ECONOMIC GEOLOGY
RESEARCH UNIT

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QUANTITATIVE COMPOSITIONAL VARIATIONS IN WITWATERSRAND CONGLOMERATES IN THE EAST RAND - DELMAS AREA, TRANSVAAL

D. H. LENTHALL

INFORMATION CIRCULAR No. 68

UNIVERSITY OF THE WITWATERSRAND

JOHANNESBURG

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by

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ABSTRACT

The relative percentages of zircon and chromite have been measured in five conglomerate horizons in the Bultfontein Basin, one of two minor basins between the East Rand Basin and the Evander Basin. Four of these horizons are of the Upper Witwatersrand Sequence, and the fifth is the conglomerate of the Kromdraai Member of the Malmani Dolomite Formation at the base of the Transvaal Sequence.

An increase in the proportion of chromite over zircon in the conglomerate horizons of the Witwatersrand Sequence, stratigraphically upwards, suggests a gradual change in the nature of the source rocks with time. Isopleths of the chlorite:sericite ratio in the matrix of the Main Reef Leader from both the Bultfontein and the East Rand basins show an increase of chlorite over sericite away from the entry point. The pattern of the isopleths suggests that the Main Reef Leader was deposited under deltaic conditions, and that structure had an important influence on the subsequent distribution of sedimentary material within the depository.

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QUANTITATIVE COMPOSITIONAL VARIATIONS IN WITWATERSRAND CONGLOMERATES IN THE EAST RAND - DELMAS AREA, TRANSVAAL

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QUANTITATIVE COMPOSITIONAL VARIATIONS IN WITWATERSRAND CONGLOMERATES IN THE EAST RAND - DELMAS AREA, TRANSVAAL

INTRODUCTION

Modal analyses and relative abundances of heavy minerals have been extensively used in sedimentological studies as indicators of the provenance and the environment of deposition of an horizon and as an aide to correlation. In addition, lateral variations in the relative abundance of component minerals of the sediment, i.e. facies changes, are useful indicators of the direction of transport of material within a depository.

Whiteside (1944) used the relative abundances of heavy minerals in certain gold-bearing horizons within the East Rand Basin as an aide to correlation. Coetzee (1962) measured the percentage frequency of various heavy minerals in certain gold-bearing horizons within the Witwatersrand Basin, and found that, although the overall mineralogy of the different horizons was similar, the relative proportion of these minerals in the different reef horizons varied. Of significance was the general decrease in the zircon/chromite ratio stratigraphically upwards, throughout the entire basin :

Horizon	Zircon/Chromite
Black Reef	0.33 - 0.35
Elsburg Reefs	0.48 - 0.59
Kimberley Reefs	0.38 - 0.56
Bird Reefs	0.80 - 1.00
Main Reef Zone	1.00

Viljoen (1963), on the basis of modal analyses of the matrix material, the ratio of zircon to chromite, and the relative abundance of unusual minerals in the Main Reef Leader of the East Rand, was able to conclude that the source rocks supplying material to form the Main Reef Leader, East Rand, were slightly different to those which supplied the Main Reef Leader of the Central Rand. Further, he concluded that the Main Reef Leader of the East Rand formed a distinct depositional unit, and that the correlation of the two similarly named conglomerates, over the Boksburg Gap, was therefore not valid.

The relative percentages of zircon and chromite have been measured in four conglomerate horizons of the Upper Witwatersrand Sequence in the Bultfontein Basin, one of two minor basins occurring between the East Rand Basin, in the west, and the Evander Basin, in the east, and preserved under a cover of Transvaal and Karroo strata (Figure 1). In addition, the relative percentages of zircon and chromite were measured in the Kromdraai Member (Black Reef) of the Malmani Dolomite Formation. Modal analyses of the matrix of the Main Reef Leader from both the Bultfontein and East Rand basins were carried out in an attempt to provide evidence to support or refute the correlation of the sediments of the Upper Witwatersrand Sequence of the Bultfontein and Middelbult basins with those of the East Rand Basin.

HORIZONS SELECTED

Nine boreholes penetrated the sediments of the Upper Division of the Witwatersrand Sequence in the Bultfontein Basin (Figure 1) :

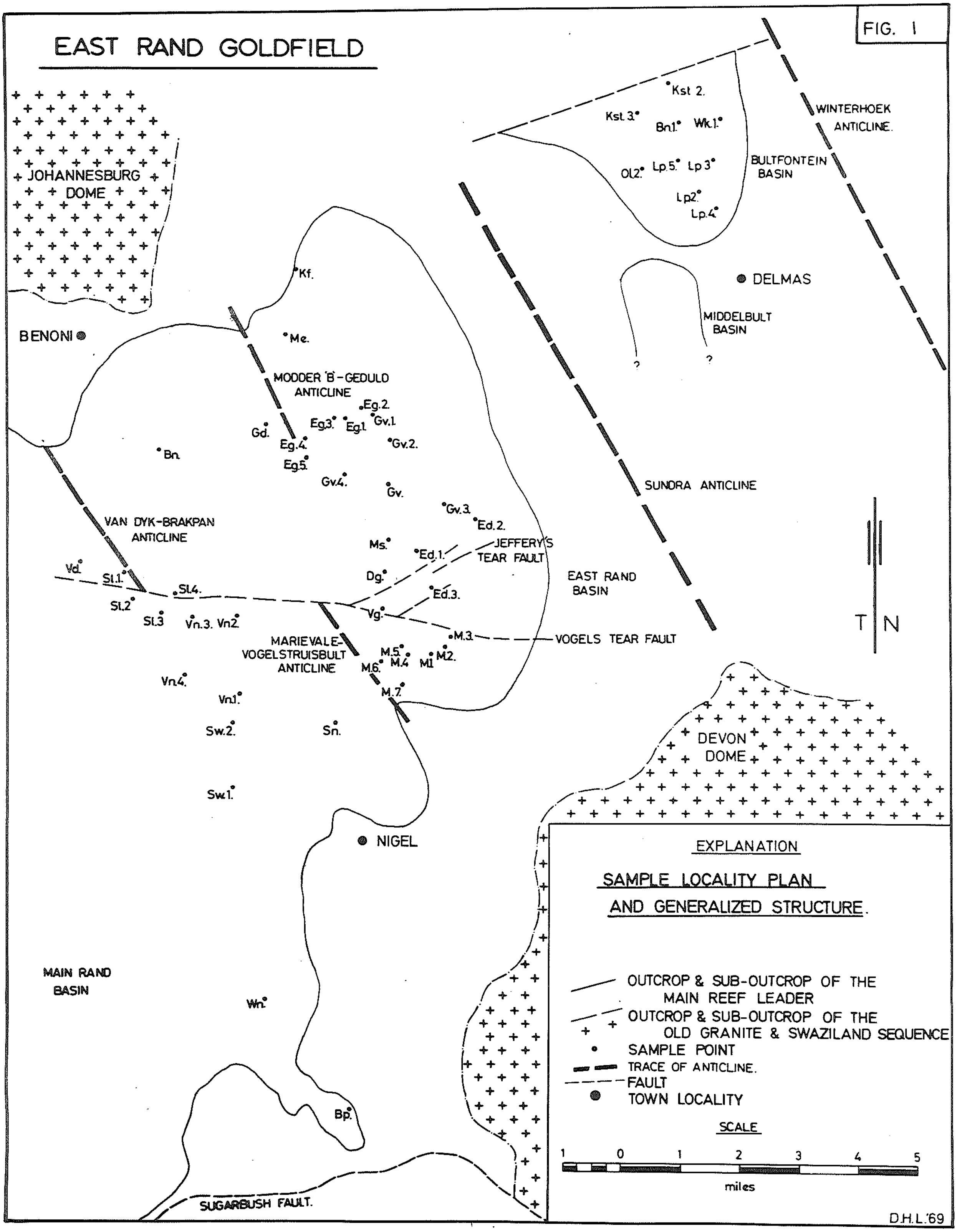


FIG. 1
EAST RAND GOLDFIELD
JOHANNESBURG DOME
BENONI
Kf.
Me.
MODDER 'B'-GEDULO ANTICLINE
Eg.2
Eg3.
Eg1.
Gv.1
Gd.
Eg.4.
Gv.2.
Bn.
Eg5.
Gv.4.
Gv.
Gv.3.
Ed.2.
VAN DYK-BRAKPAN ANTICLINE
Ms.
Ed.1.
JEFFERY'S TEAR FAULT
Vd.
Sl.1.
Dg.
Sl.4.
Ed.3.
Sl.2.
Vg.
Sl.3
Vn.3. Vn2.
M.3.
VOGELS TEAR FAULT
MARIEVALE-VOGELSTRUISBULT ANTICLINE
M.5.
M.4
M1
M.2.
M.6.
Vn.4.
M.7.
Vn1.
Sw.2.
Sn.
Sw.1.
NIGEL
MAIN RAND BASIN
Wn.
Bp.
SUGARBUSH FAULT.
Kst 2.
Kst 3.
Bn1.
Wk.1.
WINTERHOEK ANTICLINE.
Ol.2.
Lp.5.
Lp 3.
BULTFONTEIN BASIN
Lp2.
Lp.4.
DELMAS
MIDDELBULT BASIN
?
?
SUNDRA ANTICLINE
EAST RAND BASIN
T N
DEVON DOME
EXPLANATION
SAMPLE LOCALITY PLAN
AND GENERALIZED STRUCTURE.
OUTCROP & SUB-OUTCROP OF THE MAIN REEF LEADER
OUTCROP & SUB-OUTCROP OF THE OLD GRANITE & SWAZILAND SEQUENCE
SAMPLE POINT
TRACE OF ANTICLINE.
FAULT
TOWN LOCALITY
SCALE
1 0 1 2 3 4 5
miles
D.H.L.'69

Borehole	Farm
Bn.1	Bultfontein 201
Kst.2	Koffiespruit 197
Kst.3	Koffiespruit 197
Lp.2	Leeupoort 205
Lp.3	Leeupoort 205
Lp.4	Leeupoort 205
Lp.5	Leeupoort 205
Ol.2	Olifantsfontein 196
Wk.1	Witklipbank 202

The farm numbers are those which appear on topo-cadastral map - East Rand 2628 (1964).

Numerous conglomerate horizons are developed in the Upper Division of the Witwatersrand Sequence, and display varying degrees of mineralization of the matrix. The five conglomerate bands were selected for study on the basis of :

(a) the degree of mineralization of the matrix,

(b) their lateral persistence, and

(c) the degree of certainty of the correlation of the horizons between each of the boreholes.

The horizons selected were in order of increasing depth :

(i) Kromdraai Member of the Malmani Dolomite

It is developed at all boreholes localities. In Borehole Lp.4, it consists almost entirely of fine-grained carbonaceous quartzites and shales; no conglomerate bands are present. In Borehole Ol.2, there was a 3.6 m core-loss of the Kromdraai Member during drilling operations. The core of Borehole Kst.2 was not available for study.

(ii) Kimberley Reef

The horizon referred to as the Kimberley Reef (Figure 2) is the probable lithologic equivalent of the conglomerate known as the UK.9A Reef, or the May Reef, which is developed over much of the East Rand. It is a thin band of conglomerate in the Bultfontein Basin, having a maximum intersected thickness of 16.5 cm. Although commonly auriferous, the values are not high. The Kimberley Reef has been intersected at six localities in the Bultfontein Basin. In the remaining three boreholes, Ol.2, Lp.2, and Lp.4, the reef was stripped off during a pre-Transvaal cycle of erosion. Core of the Kimberley Reef from Borehole Lp.5 was not available for study.

(iii) Zone K.4, Kimberley Stage

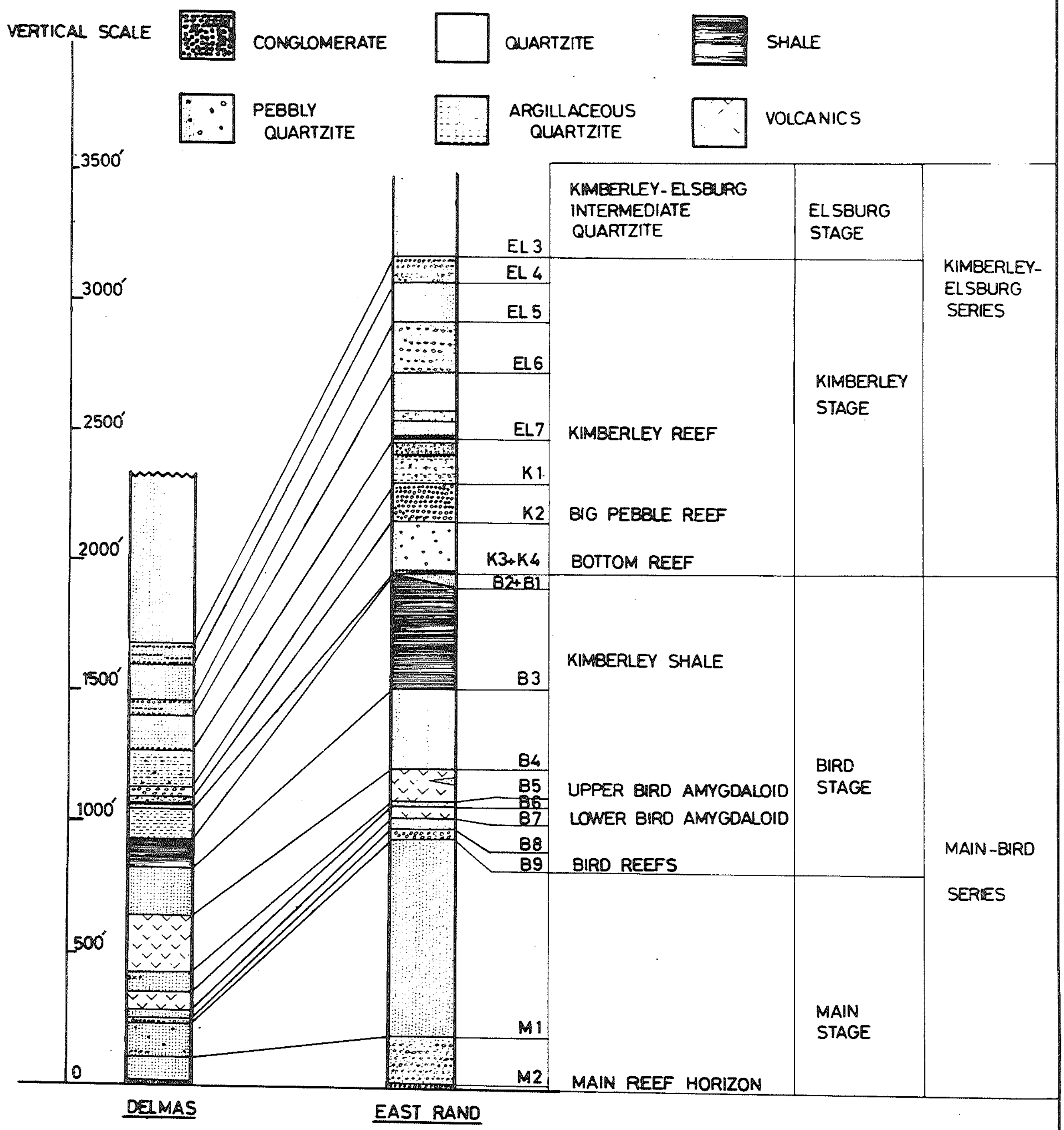
Zone K.4 consists of an alternation of conglomerate and quartzite. This conglomerate zone has a maximum thickness of 3.35 m. The lowermost conglomerate band in the zone may be the lithologic equivalent of the Bottom Reef (de Jager, 1957). It is the Bottom Reef proper that was selected from this zone for study. Zone K.4 was intersected in seven boreholes, being stripped off by a pre-Transvaal cycle of erosion in Boreholes Ol.2 and Lp.4.

(iv) Bird Reef Zone

This zone is the equivalent of a succession of conglomerates known as the Bird Reefs or Bird Reef Group elsewhere in the Witwatersrand. The average thickness of the zone is of the order of 6.40 m. The conglomerates are concentrated at the top, middle, and base of the

GENERALIZED STRATIGRAPHIC COLUMNS OF THE UPPER WITWATERSRAND SEQUENCE IN THE EAST RAND AND DELMAS AREAS.

FIG. 2



horizon. The Bird Reefs are developed in all boreholes. Core of the Bird Reefs from Borehole Kst.2 was not available for study.

(v) Main Reef Leader

The Main Reef Leader, at the base of the Upper Division of the Witwatersrand Sequence and resting on argillaceous sediments of the Jeppestown Series, consists of a narrow conglomerate band with a maximum thickness of 22.9 cm. It is auriferous in all intersections, but values were low. The Main Reef Leader was intersected at all localities, but the core from Kst.2 was not available for study.

RELATIVE ABUNDANCE OF HEAVY MINERALS

(i) Minerals Considered

During the course of the investigation, counts were made of the heavy mineral constituents with a view to determining the relative percentages of the dominant and most persistent groups. Apart from pyrite and smaller amounts of pyrrhotite, the only other minerals which occurred in any abundance were zircon and chromite. The sulphides were not used, since much of the sulphide has been reconstituted subsequent to deposition, and it is so far in excess of zircon and chromite as to render ratios of these minerals and sulphides meaningless.

(ii) Method of Analysis

In order to minimize possible local variations in the relative zircon/chromite content, grain counts were made on all deflections of each borehole in the Main Reef Leader and Kimberley Reef and on representative samples throughout the full vertical extent of the other three horizons.

Two methods of measuring the relative abundances of minerals are commonly used. The first involves the direct comparison of the number frequencies expressed as relative percentages, providing similar numbers of grains are counted in each sample. The second, involves selecting a certain mineral, say garnet, as a standard, and comparing the relative proportions of the other minerals to the standard. Zircon and chromite proved to be the only suitable minerals, and were consequently compared, using the first method described.

It is necessary to establish the minimum number of grains that should be counted in order to arrive at a reliable estimate of the relative proportions of the heavy minerals. Dryden (1931), quoted by Krumbein and Pettijohn (1938), showed that not more than two significant figures are justified, even when as many as 4000 grains are counted, pointing out that the accuracy of the estimation of the relative proportions of the heavy minerals is a function of the square root of the number of grains counted. The reduction in the percentage probable error decreases very slowly after 300 grains are counted, and this value provides a statistically suitable lower limit of the number of grains that should be counted. In all cases, as many grains as were available in polished slabs of the core samples were counted optically. Generally, the number was in excess of 250 grains.

At this sample size, the probable percentage errors in estimating the percentage proportion of the minerals, as given by the curves presented by Dryden (1931), are as follows:

% Proportion	% of Error	Sample Size
80	2.2	250
60	3.3	250
40	5.4	250
20	8.4	250
10	12.6	250
5	18.6	250

For example, if a mineral forms 60 per cent of the total, then, in a total count of 250 grains, the percentage error will be 3.3 percent, in the estimation of the proportion of the total that the particular mineral forms.

(iii) Relative Proportions of Heavy Minerals in the Horizons of the Bultfontein Basin

The results of the heavy mineral counts in the Main Reef Leader, Bird Reefs, Bottom Reef, Kimberley Reef, and basal conglomerate of the Transvaal Sequence of the Bultfontein Basin are presented in Appendix I. A summary of the results is as follows :

Horizon	% Zircon	% Chromite	Zircon/Chromite
Kromdraai Member	12	88	0.13
Kimberley Reef	33	67	0.50
Bottom Reef	11	89	0.13
Bird Reef	41	59	0.69
Main Reef Leader	62	38	1.66

Zircon in the Main Reef Leader is in excess of chromite throughout the Bultfontein Basin, to the extent of 1.70:1. Viljoen (1963) obtained an average ratio of zircon to chromite in the Main Reef Leader of the East Rand Basin of 1.30, while Coetzee (1962) reported an average zircon to chromite ratio for the Main Reef Zone of 1.00. The zircon/chromite ratio of the Main Reef Leader of the Bultfontein Basin is higher than previously recorded for this horizon. The enrichment of zircon may be explained by two factors :

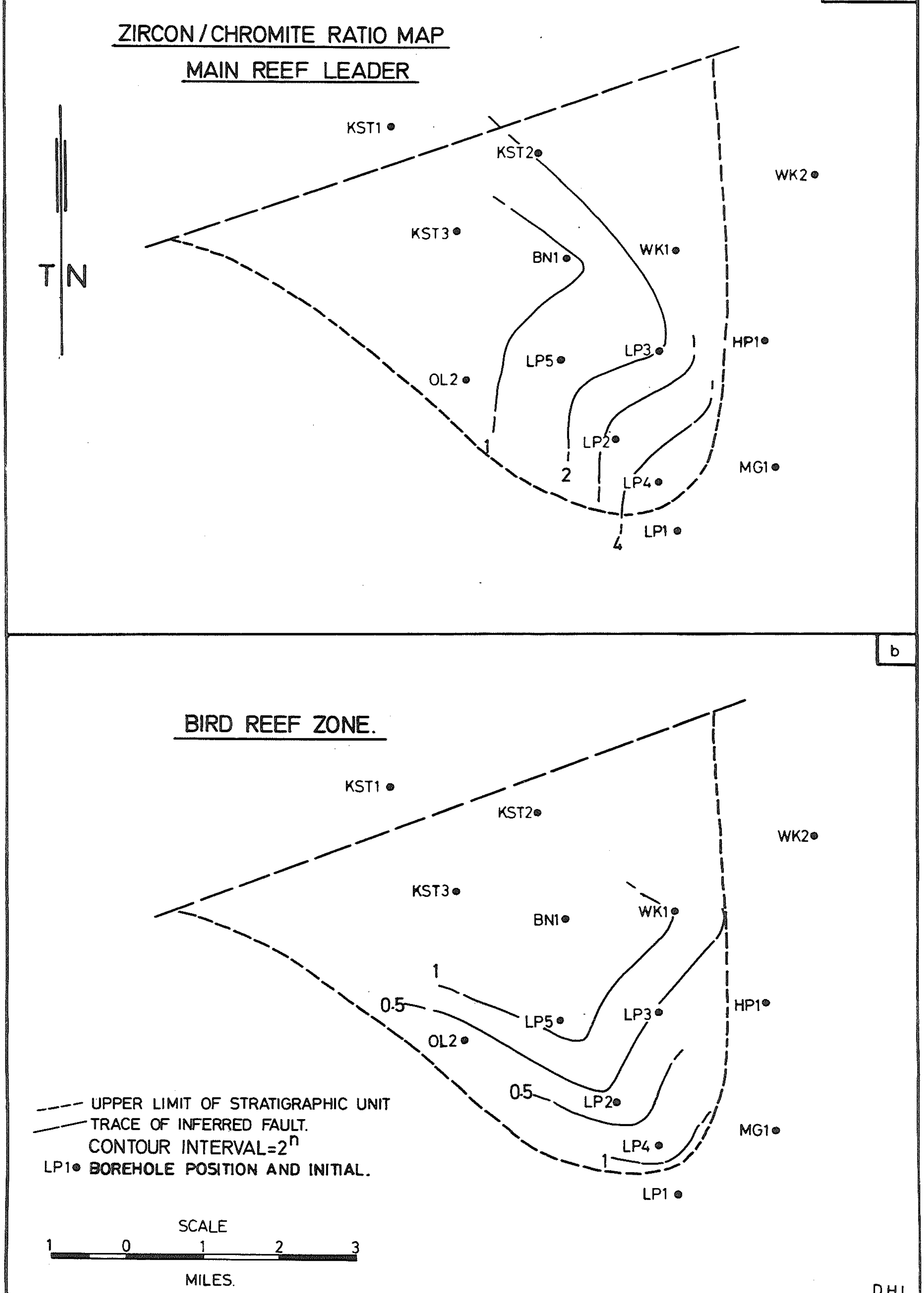
(a) Zircon is one of the most stable minerals, chemically and physically, and its abundance has been used as a maturity index. Therefore, with increasing distance from the source area or entry point, it could be theoretically expected that an increase in the zircon content would take place. However, as Pettijohn (1957) points out, on the basis of the work of Wentworth (1919), Krumbein (1941) and Marshall (1927), the rate of abrasion is most rapid in gravels and sands in which gravels occur, but is almost insignificant in pure sand loads. Therefore, the likelihood is small that chromite has been destroyed by abrasion during the transport from the entry point to the basin, a distance of less than 50 km. Similarly, chemical destruction of chromite in the interval between entering the depository and final deposition is also considered unlikely.

(b) A second explanation is dependent upon the shapes of individual grains. The rate of settling of a particle through a fluid medium is inversely proportional to the surface area. Consequently, spherical grains of chromite would tend to settle more rapidly than elongate grains of zircon having similar specific gravity and volume, but slightly greater surface area.

It is thought that the greater proportion of chromite had already been deposited prior to reaching the Bultfontein Basin, and that, in effect, the zircon had been floated out. This could have been modified and amplified by the nature of the original source material from which the horizon was derived. Assuming that the source material had a higher proportion of small zircon grains than chromite grains, then it would be expected that, as the competence of the transporting medium decreased, automatically the proportion of zircon would have increased. In order to verify these assumptions, an isopleth map was prepared for the zircon/chromite ratio in the Main Reef Leader in the Bultfontein Basin, to see whether or not any systematic lateral variation did occur. The isopleth map is presented in Figure 3a. From the work of Dryden (1931), the expected percentage error in estimating the relative proportions of zircon and chromite is between 3 and 5 per cent. Consequently, all variations, as expressed in the map, are significant. As the laterally distributed quantities are ratios, geometric, rather than arithmetic, contour intervals have been used, starting with one and increasing by a factor of two.

The map shows a rapid decrease in the chromite content from WNW. to ESE. This trend is thought to be a significant indication of the transport direction in the Bultfontein Basin.

FIG 3a


ZIRCON / CHROMITE RATIO MAP
MAIN REEF LEADER
T N
KST1
KST2
KST3
BN1
WK1
WK2
HP1
LP3
LP5
OL2
LP2
MG1
LP4
LP1
1
2
4
b
BIRD REEF ZONE.
KST1
KST2
WK2
KST3
BN1
WK1
1
0.5
LP5
LP3
HP1
OL2
0.5
LP2
LP4
MG1
1
LP1
UPPER LIMIT OF STRATIGRAPHIC UNIT
TRACE OF INFERRED FAULT.
CONTOUR INTERVAL=2^n
LP1 BOREHOLE POSITION AND INITIAL.
SCALE
1 0 1 2 3
MILES.
D.H.L.

No systematic variation in the zircon to chromite ratio could be discerned in the East Rand Basin. However, it was noted that, in the vicinity of the Van Dyke and S.A. Lands mines, the concentration of chromite in the Main Reef Leader was abnormally low, but increased in a southerly direction.

The overall zircon/chromite ratio in the Bird Reefs of the Bultfontein Basin decreases to 0.69, from 1.66 in the Main Reef Leader. However, the lateral fluctuations in the zircon content of the two horizons remains much the same (37 per cent variation in the zircon content of the Main Reef Leader compared with 39 per cent variation in the Bird Reef Zone). The reason for the change in the zircon/chromite ratio from the Main Reef Leader to the Bird Reefs, may be due to a number of factors acting either individually or together. A change in the nature of the source rocks being eroded can automatically result in a change of the nature of the sediment, regardless of the environmental processes which may modify the sediment. The zircon/chromite ratio of the Bird Reef Zone is consistently lower than the zircon/chromite ratio throughout the full extent of the Main Reef Leader. Therefore, the source material giving rise to the Bird Reefs must have been consistently richer in chromite than that which formed the Main Reef Leader. As shown from the discussion of the lateral variation of the zircon/chromite ratio in the Main Reef Leader of the Bultfontein Basin, the relative proportions of the minerals vary laterally. Consequently, the value of the zircon/chromite ratio at any particular point within a depository is therefore also dependent upon the position occupied by that point in the depository.

A zircon/chromite isopleth map was prepared for the Bird Reef Zone to see whether systematic variations occurred (Figure 3b). The percentage expected error in the estimation of the relative proportion of the heavy minerals varies from 3 to 8 per cent. The geometric contour interval used in the map therefore represents a significant variation in the zircon/chromite ratio. The isopleth map shows an initial decrease in the ratio from +1.00 to 0.50. This low is followed by an increase in the ratio to a value +1.00, in an east-southeasterly direction.

In the Bottom Reef, the zircon content decreases even farther, to an average of only 11 per cent. The error of estimation of the relative proportion of zircon in samples of 250 grains is approximately 12.6 per cent. It is therefore impossible to draw any conclusion as to the lateral variation of the zircon/chromite ratio, owing to this large probable error. From the Main Reef Leader through the Bird Reef Zone to the Bottom Reef, there is a consistent decrease in the zircon content, relative to chromite, which would seem to be primarily due to a variation in the nature of the source rocks, and, to a certain extent, to the modifying effect of variations in facies under which the horizons were deposited.

In the Kimberley Reefs, zircon content increases, and an average zircon/chromite ratio of 0.50 is recorded. Lateral variations in the relative abundances of zircon and chromite could not be traced, due to an insufficient number of samples.

In the Kromdraai Member of the Malmani Dolomite Formation, the relative proportion of zircon has decreased to much the same value as it was in the Bottom Reef and constitutes only 11.67 per cent.

The average ratio of zircon to chromite for the different horizons show, except for the Kimberley Reef, an upwards increase in the relative proportion of chromite. If the nature of the heavy minerals is any reflection of the provenance, it may be concluded that, during progressive erosion, the proportion of basic rocks in the source area increased downwards. That the Kimberley Reef does not fit the trend is a result of the nature of its formation. The Kimberley Reef (UK.9A) is to a large extent, comprised of reworked Middle and Lower Kimberley sediments (de Jager, 1957; Armstrong, 1965), and lies on an erosional surface. The ratio of the zircon to chromite is still a reflection of the source material which is now reworked Middle and Lower Kimberley sediments and not a primary product of the original source area.

The reason that no systematic variation exists in the zircon/chromite ratio of the Main Reef Leader in the East Rand Basin is thought to be a result of the mode of deposition. In the upper reaches of the Main Reef Leader, according to the work of Reinecke (1927), the sediment was distributed by a system of braided streams. Under this dispersal system, rather erratic variations occurred in sedimentological parameters other than average grain-size. As the energy of the environment became more uniform, with decreasing competence away from the source area and entry point into the basin, systematic trends, on a microscopic scale, become more evident. Therefore, ratios of minerals, especially heavy minerals, will only show systematic lateral variations in the lower, more uniform energy environments. Consequently, the use of ratios as trend indicators only becomes feasible in lower energy environments, and where the sample density is such that these trends may be effectively traced. The suggestion is made that the lateral variation in the ratio of two minerals may be more effective than granulometric analyses of fine-grained sediments in which lateral variations are of the order of the error which result from grain-size measurement.

To be noted is the poor correlation between the relative proportions of zircon and chromite from the horizons of the Bultfontein Basin and those reported by Coetzee (1962). The greater proportion of the samples studied by Coetzee were obtained from areas being exploited for gold. In the Bultfontein Basin, however, all the horizons are non-payable. The horizons in the Bultfontein Basin represent lower-energy equivalents of those studied by Coetzee.

RELATIVE ABUNDANCE OF MATRIX MINERALS IN THE MAIN REEF LEADER

Pirow (1920), in describing the nature of the matrix of the Main Reef Leader of the East Rand Basin, stated " ..... there is a zone of chloritic material on the Far East Rand, which appears to increase in intensity of chloritization in a direction roughly North to South". Viljoen (1963) carried out an extensive modal analysis of the matrix of the East Rand. He showed that chlorite is almost invariably subordinate to sericite (including muscovite and pyrophyllite). Further, the relative proportions of sericite and chlorite in the matrix of the Main Reef Leader are a reflection of the nature of the footwall. Finally, he stated that, as far as could be ascertained, there was no systematic variation in the relative abundances of the phyllosilicates.

The two conclusions are contradictory. An attempt at resolution was made during the present investigations, using larger amounts of data.

(i) Minerals Considered

In the study of the matrix material, allogenic grains with diameters or horizontal intercepts of 2 mm in thin-section, or less, were considered. Only phyllosilicates were measured, and no counts of heavy minerals and ore minerals were made.

(ii) Method of Analysis

Initially, an attempt was made to analyse the matrix of all the horizons studied in the Bultfontein Basin. Large with-in sample variations in the composition of the matrix and the small number of samples available made the study of the horizons, other than the Main Reef Leader, impractical. An additional twenty-eight samples of the Main Reef Leader were collected from various localities throughout the East Rand Basin, to supplement the data of Viljoen (1963), bringing the combined number of samples of Main Reef Leader to forty-nine. (Figure 1). The key to all these sample localities is as follows :

Bn.	Brakpan Mines Limited
Bp.	Blinkpoort 394
Dg.	Daggafontein Mines Limited (V)
Ed.1	East Daggafontein Mines Limited
Ed.2	East Daggafontein Mines Limited
Ed.3	East Daggafontein Mines Limited
Eg.1	East Geduld Mines Limited (V)
Eg.2	East Geduld Mines Limited
Eg.3	East Geduld Mines Limited
Eg.4	East Geduld Mines Limited
Eg.5	East Geduld Mines Limited

Gd.	Geduld Proprietary Mines Limited (V)
Gv.	Grootvlei Proprietary Mines Limited (V)
Gv.1	Grootvlei Proprietary Mines Limited
Gv.2	Grootvlei Proprietary Mines Limited
Gv.3	Grootvlei Proprietary Mines Limited
Gv.4	Grootvlei Proprietary Mines Limited
Kf.	Klipfontein 70
M.1	Marievale Consolidated Mines Limited (V)
M.2	Marievale Consolidated Mines Limited
M.3	Marievale Consolidated Mines Limited
M.4	Marievale Consolidated Mines Limited
M.5	Marievale Consolidated Mines Limited
M.6	Marievale Consolidated Mines Limited
M.7	Marievale Consolidated Mines Limited
Me.	Modderfontein East Limited (V)
Ms.	May Shaft (on the common boundary of the Daggafontein and East Daggafontein mines)
Sl.1	S.A. Land and Exploration Company Limited (V)
Sl.2	S.A. Land and Exploration Company Limited
Sl.3	S.A. Land and Exploration Company Limited
Sl.4	S.A. Land and Exploration Company Limited
Sn.	The Sub-Nigel Limited (V)
Sw.1	Spaarwater Gold Mining Company Limited (V)
Sw.2	Spaarwater Gold Mining Company Limited
Vg.	Vogelstruisbult Gold Mining Areas Limited (V)
Vd.	Van Dyk Consolidated Mines Limites (V)
Vn.1	Vlakfontein Gold Mining Company Limited
Vn.2	Vlakfontein Gold Mining Company Limited
Vn.3	Vlakfontein Gold Mining Company Limited
Vn.4	Vlakfontein Gold Mining Company Limited
Wn.	Witwatersrand Nigel Limited

Farm numbers are those occurring on the topo-cadastral map - East Rand 2628 (1964). The symbol (V) after a locality indicates that the relevant data was obtained from Viljoen (1963).

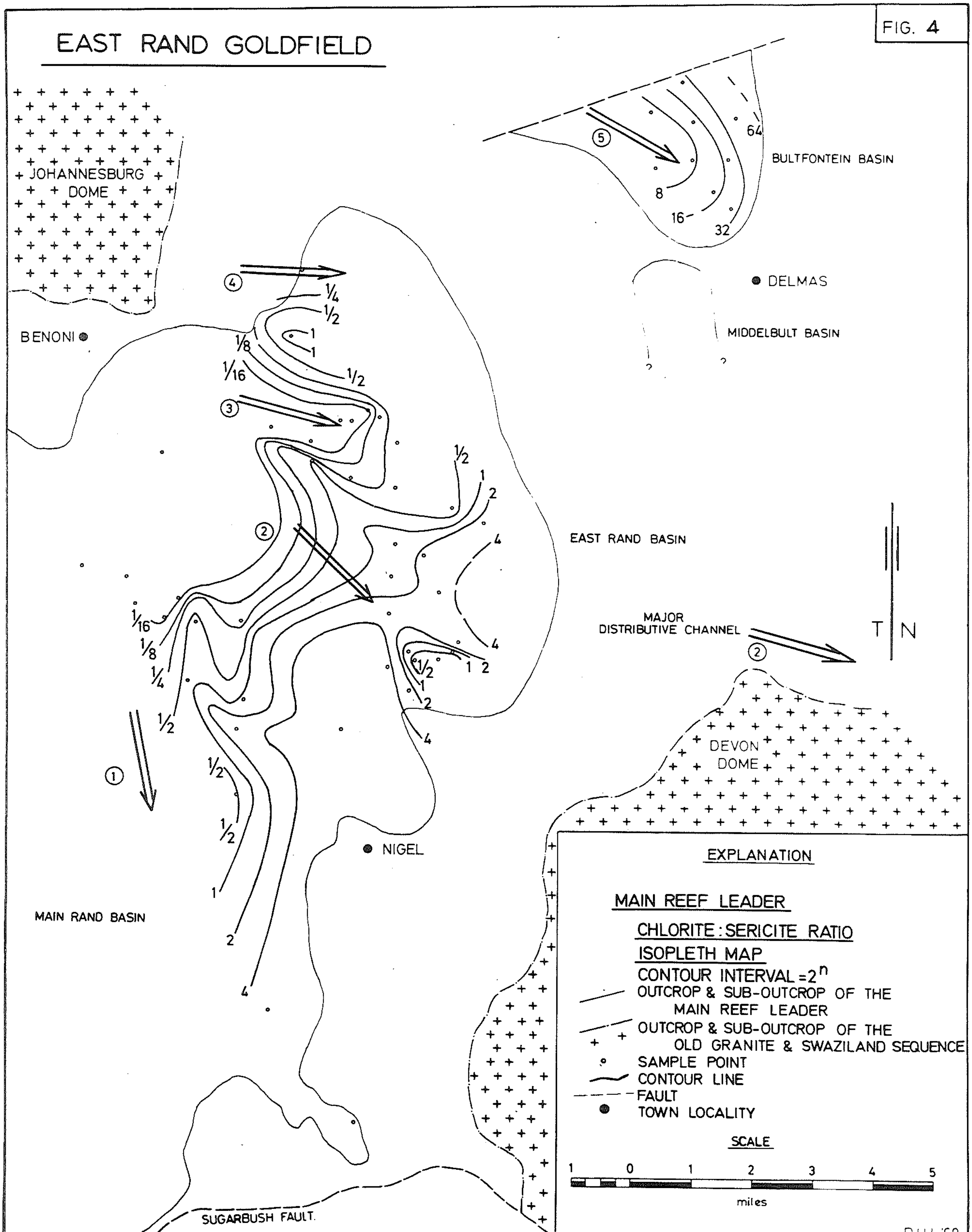
At no locality, other than in the various boreholes, in the Bultfontein Basin was there more than one sample available. Two thin-sections were cut from each sample in the East Rand and one thin-section was made from each deflection in a borehole. The mode of each sample was calculated and totalled for the thin-sections, to give a volumetric appraisal of the composition of the matrix in a particular locality.

The minerals included in the modal analysis were allogenic quartz sand-size (+ 0.063 mm), quartz silt-size (-0.063 mm), sericite (including muscovite and pyrophyllite), and chlorite. The modal counts were made using a Swift Point Counter. Regular east-west traverses 0.5 mm apart, with counts approximately 0.25 mm apart, were made. Approximately 1000 counts were effected on each thin-section, giving a total of approximately 2000 counts per locality. Medium-power lenses were used in preference to low-power lenses, in order to distinguish between fine-grained allogenic and authigenic material.

(iii) Relative Proportions of the Matrix Minerals

In a two-dimensional analysis of the matrix material of the Main Reef Leader of the East Rand and of the Main Reef and Main Reef Leader of the Central Rand, Viljoen (1963) found that significant variations in the relative percentages of the phyllosilicates occurred from reef to reef. The Main Reef Leader of the East Rand was found to be characterized by a complete absence of chloritoid and by the dominance of sericite over chlorite.

An attempt was made in the present study to ascertain whether or not systematic lateral variations exist in the relative proportions of the constituents of the matrix of the Main Reef Leader. The different modes and combinations thereof were calculated. These


EAST RAND GOLDFIELD
FIG. 4
JOHANNESBURG DOME
BENONI
BULTFONTEIN BASIN
DELMAS
MIDDELBULT BASIN
EAST RAND BASIN
MAJOR DISTRIBUTIVE CHANNEL
T N
DEVON DOME
NIGEL
MAIN RAND BASIN
SUGARBUSH FAULT.
EXPLANATION
MAIN REEF LEADER
CHLORITE : SERICITE RATIO
ISOPLETH MAP
CONTOUR INTERVAL = 2^n
OUTCROP & SUB-OUTCROP OF THE MAIN REEF LEADER
OUTCROP & SUB-OUTCROP OF THE OLD GRANITE & SWAZILAND SEQUENCE
SAMPLE POINT
CONTOUR LINE
FAULT
TOWN LOCALITY
SCALE
1 0 1 2 3 4 5
miles
DHL '69

included, quartz sand/quartz silt, (quartz sand plus sericite)/(quartz silt plus chlorite), and chlorite/sericite. Only the chlorite/sericite ratio showed any significant lateral variation. The isopleth map is presented in Figure 4. Geometric class intervals were chosen, starting with one and increasing or decreasing by a factor 2^n.

Towards the northern rim of the East Rand Basin, sericite is the dominant phyllosilicate, chlorite being distinctly subordinate. Away from the northern rim, the chlorite content increases gradually, so that in the southeastern corner of the East Rand Basin, in the vicinity of East Daggafontein and Marievale mines, chlorite becomes the more important phyllosilicate. In the Bultfontein Basin, sericite in the matrix of the Main Reef Leader is almost insignificant. The pattern present is somewhat reminiscent of a number of diverging channels. Four such channels can be seen in the East Rand Basin :

1. on the extreme western limit of the basin, high sericite concentrations extend as far south as a line running east-west through Nigel;

2. a second channel extends from the centre of the East Rand Basin, to the east of the Marievale-Vogelstruisbult anticline, to the Marievale Mine;

3. farther north, a channel moves out from the centre of the northern rim of the East Rand Basin and extends to Grootvlei Mines, after crossing the Geduld and East Geduld mines; and

4. the fourth channel, the extent of which is not completely delineated, is in the extreme northeastern corner of the East Rand Basin, in the vicinity of Klipfontein, to the north of Modder East Mine. Cross-bedding in the quartzites immediately overlying the Main Reef Leader in this area consistently indicate a transport direction at right-angles to the strike, away from the Johannesburg Dome.

In the Bultfontein Basin, chlorite in the matrix of the Main Reef Leader increases away from the Johannesburg Dome, to the almost total exclusion of sericite.

(iv) Significance of the Relative Abundances of Phyllosilicates

The phyllosilicates in the Witwatersrand Sequence are dominantly sericite, chlorite, and chloritoid, which are the end-products of the greenschist grade of metamorphism that the sequence, as a whole, has undergone. The nature of the original clays is somewhat obscure. Grim (1962) states that illite and chlorite are the most abundant clay minerals occurring in ancient sediments. Illite minerals are similar in their general structural characteristics to the micas (Grim and Bradley, 1937; Grim, Bradley, and Brown, 1951), and have an identical composition to muscovite. The basic structural unit of illite is a layer of two silica tetrahedral sheets with a central octahedral sheet. Some of the Si^{4+} ions are replaced by alumina Al^{3+} ions, thereby creating a resultant charge deficiency which is balanced by positive cations (usually K^+), loosely bound between the different layers. In water, illite tends to disaggregate considerably. However, when introduced into a medium with high cation concentration, the illite tends to floculate and settle. The effects of these processes can be identified in the East Rand Basin as explaining the prevalence of sericite towards the entry point.

Relatively fresh water, containing illite and chlorite, from the source area, was discharged into the main basin. The illite, upon coming into contact with a relatively high cation concentration in the waters of the basin, floculated and settled, leaving the distributive streams enriched in chlorite which was chemically more stable and which settled under normal conditions, farther away from the entry point. Along channels of any magnitude, illite was carried out farther into the basin, and the higher concentration of illite in distinct zones therefore reflects the presence of these channels.

The chlorite/sericite ratio isopleth map shows a considerably rapid increase in the chlorite content towards the eastern and southeastern rim of the East Rand Basin, when compared to the more gradual increase in the chlorite content to the west and southwest into the Main Rand Basin. This pattern is significant in deciphering the overall movement of

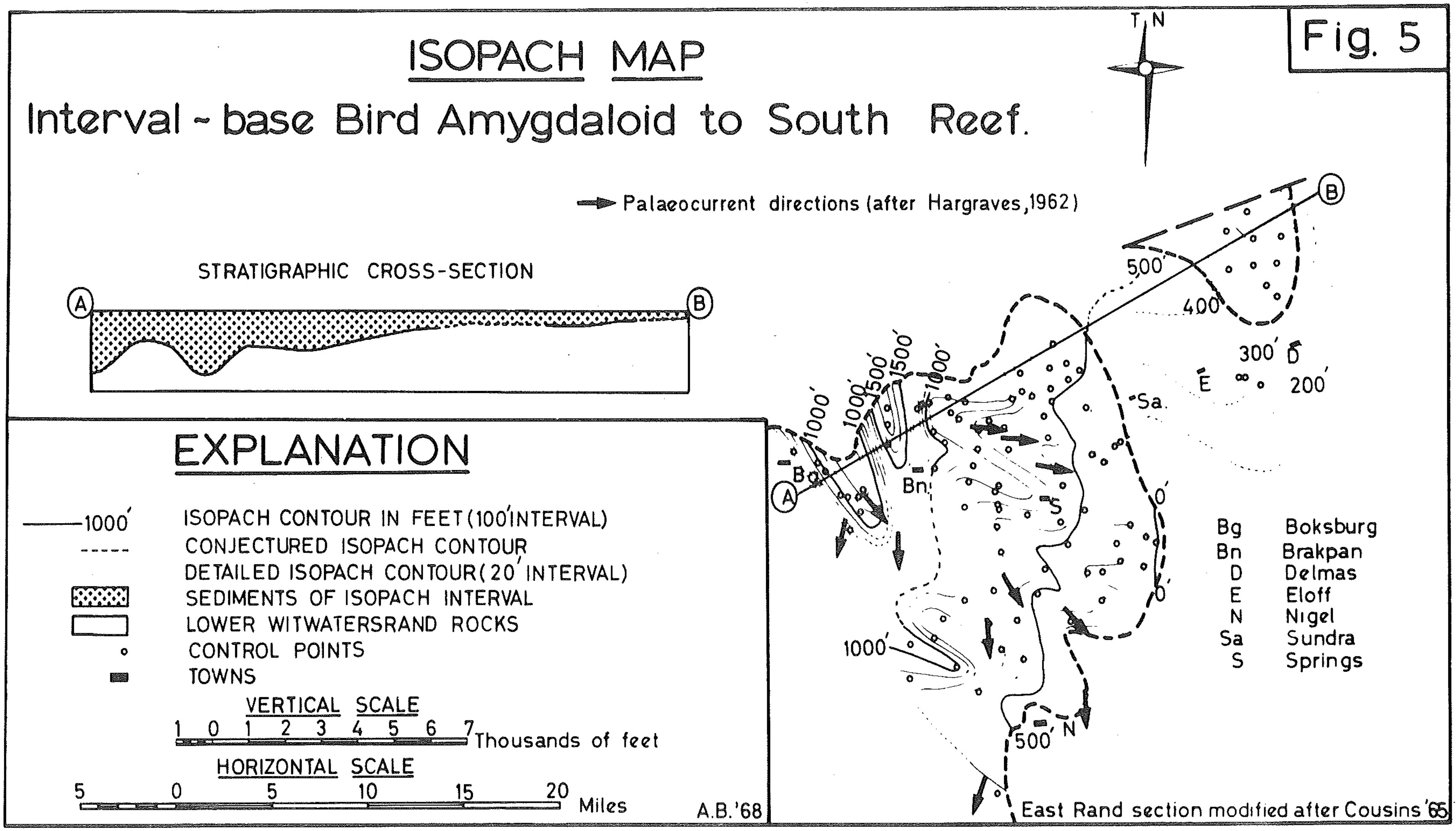


Fig. 5
ISOPACH MAP
Interval - base Bird Amygdaloid to South Reef.
T N
Palaeocurrent directions (after Hargraves, 1962)
STRATIGRAPHIC CROSS-SECTION
A
B
EXPLANATION
1000′ ISOPACH CONTOUR IN FEET (100′ INTERVAL)
CONJECTURED ISOPACH CONTOUR
DETAILED ISOPACH CONTOUR (20′ INTERVAL)
SEDIMENTS OF ISOPACH INTERVAL
LOWER WITWATERSRAND ROCKS
CONTROL POINTS
TOWNS
VERTICAL SCALE
1 0 1 2 3 4 5 6 7 Thousands of feet
HORIZONTAL SCALE
5 0 5 10 15 20 Miles
A.B.'68
1000′
1500′
500′
400′
300′
200′
0′
Bg
Bn
D
E
N
Sa
S
Bg Boksburg
Bn Brakpan
D Delmas
E Eloff
N Nigel
Sa Sundra
S Springs
East Rand section modified after Cousins '65

water in the East Rand Basin. The rapid increase in the chlorite content to the east and southeast, even along the major distributive channels, suggests that a barrier effectively impeded the flow in these directions.

Antrobus and Whiteside (1964), de Jager (1957), Pretorius (1966) and Cousins (1965) have all emphasised the sustained activity along anticlines within the Witwatersrand Basin before, during, and after the deposition of the Witwatersrand Sequence, and the influence that structure had on the subsequent distribution of material within the depository. The rapid increase in the proportion of chlorite to the east and southeast is attributed to the combined effect of the Sundra and Winterhoek anticlines, the main influence of which was to impede any large scale movement of water in that direction. A similar, rapid increase in the chlorite content to the south appears to be a direct result of the presence of an active Devon Dome, to the south of the East Rand Basin, during the deposition of the Witwatersrand Sequence.

The isopach map (Figure 5) of Cousins (1965), modified by Button (1968), suggests the influence of the Devon Dome on sedimentation within the East Rand Basin, and as such provides confirmatory evidence in support of this hypothesis.

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APPENDIX 1 : Proportions of Zircon and Chromite in Horizons of the Bultfontein Basin

Main Reef Leader

Borehole	% Zircon	% Chromite	Zircon/Chromite
Bn.1	45	55	0.8
Kst.2	69	31	2.3
Lp.2	77	23	4.7
Lp.3	67	33	2.0
Lp.4	82	18	4.7
Lp.5	57	43	1.3
01.2	46	54	0.9
Wk.1	72	28	2.6

Bird Reefs

Borehole	% Zircon	% Chromite	Zircon/Chromite
Bn.1	52	48	1.08
Kst.3	54	46	1.17
Lp.2	27	73	0.36
Lp.4	47	53	0.87
Lp.5	58	42	1.37
Ol.2	19	81	0.23
Wk.1	50	50	0.98

Bottom Reef

Borehole	% Zircon	% Chromite	Zircon/Chromite
Bn.1	8	92	0.09
Kst.2	11	89	0.13
Kst.3	10	90	0.11
Lp.2	13	87	0.15
Lp.3	14	86	0.17
Lp.5	8	92	0.08
Wk.1	12	88	0.14

Kimberley Reef

Borehole	% Zircon	% Chromite	Zircon/Chromite
Bn.1	46	54	0.86
Kst.2	26	74	0.36
Kst.3	26	74	0.34
Lp.3	26	74	0.35
Wk.1	46	54	0.86

Kromdraai Member

Borehole	% Zircon	% Chromite	Zircon/Chromite
Bn.1	11	89	0.12
Kst.3	9	91	0.10
Lp.2	9	91	0.10
Lp.3	19	81	0.23
Lp.5	10	90	0.11
Wk.1	14	86	0.16

APPENDIX 2 : Ratios of Chlorite to Sericite in the Main Reef Leader

Sample	Chlorite/Sericite	Sample	Chlorite/Sericite
Bn.	0.01	Me.	1.62
Bp.	-	Ms.	1.33
Dg.	1.47	Sl.1	n.o.
Ed.1	2.03	Sl.2	0.05
Ed.2	2.61	Sl.3	0.06
Ed.3	3.90	Sl.4	0.03
Eg.1	n.o.	Sn.	6.93
Eg.2	0.04	Sw.1	0.36
Eg.3	0.06	Sw.2	3.21
Eg.4	0.55	Vg.	3.60
Eg.5	0.05	Vd.	n.o.
Gd.	n.o.	Vn.1	1.03
Gv.	0.27	Vn.2	0.20
Gv.1	0.14	Vn.3	0.62
Gv.2	0.31	Vn.4	0.72
Gv.3	0.31	Wn.	4.29
Gv.4	0.22	Bn.1	12.61
Kf.	0.13	Kst.3	26.13
M.1	0.32	Lp.2	12.40
M.2	0.21	Lp.3	22.70
M.3	2.34	Lp.4	28.67
M.4	0.19	Lp.5	7.52
M.5	0.82	Ol.2	7.16
M.6	4.32	Wk.1	47.27
M.7	2.31		

n.o. = no chlorite observed

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