of the Eastern East Rand.

The evidence therefore suggests the existence also in the West Rand area of the three major unconformities recognised within the Kimberley group of sediments in the East Rand Basin :

1. Below the Bottom Reef.

The upper quartzite phase of the Kimberley Shales is non-existent in the West Rand Consolidated South Shaft (plate XIV). Well to the east and to the south-west, in the Simmer and Jack South Deep Shaft and in borehole E.9H, this unit is again well developed.

2. Below the Big Pebble Conglomerate.

There is a very marked divergence between the Big Pebble Conglomerate and the Bottom Reef south-westwards from Luipaardsvlei Estates.

3. Below the May Reef.

The Big Pebble Conglomerate and the May Reef diverge in the same direction.

F. Klerksdorp Area

Borehole No.2 on Witkop 46 and borehole No.2 on Pilgrim's Estate 722 (Baines (2) plate VIII) suggest the existence of the Kimberley Shales

/in the .....

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in the Klerksdorp area. A conglomerate which is locally known as the Gold Estates Reef most likely correlates with the Big Pebble Conglomerate of other areas, for three reasons :

1. It occurs in a suitable stratigraphic position to be the Big Pebble Conglomerate.

2. Beetz's description of the Gold Estates Reef as summarized by Baines (2) fits the Big Pebble Conglomerate of other areas, except for the pebbles and boulders of "black mineralized shale". This summary reads :

> "a large pebble reef with intercalated layers of coarse quartzite; pebbles and boulders up to 8 inches in diameter of many different rocks, mainly quartz, chert, quartzite and black mineralized shale".

3. The Gold Estates Reef rests with strong unconformity on its footwall beds, according to Nel (28), Baines (2) and Beetz (4). It appears that the erosion surface has cut right through the Kimberley Shales in some areas, also eliminating the Vaal Reef, which is the equivalent of the Basal Reef of the Orange Free State.

Baines (2) states that the "upper portion" of the Big Pebble Conglomerate is being mined by New Klerksdorp Gold Estates Co., Ltd. The author suggests that these upper bands correlate with the May Reef. The relationship would then be the same as between the Battery Reef and Boulder Reef on Luipaardsvlei Estates.

We are therefore apparently dealing with at least two important unconformities in the Kimberley group of sediments in the Klerksdorp area, one below the May Reef and the other below the Big Pebble Conglomerate.

G. The Orange Free State Gold Field

de Kock (14) (p. 130) writes about the economic reefs in this field:

> 'The principal economic reef horizons so far disclosed in the Free State are in order of importance: The "Basal" Reef; the "Leader" Reef; the "B" Reef; the "A" Reef; the "Upper" Reefs and the "Ventersdorp Contact" Reef. Of these the Basal Reef is by far the most important gold carrier in the Free State. Although it is too early for a final

/correlation .....

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correlation the following tentative correlation of these reefs with those better known on the Rand is suggested. The Ventersdorp Contact Reef occurring at the base of the Ventersdorp Lower Lava is the counterpart of the same reef as known on Venterspost and Western Reefs. The Upper Reefs with their principal development in the Van den Heevers Rust area may be the equivalent of the Elsburg Reefs known in the Western Reefs mine. The "A" Reef strongly resembles the "May" Reef of the Kimberley Reef group of the East Rand. The "B" Reef is closely similar to the lower Kimberley Reef which generally rests on the Kimberley Shales. The Leader Reef and Basal Reef can be correlated with reefs in the Bird Reef group, whilst there is now little doubt that the Basal Reef and the Vaal Reef occur on the same horizon'.

Many of the conclusions arrived at in this chapter are the direct outcome of frequent discussions with Dr. W.P. de Kock. His recognition of the May Reef in the Odendaalsrus area led the author to scrutinise the literature more closely. Dr. de Kock also arranged exchange visits between the author and Mr. G.W.S. Baumbach, resident geologist for New Consolidated Gold Fields in the Orange Free State. Mr. Baumbach recognised the close correspondence between the Vogelstruisbult Mine and certain parts of the Orange Free State gold field as regards the Kimberley group of sediments.

The areas to the south and south-east of Odendaalsrus are being discussed separately.

(a) <u>The Area to the South-East of Odendaalsrus:</u>

A study of the literature on this area (Borchers and White (5) and Baines (2)) and an examination of borehole cores (shown to the author by Mr. Baumbach) revealed the fact that the group of sediments immediately above the Upper Shale Marker could be resolved into the fundamental units of the Kimberley group of sediments as known elsewhere. Correlation is thereby established. Reference to the average column by Borchers and White (5, fig. 1) is necessary to explain the details of the suggested correlation.

1. <u>Kimberley Shales</u>

/The Upper Shale .....

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The Upper Shale Marker is considered to be the equivalent of the Kimberley Shales. Borchers and White reported these beds to be chloritoid-rich. A personal inspection of various boreholes did not confirm this.

2. The Bottom Reef or "B" Reef

A certain amount of erosion took place prior to the deposition of this reef, so that it may rest on either the Kimberley Shales or on the dull-grey quartzites which normally underlie the Kimberley Shales. It is of economic importance in some areas. When the Kimberley Shale Zone is absent due to the stratigraphic break, the "B" reef can only be identified with certainty when the section above it is complete or nearly complete (Baines (2) plate IX).

3. The Chert-pebble Quartzite Zone

This suite of sediments has been recognised in the area south-east of Odendaalsrus. It embraces an upper zone, "E.C.3 Elsburg Rare Conglomerates", and a lower zone "E.C.4 Elsburg Mixed Pebble Reefs".

The lower zone contains some robust conglomerate bands, which are probably highly lenticular. Otherwise the zone is a pebbly quartzite. Pebble types include white quartz, grey, black and banded chert, occasional red jaspers, and an unidentified khaki-yellow siliceous rock.

Generally speaking the upper zone is not much different from the lower. The quartzites of the upper zone are perhaps more argillaceous, while the pebbles may be somewhat smaller and more scattered. However, there appears to be no need for a separation into an upper and a lower zone. This is one sedimentary phase. The beds are grouped together under the name suggested above.

4. The Big Pebble Conglomerate : (E.C.2 Elsburg Big Pebble Reef Marker.)

This horizon is a very important marker in the Orange Free State. The zone may be up to 180 feet thick. Pebble types include white quartz (quite often predominating), black and banded chert, while occasional shale pebbles have been encountered. The pebbles are usually up to 2 or 3 inches in diameter, except towards the base when they may reach a maximum diameter of 6 inches.

The Big Pebble Conglomerate is not always readily identified in borehole cores, for three reasons :

/ (i) It may .....

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(i) It may change laterally into a quartzite zone, thereby rendering recognition difficult.

(ii) In some areas the zone is entirely eliminated by the unconformity below the May Reef.

(iii) Similar robust conglomerates may appear in the suite designated the "Chloritoid Shale" Marker. The upper limit of the Big Pebble Conglomerate can therefore not always be determined with certainty.

There is positive evidence that the Big Pebble Conglomerate covers an erosion surface (Baines (2) p. 313). This is additional evidence in favour of the correlation put forward in this account.

5. The Puddingstone Reef

This conglomerate was recognised in one borehole from the area south-east of Odendaalsrus. It occurs in the correct stratigraphic position. Isolated pebbles of about $\frac{3}{4}$ inch diameter occur embedded in a shaly matrix. The core of this borehole was shown to the author by Mr. G.W.S. Baumbach.

This peculiar conglomerate is apparently intermittently developed in the sector under review. It has not been described in any of the publications.

6. The "Chloritoid Shale" Marker

Typical chloritoid-rich shale sometimes occurs above the Big Pebble Conglomerate. The tiny chloritoid crystals can be observed in hand specimen, scintillating with numerous pin-points of light. It is noteworthy that the Kimberley Shales (Upper Shale Marker) generally do not display this characteristic. The reason for this fundamental difference in the behaviour of the two shales is not clearly understood.

In areas where the typical chloritoid-rich shales are not developed, the "Chloritoid Shale" Marker may be recognised in a different form, as is also the case in the East Rand Basin. The "E.C. 1 Elsburg Conglomerate Zone" of Borchers and White appears to be the equivalent of the "Chloritoid Shale" Marker. It is largely composed of an argillaceous quartzite with a distinct yellowish tinge. This characteristic colour is almost certainly due to an abundance of the small rutile crystals. The zone includes a number of conglomerate bands.

7. The May Reef

/The "A" Reef .....

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The "A" Reef (Baines (2) p. 311) which occurs on the average about 70 feet above the Big Pebble Conglomerate, is considered to be the equivalent of the May Reef.

It is not always readily identified for the following reasons :

(i) In some areas it occurs sandwiched in between other conglomerates.

(ii) It is of lense-like character according to Baines. It may thus apparently degenerate into a mere pencil-line contact. An intimate knowledge of the hanging - and footwall rocks would then be necessary in order to recognise the horizon.

(iii) A high gold content would assist to single out the horizon.

Features of the reef are the dark matrix and the small smoky quartz pebbles. Occasionally it rests on chloritoid-rich shales, when correlation offers no difficulty.

8. The '80' Foot Marker

The "V.S. 5 Ventersdorp Basal Agglomerate - Conglomerate" of Borchers and White (5) appears to be the equivalent of the '80' Foot Marker of other areas.

The V.S. 5 may develop into a zone of conglomerates up to 100 feet in thickness. On the other extreme, it is often represented by a single narrow pebble bed.

9. The Elsburg Group of Conglomerates

It is possible that the "V.S.1 Ventersdorp Agglomerate - Conglomerate" corresponds to the Elsburg conglomerate group of the Rand. The zone has an average thickness of between 700 and 800 feet.

(b) The Area to the South of Odendaalsrus - the St. Helena Sector

The information for this area has largely been obtained from a publication by Frost and others (17).

Reference to plate VII of this publication is necessary.

Considering the detailed section of the "St. Helena Reef Zone", the following remarks are offered in connection with the subject of correlation :

1. The correlation of the "St. Helena Reef Zone" as a whole with the "Upper Elsburg Reef Zone" can now be revised.

/2. The sediments ....

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2. The sediments from the base of the socalled "Ventersdorp Basal Conglomerate" down to and including Frost's "Leader Reef" are tentatively correlated with the Kimberley group of conglomerates, the evidence being :

(i) The Big Pebble Conglomerate is now known and accepted as a regional marker, and undoubtedly belongs to the Kimberley conglomerate group.

(ii) The narrow persistent reef shown about 12 feet above the Big Pebble Conglomerate occurs in a suitable stratigraphic position to be the May Reef.

(iii) Lithologically the Mixed Pebble Conglomerate Zone compares well with the Chert-pebble Quartzite Zone of other areas (E.C. 3 and E.C. 4 of Borchers and White).

(iv) The "B" Reef occurs at the base of the Chert-pebble Quartzite Zone. That would indicate that Frost's "Leader Reef" is not the same horizon as the Borchers-White "Leader Reef". The former appears to be the Bottom Reef of the Kimberley group, while the latter is considered by de Kock (14) to be a member of the Bird Reef group. The explanation is found in the stratigraphic break immediately below the Bottom Reef, which resulted in the elimination of the Kimberley Shales and the uppermost Bird Reefs. The Bird Reefs therefore apparently contributed towards the mineral content of the "B" Reef in some areas.

3. It is possible that the Kimberley Shales have been preserved in some small areas in the sector under review.

4. It therefore follows that the Basal Reef and the Leader Reef proper should fall within the Main-Bird Series, apparently Upper Main-Bird, and may therefore be members of the Bird Reef group.

5. The correlation of the socalled "Ventersdorp Basal Conglomerate" with the Elsburg conglomerate group is a possibility.

(c) In support of the above analysis, the following passages are quoted from Baines and Borchers.

1. Baines (2) page 310 :

> 'It should be remembered, however, that the Leader Reef of the St. Helena Area is called the "B" Reef elsewhere, and that the Leader Reef of elsewhere does not

/occur .....

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occur in the St. Helena Area borehole cores except possibly in some instances in close proximity to the "B" Reef'.

2. Borchers (6) page 29 :

"Again St. Helena is unique in that no shales are developed in the Reef Zone whereas, almost without exception, everywhere else either the Khaki shale (above the Basal Reef) or the Upper Shale Marker or both, and at times a third shale horizon, are strongly developed and of very considerable importance as Marker Horizons".

H. The Vredefort Area

Sharpe (10) reported chloritoid-rich sediments from the Kimberley beds in the Great Western Mine near Vredefort.

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XIV. THE DEPOSITIONAL ASPECT

A. Continuity of Horizons

It has been shown that the Kimberley-Elsburg Series or portions thereof can be recognised over the bigger part of the large structural basin as defined in the introductory pages. It has furthermore been shown that a regional correlation of individual stratigraphic units of the Kimberley-Elsburg Series can be effected.

The sedimentary column and the lithological characteristics of these rocks in the East Rand Basin have been used in recognising the Series in other areas. Except for minor differences of which there may be many, the broad pattern indicated is considered to be substantially correct. One has to review the entire structural basin in order to arrive at a better perspective of some aspects of the problem.

The remarkable continuity of certain horizons over large areas, and the constancy of the lithological character of these horizons, concerning both coarse and fine sediments, assist in long-distance correlation, and have contributed to the rapid expansion of the Orange Free State gold fields. Of importance in this respect are :

(a) The Kimberley Shales, which are regarded by the author as the upper phase of the Main-Bird Series.

(b) The Chert-pebble Quartzite Zone.

(c) The Big Pebble Conglomerate.

(d) The '80' Foot Marker, and

(e) zones of clear quartzites.

In an endeavour to determine the environment(s) and modes of deposition of the sediments of the Kimberley-Elsburg Series, certain environments can thus be eliminated at the outset.

The phenomenal persistence regionally of such a coarse unit as the Big Pebble Conglomerate indicates very powerful transporting and distributing agents. Furthermore its very constant lithological character indicates -

1. The same set of conditions controlling its deposition over a very large area, and/or

2. derivation of the constituent materials from a lithologically constant terrane.

The units of clear quartzites also have very wide

/distribution

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distribution, indicating -

1. Constant type of material supplied, and/or

2. constant conditions of deposition over large areas.

There is one important exception to the above general rules, namely the suite of sediments designated the "Chloritoid Shale" Marker, which exhibits a very marked change of facies. In the East Rand Basin the change from coarse to fine takes place from west to east, or probably more correct from north-west to south-east.

The lateral change of conglomerate zones into clear quartzites (e.g. the upper Kimberley conglomerate clusters in the East Rand Basin) conforms to a perfectly normal behaviour of coarse clastics the world over. Such a feature indicates the direction from which the sediments came, and is not in the first place a pointer to a specific environment of deposition.

Ilmenite was continuously available during the time of formation of the Kimberley Shales, as indeed it was during the period of formation of the entire Upper Witwatersrand System, as indicated by the alteration products leucoxene and rutile. All three minerals occur in the Jeppestown Shales immediately below the Main Reef in the East Rand Basin.

Of paramount importance is the fact that certain stratigraphic breaks instituted within the succession assume a regional character. From an economic point of view it is very important to recognise these regional surfaces of erosion. Not only do they assist in long-distance correlation, but they have also a very important bearing on the economic possibilities of certain reefs. Only detailed stratigraphic study made possible their recognition. The May Reef could be related to older (parent) gravels. The same remark apparently applies to the "B" Reef in certain parts of the Orange Free State gold field, notably in the area immediately to the south of Odendaalsrus. A knowledge of the sum total of the gold contained in the source gravels is of prime importance in assessing the economic possibilities of the May Reef and "B" Reef in those areas where the erosion surfaces cut into the older gravels. The May Reef represents the heavy, resistant and coarse fraction of a large volume of sediments.

The sub-May Reef erosion surface has always a low relief, but the

/erosion .....

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erosion surface on which the Big Pebble Conglomerate rests has considerable relief locally. The unconformity below the "B" Reef is apparently also one of low relief.

B. A Discussion of the Environments Considered

This discussion is based on the classification of environments by Twenhofel (40 and 41).

It is conceivable that the sediments of the Kimberley-Elsburg Series could have formed partly under one and partly under another environment. The possibility that the sediments of the Kimberley-Elsburg Series occupied dry land at one or more stages has been investigated.

The following environments have been given consideration :

(a) Continental Environments

Of these the desert environment requires no comment, as there is no evidence to support the deposition of even a portion of the Kimberley-Elsburg Series in this environment.

Considering the abundance of gravel that was necessary for the formation of the Big Pebble Conglomerate, the possibility of glacial accumulations in the piedmont and lower piedmont cannot be ignored. It is, however, not suggested that the Big Pebble Conglomerate was deposited by glacial action on a piedmont plain. The gravels might have been produced in part and brought nearer to the site of permanent deposition by glacial action.

The aqueous environments piedmont, valley flat and lacustrine are discussed.

(b) Transitional Environments

The littoral and delta environments have been given consideration.

(c) Epicontinental Seas and the Marine Neritic Environment

There is positive proof that portions of the Kimberley-Elsburg Series have been deposited in the marine neritic environment.

(a) Continental Environments:

1. The Piedmont Environment

Important characteristics of these deposits are :

(i) The types of deposits range from alluvial cones and fans to alluvial screes on steep slopes.

/ (ii) Original .....

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(ii) Original inclinations of units are therefore expected to be high.

(iii) Sorting and stratification are usually imperfect, also in the lower reaches of the environment, where it grades into that of the valley flat. Extensive continuity of individual horizons is therefore not to be expected, neither regional surfaces of erosion of low relief. A piedmont environment for the sediments under review is therefore eliminated.

The great Siwalic System of Northern India was partly deposited in this environment.

2. The Valley Flat Environment

Based on lithological characteristics the following suites of sediments are not incompatible with the flood plain environment.

(i) The "Chloritoid Shale" Marker.

(ii) The Chert-pebble Quartzite Zone.

(iii) Zones of clear quartzites.

However, these sediments can also be reconciled with the marine neritic environment.

The deep erosion in portions of the Eastern East Rand which resulted in the elimination of the entire Kimberley Shale Zone along limited zones, must be ascribed to processes of the valley flat environment.

Sea currents can act to surprising depths and may seriously interfere with sedimentation processes. It is not clear to what extent they can erode a bottom. Along narrow passages between islands one could expect destructive work to be accomplished and the creation of hard bottom at considerable depths. But in open neritic waters it is extremely doubtful whether a marine current could create scour depressions comparable to those on Marievale and in the May Shaft area on East Daggafontein.

In the flood plain environment the streams have got lesser capacity and competency as compared to the piedmont environment. A regional horizontal persistence of individual horizons, especially if composed of coarse clastics, is therefore not to be expected. Extensive sheets of gravel, although possible, are generally not repeated many times in the same system of flood plain deposits. The author considers that the Big Pebble Conglomerate can not be reconciled with flood plain deposits. At the same time it has been shown that the Big Pebble Conglomerate was

/the initial .....

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the initial deposit in the scour depressions of the Eastern East Rand, occurring also outside these depressions over large areas on an apparently even floor. This relationship will be discussed in more detail in the final chapter.

The Siwalic System of Northern India was partly deposited in this environment.

Reynecke (33) paralleled the Witwatersrand System with the Siwalic formation as regards the general lithology of the stratigraphic column and environments of deposition. His arguments are very convincing, except for the one fact that nothing like the extensive gravel sheets of the Witwatersrand System (Government Reef, Main Reef, Main Reef Leader, Big Pebble Conglomerate, May Reef, etc.) have been described from the Siwalic.

3. The Lacustrine Environment

The evidence produced here suggest that the sediments of the Kimberley-Elsburg Series were deposited, at times, in an environment characterized by strong waves and currents.

Positive and negative movements of shore lines must have been important factors controlling the production and deposition of some of these sediments.

As strong waves and currents generally do not develop in relatively small, relatively shallow enclosed bodies of water, the author also eliminates the lacustrine environment.

(b) Transitional Environments:

1. The Littoral

This is the part of the shore zone exposed at low tide and flooded at high tide. The sediments of the littoral environment (boulders to clays) seldom attain permanent deposition. They are of little quantitative importance in the preserved sediments of the world.

2. The Delta Environment

The component parts of deltas have not been recognised. There is no evidence to support the deposition of even a portion of the Kimberley-Elsburg Series in this environment.

(c) The Marine Neritic Environment:

/The May Reef .....

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The May Reef could have formed in one of two ways :

1. As a basal conglomerate developed during a period of positive advance of a wave front relative to the land, or

2. Concentrated from material eroded from a neritic floor, when the latter had been built to a base level of deposition, and subsequently raised and in parts warped to above that level.

The sediments for some distance above the May Reef can thus be classed as neritic.

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XV. CONCLUSION

During the past ten years a great amount of information has accumulated concerning the sediments of the Upper Witwatersrand System. The discoveries in the Orange Free State and Klerksdorp areas have stimulated interest, and it is today generally realized that detailed stratigraphic study is necessary for correlation purposes. Long-distance correlation is possible, and has been facilitated by the remarkable continuity of individual horizons. A fairly comprehensive picture exists of the distribution of individual reefs and suites of sediments, and of their lithological character and inter-relationships. That much has been achieved. The complete reconstruction of the environment(s) and mode of deposition of the sediments of the Upper Witwatersrand System is not yet possible. In the case of the Kimberley-Elsburg Series certain positive deductions can be made as indicated in the previous chapter. These conclusions will be discussed in more detail in this chapter.

It has been shown that three regional unconformities exist within the section extending from below the Kimberley Shales to above the May Reef (plates I and II).

Based on these three regional unconformities, the Kimberley-Elsburg Series will be discussed in four stages :

A. The Section from the May Reef to the top of the System:

This includes the upper Kimberley conglomerate clusters, the Kimberley-Elsburg Intermediate Quartzites and the Elsburg conglomerate group (plates I and II).

B. The Middle Kimberley :

This includes the section from the base of the Big Pebble Conglomerate Zone to the top of the Micaceous-gritty Quartzite (plates I and II and the Correlation Table).

C. The May Reef

D. The Lower Kimberley

This includes the "B" Reef and the Chert-pebble Quartzite Zone.

A. The Section above the May Reef

It has been shown in the previous chapter that for some distance above the May Reef the sediments can be assigned to the marine neritic

/environment. ....

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environment. As no regional breaks in the sedimentation have been discovered in the section from the May Reef to the top of the System, there is therefore no reason to assign any portion of this section to another environment.

The thick conglomerate clusters in the section under review have been used by other investigators (notably Reynecke (33)) as evidence against a marine environment. There is, however, one important feature which argues in favour of the marine environment. The '80' Foot Marker in the East Rand Basin provides this evidence. This conglomerate cluster is in the form of a zone of pebbly quartzites and lenticular conglomerates, capped by a well-developed fairly persistent coarse conglomerate (plates I, II, VIIIa and figure 5). This upper band is frequently the coarsest band in the cluster under review. In the author's opinion this feature would indicate a building up of the depositional floor to a profile of equilibrium. The uppermost coarse continuous band would then represent a layer concentrated from a considerable volume of sediments at the level of the profile of equilibrium as the associated finer sediments were carried into deeper waters. In this respect it is of interest to recall the fact that the top band of the '80' Foot Marker gave sporadic payable gold values on Government Gold Mining Areas.

The higher clusters (Sharpe's U.K.5 and U.K.3) were not examined in detail for similar features in the East Rand Basin. But a certain band in the U.K.3 cluster gave payable gold values on Government Gold Mining Areas. It is possible that it owes its higher gold content to the same sequence of events as described above.

Recently the author had an opportunity to study the core from four boreholes which penetrated these upper clusters on the Simmer and Jack Mine on the Central Rand. It was possible to recognise five such coarse persistent bands, in each case capping pebbly quartzites and apparent lenticular conglomerates in which the average pebble size is much less.

It is possible that similar features exist in the Elsburg conglomerate group.

B. <u>The Middle Kimberley</u>

/ (a) The Big .....

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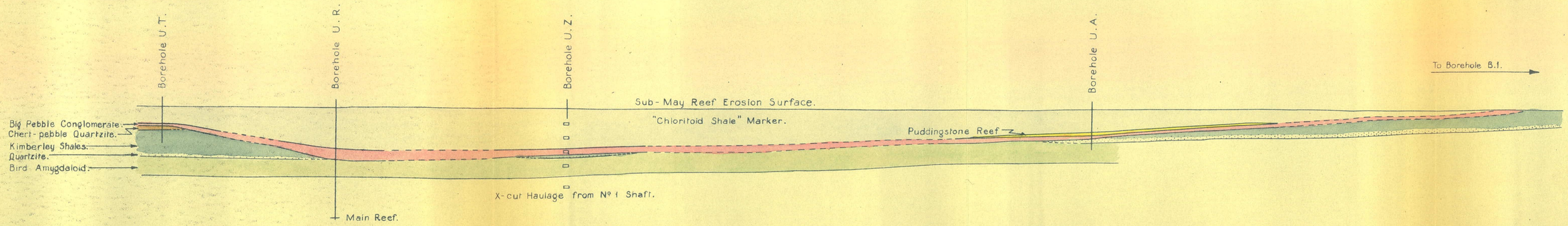
Figure 6.



A ROUGHLY EAST-WEST SECTION ACROSS THE MIDDLE OF MARIEVALE SHOWING THE PRE-BIG PEBBLE CONGLOMERATE SCOUR DEPRESSION.

(Quartzite between Kimberley Shales and Bird Amygdaloid very thin. Compare also Borehole B.3, Plate III. Intrusions not shown).

1000 500 0 1000 2000 3000

ENGLISH FEET.

Note :- For section line see plate XIII.

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(a) The Big Pebble Conglomerate

This conglomerate zone attains a maximum thickness of 160 feet in the East Rand Basin and 180 feet in the Orange Free State gold field. In the Klerksdorp area thicknesses up to 140 feet are known.

The Big Pebble Conglomerate covers an erosion surface which has considerable relief locally, e.g. in the May Shaft area on East Daggafontein and in the central portion of Marievale (plate V and figure 6). Whiteside (44) regarded the deep erosion in the May Shaft area as post-Big Pebble Conglomerate. But on Marievale the conglomerate zone that covers the base and sides of the scour depression is so similar to the Big Pebble Conglomerate, and the overlying argillaceous zone so similar to the "Chloritoid Shale" Marker of surrounding areas, that the author has no choice but to date the deep erosion in this area as immediately pre-Big Pebble Conglomerate. Outside these depressions the Big Pebble Conglomerate covers a fairly even (eroded) surface as far as can be judged from bore-holes and the underground workings. According to Beetz (4) the Gold Estates Reef (i.e. the Big Pebble Conglomerate) appears to have been deposited in scour depressions in portions of the Klerksdorp gold field.

The Big Pebble Conglomerate is incompatible with a flood plain environment, while the scour depressions which it partly fills in some areas can be ascribed only to sub-aerial erosion.

In the author's opinion the conditions that led to the formation of the Big Pebble Conglomerate are therefore as follows :

1. An initial land surface built largely of the Chert-pebble Quartzite Zone.

2. Erosion of this land surface by rivers to considerable depths along narrow belts resulting in the elimination of the entire Chert-pebble Quartzite Zone, the entire Kimberley Shale Zone and even portions of the Bird Amygdaloid (plate V).

3. Accumulations of enormous volumes of gravel in the higher reaches of this land-eroded surface.

4. Rapid submergence (drowning) of a large tract of country, resulting in the preservation of the land topography beneath the sea.

5. The sea was thus brought into contact with the accumulations of gravel as suggested above; while strong waves and currents which now

/prevailed .....

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prevailed in the invaded territory were responsible for the distribution of the coarse material to build the Big Pebble Conglomerate.

This sequence of events would explain the author's view of the Big Pebble Conglomerate forming the initial deposit in the deep scour depressions, partly filling them, and at the same time extending for great distances outside these depressions on a more even floor. We are thus apparently dealing with a case of drowned topography, smothered by marine sediments. The depressions were further filled up by muds and sands (the "Chloritoid Shale" Marker).

(b) The "Chloritoid Shale" Marker

The basal members of this suite were deposited on a fairly even floor, as the Big Pebble Conglomerate is seldom absent from below this suite (plates III, IV, VI and X). The Puddingstone Reef is regarded as a transition phase between the Big Pebble Conglomerate below and the rutile-rich shales above.

This suite can thus be regarded as following conformably above the Big Pebble Conglomerate, and may thus also be regarded as having been deposited in the sea. The change from coarse sands and gravels to fine-grained sands and muds in the East Rand Basin conforms to the general behaviour of marine gravels whereby the coarser constituents were deposited slightly antecedent to the associated finer materials.

As previously described there is evidence of a certain amount of scouring and redeposition during this period. Lanes of scour could have been produced by off-shore currents, resulting in streak-like intervening deposits. In the Sub Nigel No.3 Shaft area a lense of arenaceous shale apparently fills a shallow scour depression in conglomeratic quartzites.

The irregular fragments of shale embedded in quartzite and quartzitic shale near the base of the suite might suggest local piedmont conditions or undermining of river banks on a flood plain. However, as far as can be judged from the underground workings, the beds containing these shale fragments have been deposited on a very even floor. It would thus appear that they correspond to Twenhofel's (40) "intraformational conglomerates". On page 216 he writes:

"As defined by Walcott, these are conglomerates developed

/by the .....

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by the breaking up of a partially consolidated bed and the incorporation of the fragments in new strata nearly contemporaneous with the original beds. Such are known to be developed under marine conditions, where partially consolidated materials are torn up by strong waves and redeposited. Laminae and bedding planes arch downward between the fragments and these lie in all sorts of positions".

(c) The "Upper Parent Conglomerate" of the May Reef occurs immediately above the "Chloritoid Shale" Marker in the Western East Rand (plate I). The author suspects that it also exists on the Simmer and Jack Mine on the Central Rand. It is not known to what extent it existed in the Eastern East Rand, but judging by the map of the May Reef floor (plate XIII) it appears that it must have existed in at least a portion of the eastern sector. It has not been encountered in any other area.

A certain amount of erosion took place prior to its deposition in the northern portion of Brakpan Mines. Elsewhere in the East Rand Basin there is no positive proof of an unconformity. For practical purposes it is thus regarded as following conformably above the "Chloritoid Shale" Marker. It is difficult to reconcile it with the flood plain environment.

C. The May Reef

It has been thought best to discuss the May Reef at this stage.

As has been indicated above, there is strong evidence to regard the May Reef footwall sediments down to and including the Big Pebble Conglomerate as marine deposits. According to Whiteside's interpretation of the scour depression in the May Shaft area, the origin of the May Reef can be ascribed to the invasion of a land area by the sea. But the author has shown that these scour depressions should be dated as immediately pre-Big Pebble Conglomerate. The author believes that the May Reef was formed by the erosion of a neritic bottom, when the latter was raised regionally and arched upward over fairly large areas. The bottom was thus brought into a position to become subject to erosion. Where the floor was of such a nature as to produce gravel, the coarse and heavy fraction of the eroded material was concentrated on that part of the

/bottom .....

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bottom eroded, and finally deposited in the immediate vicinity on the sub-May Reef synclines (plates VI, X and XII). Stratigraphers have given this type of unconformity very little favour in the past, as so very little is known of the erosion processes at and above the base level of deposition. In this connection Twenhofel (41) writes :

> "The fact of wave activity affecting neritic bottoms indicates that these are nearing, and perhaps have reached, the level of the base level of deposition, so that in many instances the sediments have but temporary deposition".

To contrast the above concept with the landward migration of shore lines, the following passages are quoted from Twenhofel (40) where he discussed the sediments produced due to -

1. An invading shore line with stationary sea level, and
2. an advancing sea due to rise of sea level.

This excludes the case of extremely rapid migration due to the submergence of large tracts of country. These quotations are :

1. "An invading shoreline with stationary sea level develops an eroded bottom surface coextensive with the area of invasion. No permanent deposits are made on this surface so long as sea level remains unchanged. Materials torn from the rocks of the coast remain with the beach or in shallow water until reduced to particles sufficiently small to be transported across the wave-cut surface to deeper waters below the profile of equilibrium. The sequence should contain few or no coarse deposits".

2. ..."basal conglomerates are possible under the conditions of an advancing sea due to rise of sea level over those portions where the profile of equilibrium is above the new bottom, and are not probable under other conditions. As basal conglomerates appear to be rather rare at the bases of marine sequences, it therefore appears that the inland migration of most shores must have been very slow instead of rapid".

/Considering .....

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Considering the intimate relationship between the May Reef and the eroded anticlines and synclines (plates VI, VII, VIIIa, IX, X, XI and XII), and considering at the same time the above conclusions by Twenhofel, the author finds it impossible to ascribe the origin of the May Reef to the landward migration of a shore line, under any of the conditions outlined above.

Another feature of importance is the fact that the gold and associated heavy minerals are generally concentrated at and near the summit of the May Reef (plate IXc). In the case of a basal conglomerate due to an advancing wave front, the heavy minerals are most likely to be concentrated at and near the base of the conglomerate. As too little is known at present of the erosion processes at and above the base level of deposition in the marine neritic environment, the origin of the feature under review remains, for the present, unexplained. It is, however, conceivable that the sediments eroded from a neritic floor, when the latter is in a position at or above a profile of equilibrium or the permanent base level of deposition, would be shifted back and forth, the finer and lighter fraction ultimately escaping to deeper waters. In the case of the May Reef it could have been possible, by such action, for the fine-grained heavy minerals to have been separated from the pebbles, and finally washed on top of the latter (plate IX).

D. The Lower Kimberley

This part of the column embraces the "B" Reef and the Chert-pebble Quartzite Zone.

The "B" Reef covers an erosion surface. In the East Rand Basin this reef is intermittently developed, and lithologically does not differ from the lenticular conglomerates associated with the overlying Chert-pebble Quartzite Zone. In the East Rand Basin the constituent materials of the "B" Reef were not obtained from the floor on which it rests, but in the Orange Free State gold field the erosion surface cuts through the Kimberley Shales in some areas, eliminating also some of the upper Bird Reefs. These reefs therefore apparently contributed to the mineral content of the "B" Reef in the Orange Free State.

It has not been established whether the unconformity is due to

/erosion .....

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erosion of a neritic floor, or due to erosion by an invading sea. Based on these two possibilities, the Chert-pebble Quartzite Zone could therefore also be classed as a marine neritic deposit. But it has been shown that these sediments occupied dry land prior to the deposition of the Big Pebble Conglomerate. We are therefore apparently dealing with a withdrawal of the sea subsequent to the formation of the Chert-pebble Quartzite Zone.

SUMMARY

The evidence indicates that the sediments of the Kimberley-Elsburg Series were deposited in a sea of substantial but not excessive depth.

The unconformity on which the May Reef rests developed through sub-aqueous erosion, in some areas possibly far from land. It is possible that the unconformity below the "B" Reef developed in the same way.

The erosion surface below the Big Pebble Conglomerate developed on the land during a period of retreat of the sea. Subsequent rapid submergence resulted in but slight modification of this land-eroded surface.

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ACKNOWLEDGMENTS

The author wishes to place on record his gratitude to Dr. W.P. de Kock and Dr. R.A. Pelletier for their unfailing interest in this work during the past eight years, and to Professor M.S. Taljaard for guidance and extremely valuable advice.

Thanks are likewise due to Mr. A.A. Truter who introduced the author to the problem in 1944, and to Mr. J.O. Jackson, Chief Surveyor, Vogelstruisbult Mine, who has always shown a very keen interest in the work carried out by our Branch Office on the East Rand.

The author is also deeply indebted to Mr. J.K. Meester who traced and coloured the maps, sections and diagrams, and to Mrs. F. Jarvie who typed the thesis.

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VOGELSTRUISBULT

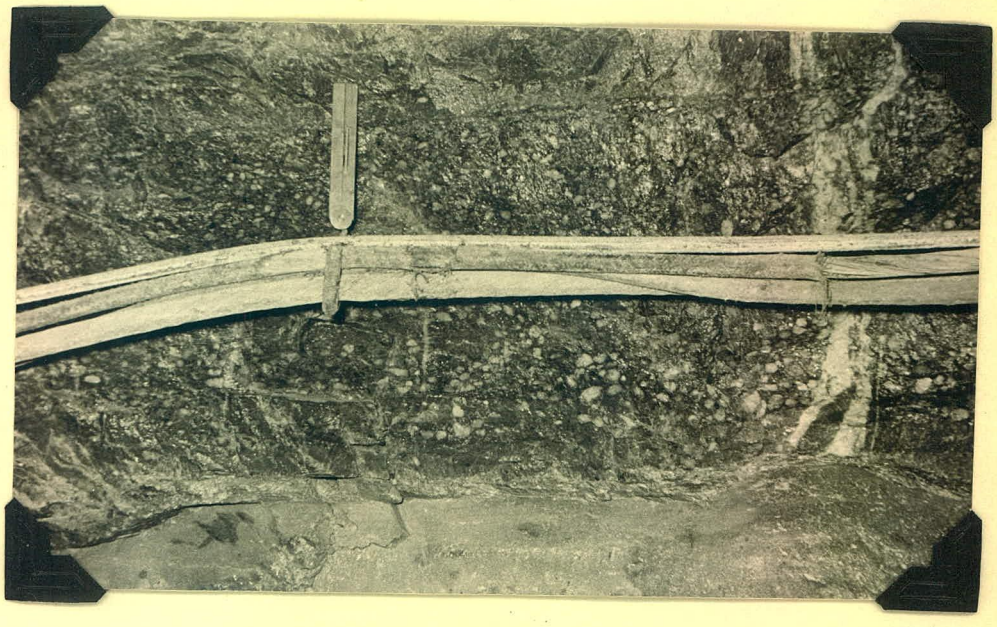

Photo No.1 : May Reef on chloritoid shale.

Note predominance of white vein quartz pebbles.

Scale : 9" rule.

Photo No.2 : 3. May Reef: an intermittent line of large chert pebbles.

2. Puddingstone Reef.

1. Chert-pebble Quartzite.

Note: (i) Angular difference between May Reef and its footwall beds.

(ii) Big Pebble Conglomerate non-existent.

Scale : 9" rule.

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VOGELSTRUISBULT

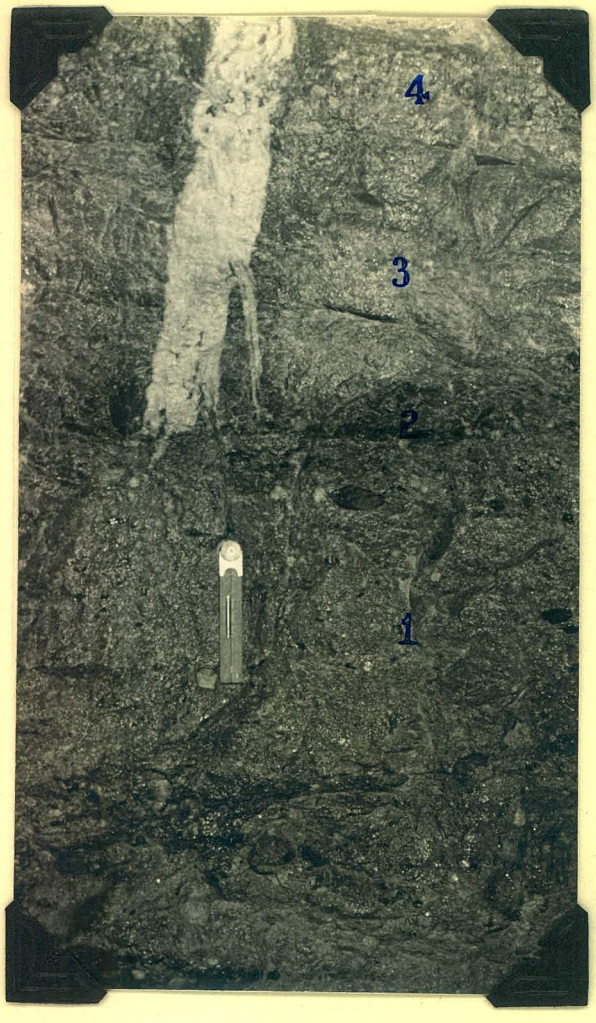

Photo No.3:

4. May Reef Hangingwall Leader.

3. Siliceous Quartzite Bar.

2. May Reef Horizon : almost a barren surface.

1. Puddingstone Reef.

Scale : 9" rule.

Photo No.4:

10" robust May Reef in direct contact with the Puddingstone Reef.

Scale : 9" rule.

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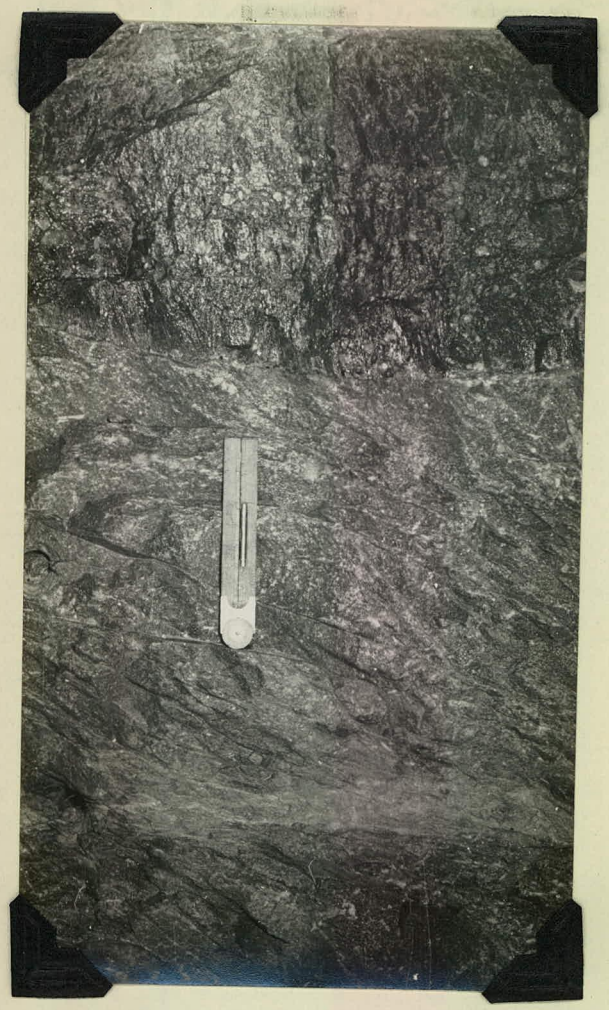

Photo No.5:

10" dark May Reef resting on a grey arenaceous shale. Pebbles of white and smoky quartz up to $\frac{3}{4}$" in diameter.

Scale : 9" rule.

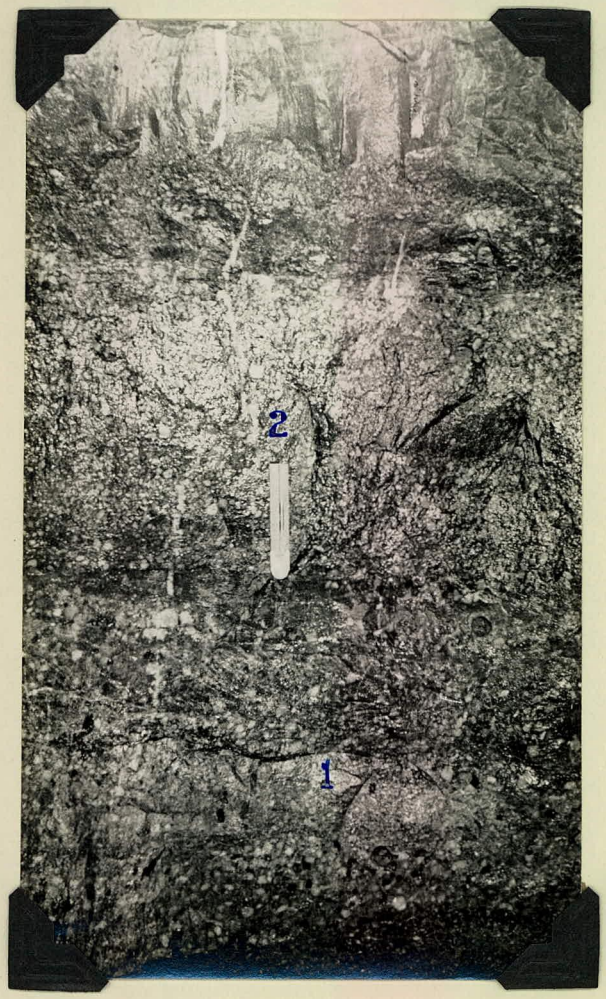

Photo No.6:

2. May Reef.

1. Big Pebble Conglomerate.

Bottom of rule at junction.

Note the black chert pebbles in the lower horizon.

Scale : 9" rule.

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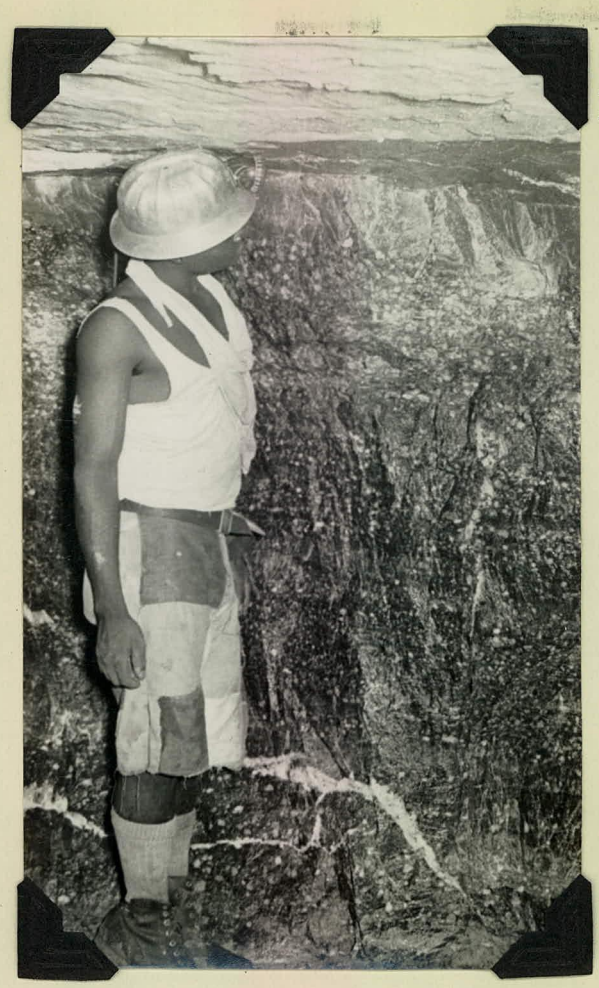

Photo No.7:

Very wide May Reef in a stope - chloritoid shale footwall.

Note predominance of small white vein quartz pebbles; very few cherts.

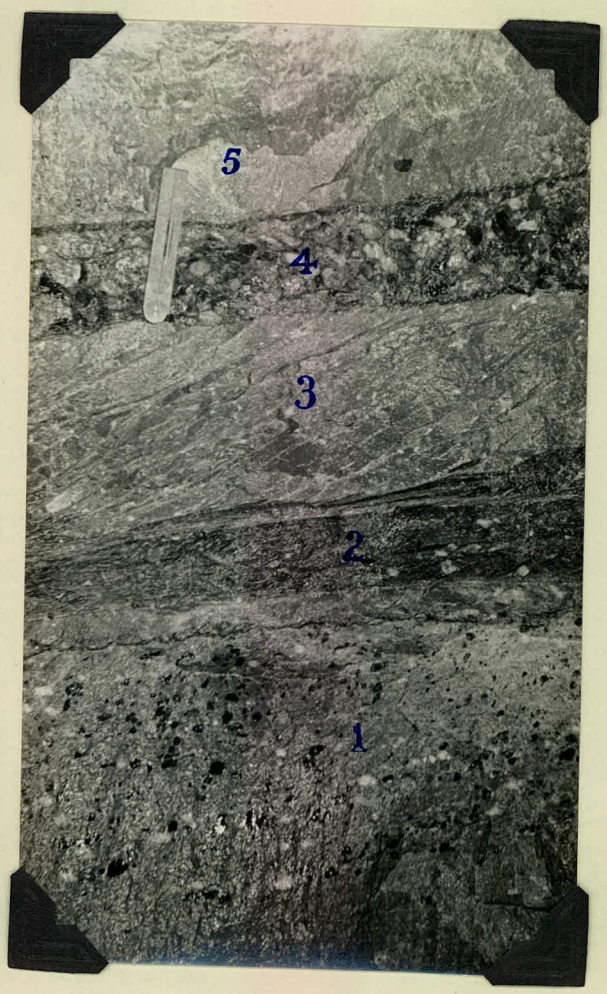

Photo No.8:

5. Siliceous Quartzite Bar. Note isolated pebble.
4. May Reef simulating the Big Pebble Conglomerate in appearance. Note large chert pebbles.
3. Quartzite ("Chloritoid Shale" Marker).
2. Puddingstone Reef.
1. Clusters of pebbles in the Chert-pebble Quartzite. Big Pebble Conglomerate non-existent.

Scale : 9" rule.

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Photo No.9:

May Reef horizon has transgressed on to the Puddingstone Reef: almost a barren surface.

Scale : 9" rule.

Photo No.10: Big Pebble Conglomerate in lower half of picture, hangingwall quartzite in upper right hand corner.

May Reef horizon not identified: it is somewhere in the vicinity of the 9" rule.

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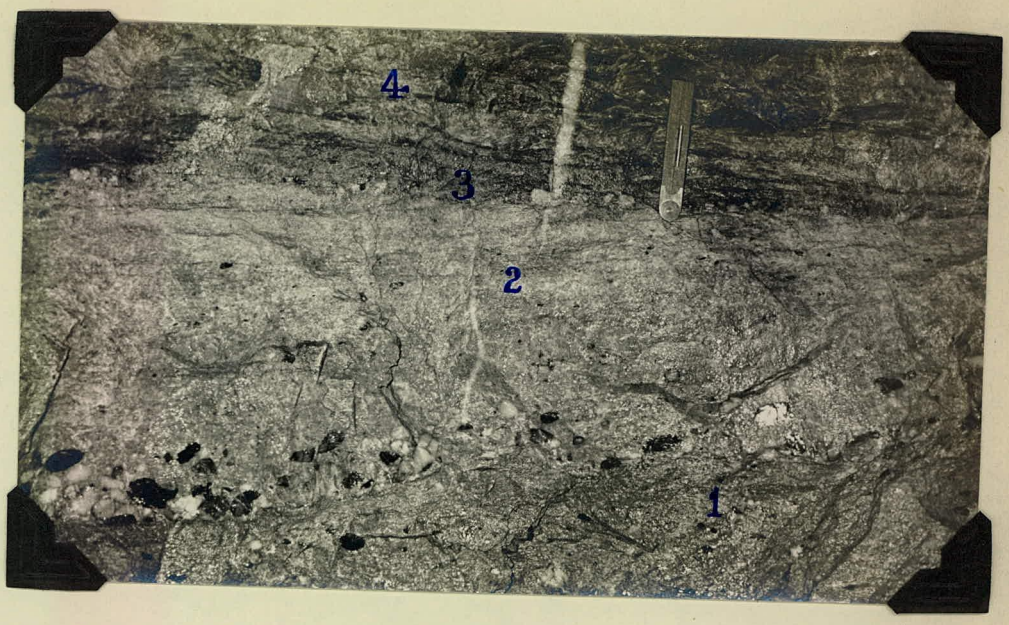

Photo No.11: 4. Dark hangingwall quartzite.

3. May Reef horizon: an intermittent line of pebbles.

2. Big Pebble Conglomerate, partly represented by quartzite.

1. Chert-pebble Quartzite.

Note transgression by the May Reef.

Scale: 9" rule.

Photo No.12: May Reef horizon has transgressed on to the Chert-pebble Quartzite. No deposition of May Reef took place here.

Note the dark hangingwall quartzite.

Scale : 9" rule.

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