ECONOMIC GEOLOGY RESEARCH UNIT

University of the Witwatersrand
Johannesburg

POST-TRANSVAAL STRUCTURAL FEATURES OF THE NORTHERN PORTION OF THE WITWATERSRAND BASIN

T. S. McCARTHY, E. G. CHARLESWORTH, and I. G. STANISTREET

INFORMATION CIRCULAR No.191

UNIVERSITY OF THE WITWATERSRAND

JOHANNESBURG

POST-TRANSVAAL STRUCTURAL FEATURES OF THE NORTHERN PORTION OF THE WITWATERSRAND BASIN

by

T.S. McCARTHY, E.G. CHARLESWORTH, and I.G. STANISTREET

(Department of Geology, University of the Witwatersrand Johannesburg)

ECONOMIC GEOLOGY RESEARCH UNIT

INFORMATION CIRCULAR NO. 191

December, 1986

POST-TRANSVAAL STRUCTURAL FEATURES OF THE NORTHERN PORTION OF THE WITWATERSRAND BASIN

ABSTRACT

A study has been undertaken of the deformation of the Black Reef Formation in the vicinity of the northern portion of the Witwatersrand Basin, to establish the nature of post-Transvaal Sequence structural features which may have affected the Witwatersrand Basin.

Deformation of the Black Reef Formation has produced major and minor, open-to-overturned folds and penetrative, simple-shear cleavage, all of which are heterogeneously developed. Strikes of folds and cleavages are parallel, and they are tangential to the Vredefort structure. Cleavage dips towards this structure and at a shallower angle than that of the axial planes of folds. It is concluded that these features are genetically related to the development of the Vredefort structure.

Cleavage in the Transvaal Sequence is regionally associated with the presence of underlying, Witwatersrand Supergroup rocks (which are also cleaved), but not Klipriviersberg volcanics, suggesting that shear was transmitted predominantly through Witwatersrand Supergroup strata. This shearing locally led to the development of bedding-sub-parallel faults. Movement on these faults may have involved an initial, outward movement, followed by later retraction. The Johannesburg Dome disperses the cleavage and, therefore, post-dates the Vredefort event. This cleavage is a useful time-datum in relative dating of the structural events in the vicinity of the Witwatersrand Basin.

In addition to the above, a set of north-to-northeasterly-striking folds have also been recognized, which are developed in the northwestern portion of the study-area, and a set of east-west-striking, right-lateral faults. The regional significance of these latter events is not known.

——— oOo ———

POST-TRANSVAAL STRUCTURAL FEATURES OF THE NORTHERN PORTION OF THE WITWATERSRAND BASIN

CONTENTS

——— oOo ———

Published by the Economic Geology Research Unit
University of the Witwatersrand
1 Jan Smuts Avenue
Johannesburg 2001

ISBN 0 85494 954 2

POST-TRANSVAAL STRUCTURAL FEATURES OF THE NORTHERN PORTION OF THE WITWATERSRAND BASIN

INTRODUCTION

During an earlier investigation of the tectonic history of the Witwatersrand Supergroup in the northern portion of the basin (Stanistreet *et al.*, 1985), it became apparent that these rocks had experienced considerable post-Transvaal Sequence deformation. It is necessary to characterize this post-Transvaal deformational history, if a full appreciation of the pre-Transvaal, post-Witwatersrand tectonic history is to be attained. Furthermore, the post-Transvaal Sequence deformation could itself have important implications in both exploration and mining of the gold- and uranium-bearing Witwatersrand placers. Accordingly, a reconnaissance investigation of post-Transvaal deformation across the northern portion of the Witwatersrand Basin was undertaken.

The limited structural work in the area encompassing the northern portion of the Witwatersrand Basin (Fig.1) has generally taken the form of detailed studies of geographically-limited extent (e.g. Cousins, 1962; Papenfus, 1964; Roering, 1968; Fripp and Gay, 1972; Fletcher and Gay, 1971; McCarthy *et al.*, 1982). In contrast to these studies, Simpson (1977) undertook a more regional study of deformation of the Transvaal Sequence in the Potchefstroom synclinorium. No attempt, however, has been made to integrate structural studies of Transvaal Sequence rocks or to examine their possible implications for the underlying Witwatersrand Supergroup.

It was decided to use predominantly the Black Reef Formation in this study, for the following reasons: (i) it lies at the interface between Transvaal Sequence and older rocks, in particular the Witwatersrand Supergroup; (ii) it is of wide geographic extent; (iii) it normally contains both arenaceous and argillaceous units which are susceptible to the development of cleavage, while competency-differences register folding; and (iv) the unit is reasonably well exposed. This investigation involved field-examination of the Black Reef Formation and Witwatersrand Supergroup in an arc extending from Klerksdorp, in the west, northeastwards across the Rand Anticline and the Johannesburg Dome (Fig.1) and southeastwards to Heidelberg. Maps published by the Geological Survey and others provided important data-sources.

DEFORMATIONAL STYLES IN THE BLACK REEF FORMATION

Few, previous, specific studies of deformation of the Black Reef Formation have been undertaken. The most detailed is that of Papenfus (1964), who noted that this unit had experienced considerable folding about northwesterly-striking fold-axes in the East Rand basin. Other workers have dealt with this deformation on a less specific basis (e.g. Mellor, 1917; Nel, 1935; Rogers, 1922).

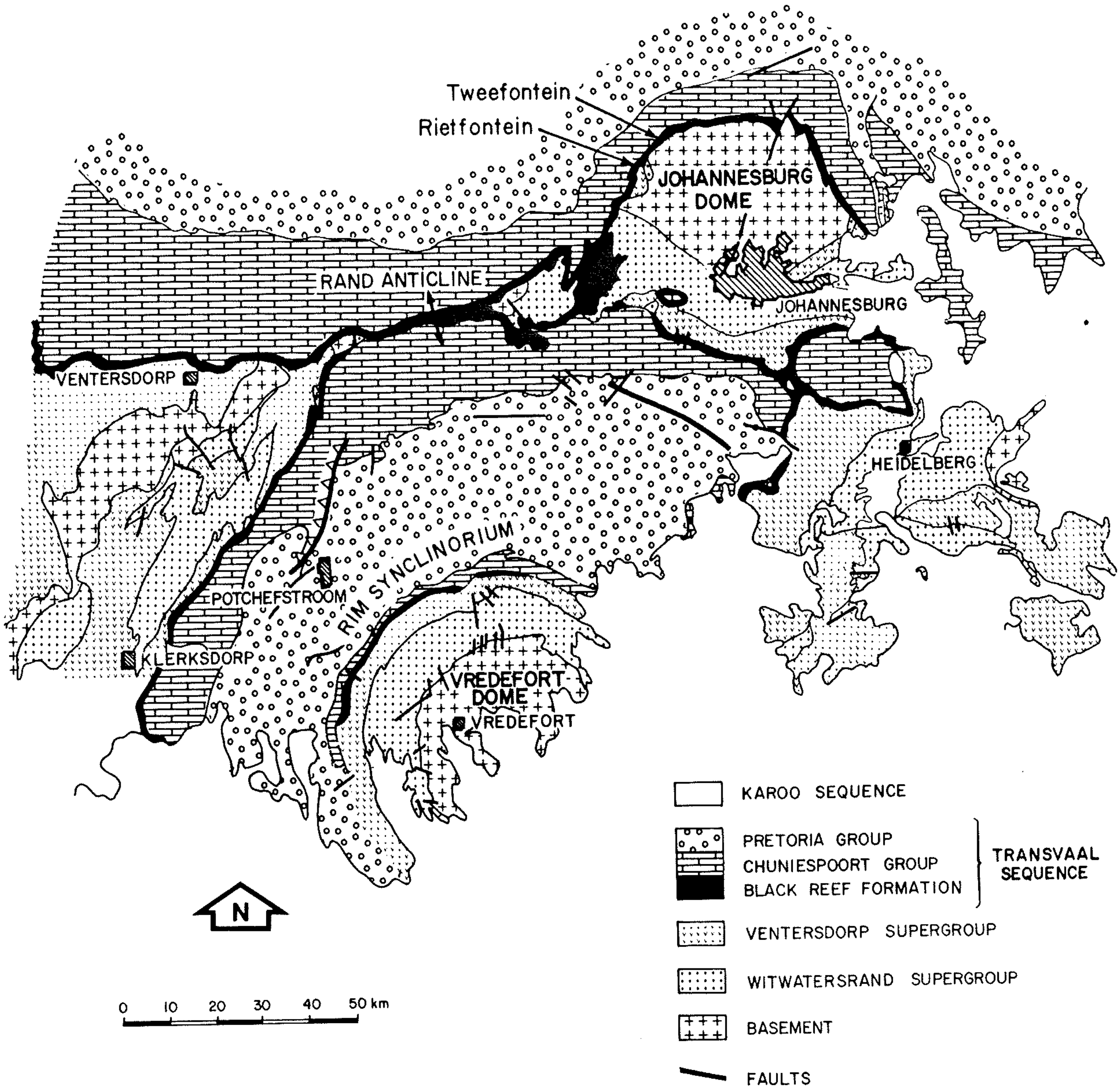


Figure I : Locality map

Deformation of the Black Reef Formation takes the form of: (i) large-scale, open-to-overturned folds; (ii) small-scale, open-to-overturned folds; (iii) penetrative cleavage locally associated with linear fabrics; and (iv) faults. In addition to the above, the Black Reef Formation has been affected by doming (e.g. Johannesburg and Vredefort domes and the Rand Anticline, Fig. 1).

Large-Scale Folds

Regional mapping and studies of borehole-cores and underground exposures in the northern portion of the Witwatersrand Basin (Mellor, 1917; Nel, 1935; Rogers, 1922; Papenfus, 1964) have indicated the presence of folds in the Black Reef Formation, varying in wavelength from hundreds of metres to kilometres, which typically are periclinal (double-plunging) in form. These folds vary from gentle warps to folds with near-vertical

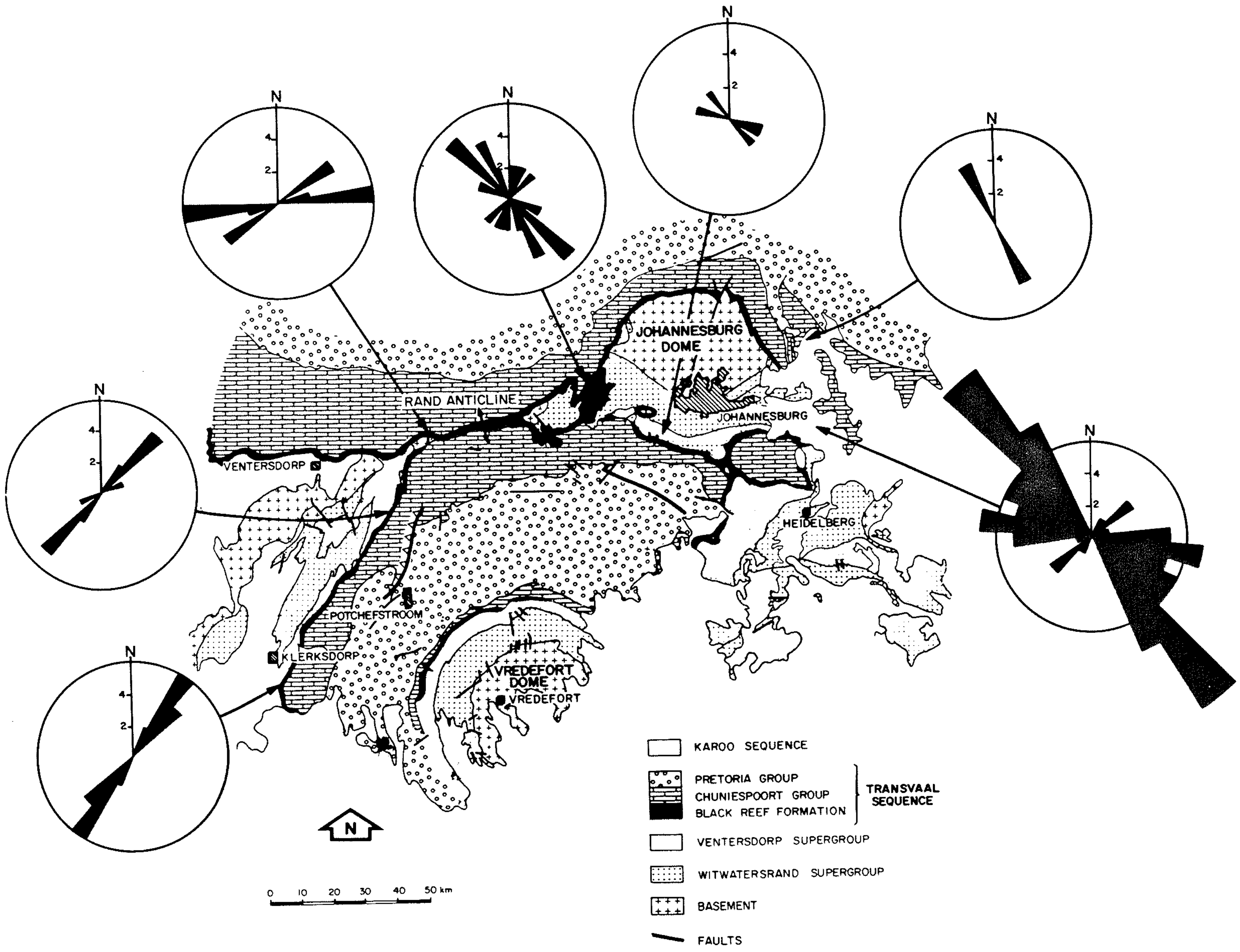


Figure 2 : *Regional variation of the strike of major folds in the Black Reef Formation through the study-region. Data obtained from Mellor (1917), Nel (1935), and Papenfus (1964).*

limbs. The largest of these structures occurs on the farm Vogelstruisfontein, south of Durban Roodepoort Deep Gold Mine. The orientation of the folds is not uniform throughout the area, but varies systematically. In Figure 2, the orientation of the axes of these folds is illustrated in relation to geographical position. In the east, the folds tend to strike northwest, changing to east-west along the West Rand and the Rand Anticline and, finally, striking northeast, in the west (Potchefstroom-Klerksdorp area). In the West Rand area, two fold-orientations are evident: one striking essentially northwest and the second striking northeast. The interference of these sets is responsible for the extensive preservation of Black Reef Formation in minor depressions in the region (Mellor, 1917).

The orientation of major folds in the Black Reef Formation in the East Rand basin coincides with fold-orientations recorded in the underlying Main Reef Leader conglomerate of the Witwatersrand Supergroup (Papenfus, 1964). Although this coincidence has been considered to reflect simple reactivation (Papenfus, 1964), the present study considers the fold-orientation in the older Witwatersrand rocks to be a primary feature, related to pre-Transvaal Sequence wrench-faulting (Stanistreet *et al.*, 1985). These folds may well have been reactivated to a limited extent during the post-Transvaal Sequence folding.

Small-Scale Folds

These folds vary in wavelength from metres to tens of metres and are periclinal; amplitude is normally small and the folds vary from gentle warps to folds with slightly-overturned limbs (e.g. Tweefontein, Fig. 3). Small-scale folds are common features of the Black Reef Formation, and they have been measured at selected localities in the central and western portion of the region.

In Figure 4, the plunges of these minor folds are shown in relation to geographic position. Typically, the plunge of the folds is shallow. There is also a systematic variation in fold-orientation through the study-region, generally lying parallel to the larger structures. An interfering fold-set, similar to the major folds in the West Rand, noted above, is also locally developed.

Figure 3 : Overfolded, Black Reef Formation quartzite and conglomerate at Tweefontein. Regional dip is to the right (north), but, at this locality, the Black Reef Formation arenites dip steeply to the left (south). The fold-structure responsible for the overturning plunges into the plane of the photograph. The person in the photograph is standing on cleavage surfaces.

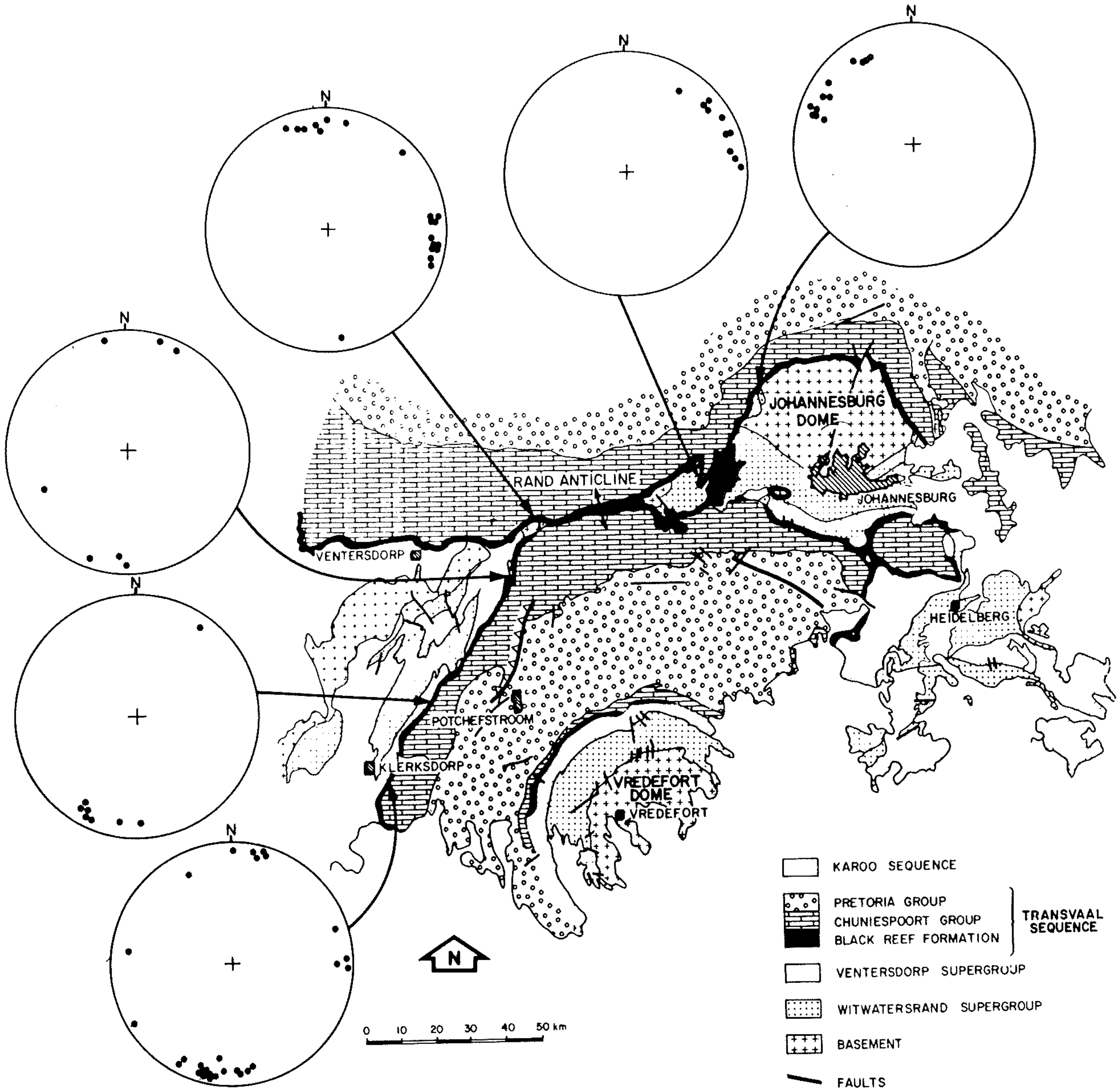


Figure 4 : *Regional variation in the plunges of minor folds in the Black Reef Formation through the study-region (lower-hemisphere, equal-area projections).*

Cleavage

Exposures of Black Reef Formation mudstones are uncommon, but are particularly well developed along the northwestern margin of the Johannesburg Dome. This is an especially-good area for examining the relations between the deformation in the Black Reef Formation and the underlying rocks. A closely-spaced, penetrative cleavage is developed in the Black Reef Formation mudstones in the area. However, cleavage-intensity is variable. At a locality on the farm Rietfontein (Fig. 1), the contact between the Black Reef Formation and the underlying Ventersdorp Supergroup (Platberg Group) rocks is well exposed. At this locality, both rock-suites are strongly cleaved. The orientation of cleavage in the Black Reef Formation and Ventersdorp Supergroup rocks is shown in Figure 5 and is essentially the same in the two sequences.

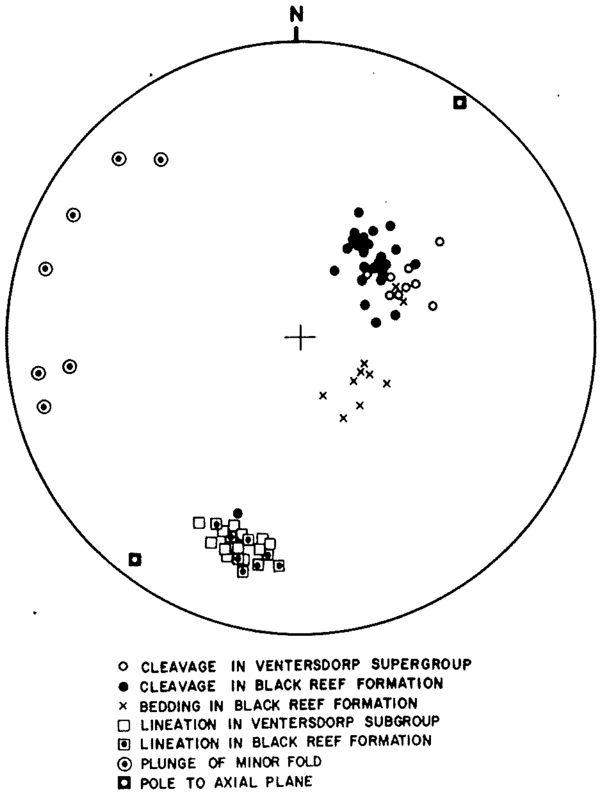
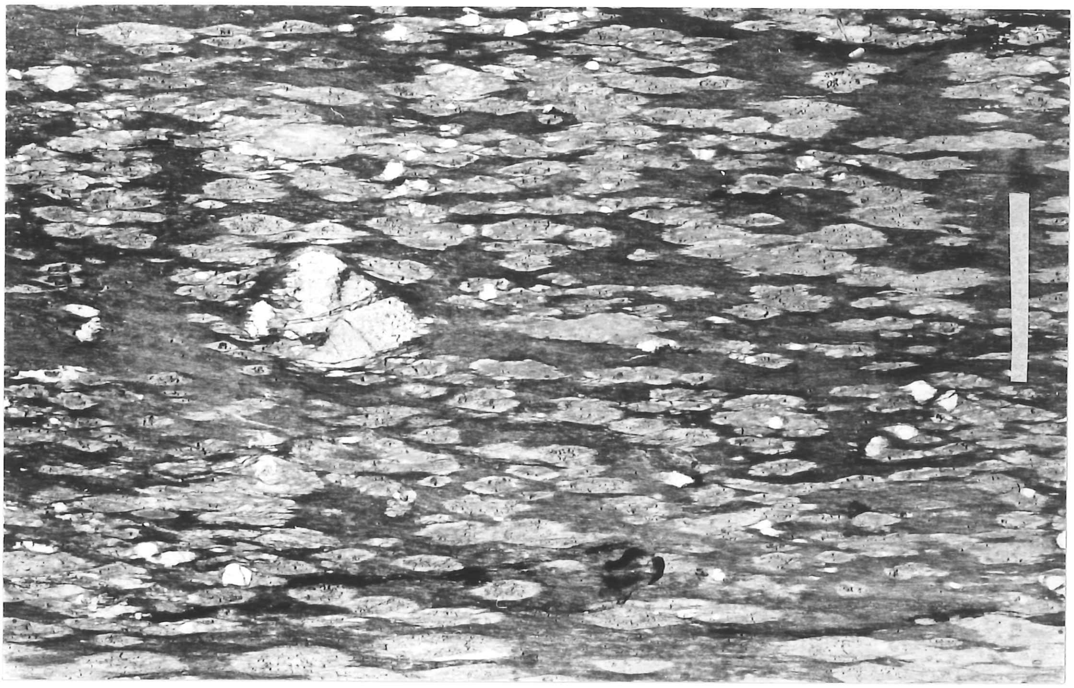


Figure 5 : Orientation of cleavage and lineations in the Black Reef Formation and underlying, Platberg Group rocks at Rietfontein. The orientations of minor folds in the Black Reef Formation are also shown (lower-hemisphere, equal-area projection).

At this locality, both the Transvaal and Ventersdorp rocks are characterized by a metamorphic-mineral growth, represented now by a quartz-mica (probably pyrophyllite) assemblage. These spots are elongated and flattened in the cleavage (Fig. 6) and define a linear fabric. The orientation of this fabric in the Black Reef Formation and Ventersdorp

Supergroup rocks is identical (Fig. 5). It should be noted that this linear fabric does not plunge down the dip of the cleavage. The shape of the spots is a measure of the finite strain in the rock. The average dimensions of the spots were measured on planes orientated through the principal planes of the strain-ellipse and average ratios of maximum-to-intermediate and intermediate-to-minimum dimensions were calculated. These are: Ventersdorp Supergroup spots, $2{,}14 \pm 0{,}57$ and $2{,}40 \pm 0{,}83$, respectively; Black Reef Formation spots $4{,}36 \pm 1{,}56$ and $3{,}74 \pm 1{,}22$ respectively.



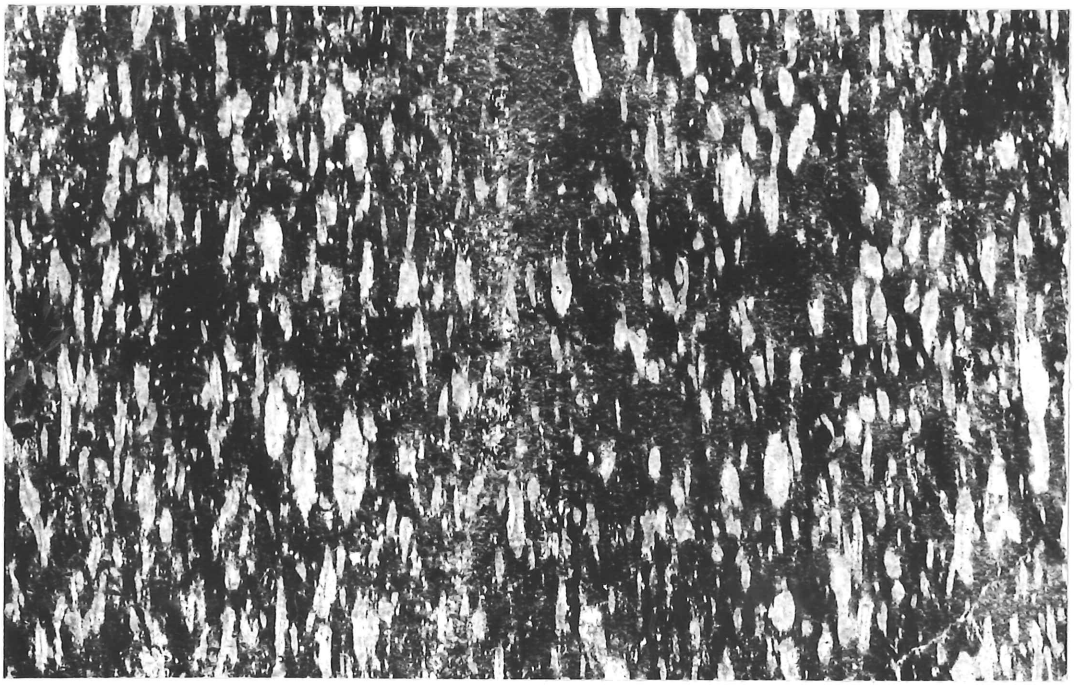


Figure 6 : *Elongation of quartz-mica intergrowth in Ventersdorp Supergroup (Platberg Group) mudstones (A) and Black Reef Formation mudstones (B). This elongation defines the lineation plotted in Figure 5. Scale bars represent 5mm.*

Cleavage-orientation in the Ventersdorp and Witwatersrand Supergroup outliers in this area is shown in Figure 7 and is similar in orientation to the cleavages recorded at the Rietfontein locality (Fig. 5). It is inferred from these data that the cleavage in these outliers is post-Black Reef Formation in age.

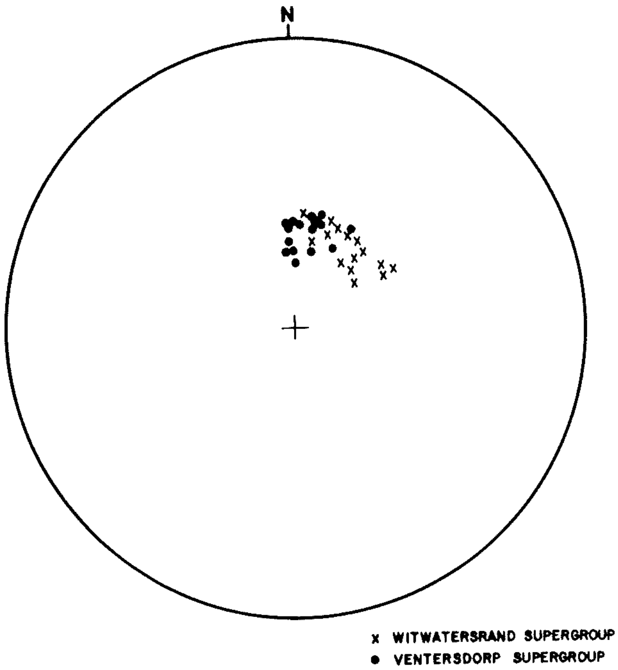


Figure 7 : Oriention of cleavage in the Witwatersrand and Ventersdorp Supergroup outliers in the Zwartkop area (lower-hemisphere, equal-area projection).

A closely-spaced, penetrative cleavage is developed in Witwatersrand and Ventersdorp rocks throughout the Central Rand. This cleavage, like that in the area just described, strikes east-west and generally dips towards the south, although, in detail, small variations in strike and larger differences in dip do occur (Fig. 8). In general, the dip of the cleavage is shallower on the northern flank of the Johannesburg Dome. Roering (1968) has noted that this cleavage is superimposed on the post-Ventersdorp, pre-Transvaal West Rand syncline,which strikes northwest. In this regard, it has been noted that the cleavage strikes at right-angles to the steeply-dipping western limb of the West Rand syncline (Fig. 9). McCarthy *et al.*, (1982) also recognized cleavage-superimposition on older structures in the Central Rand.

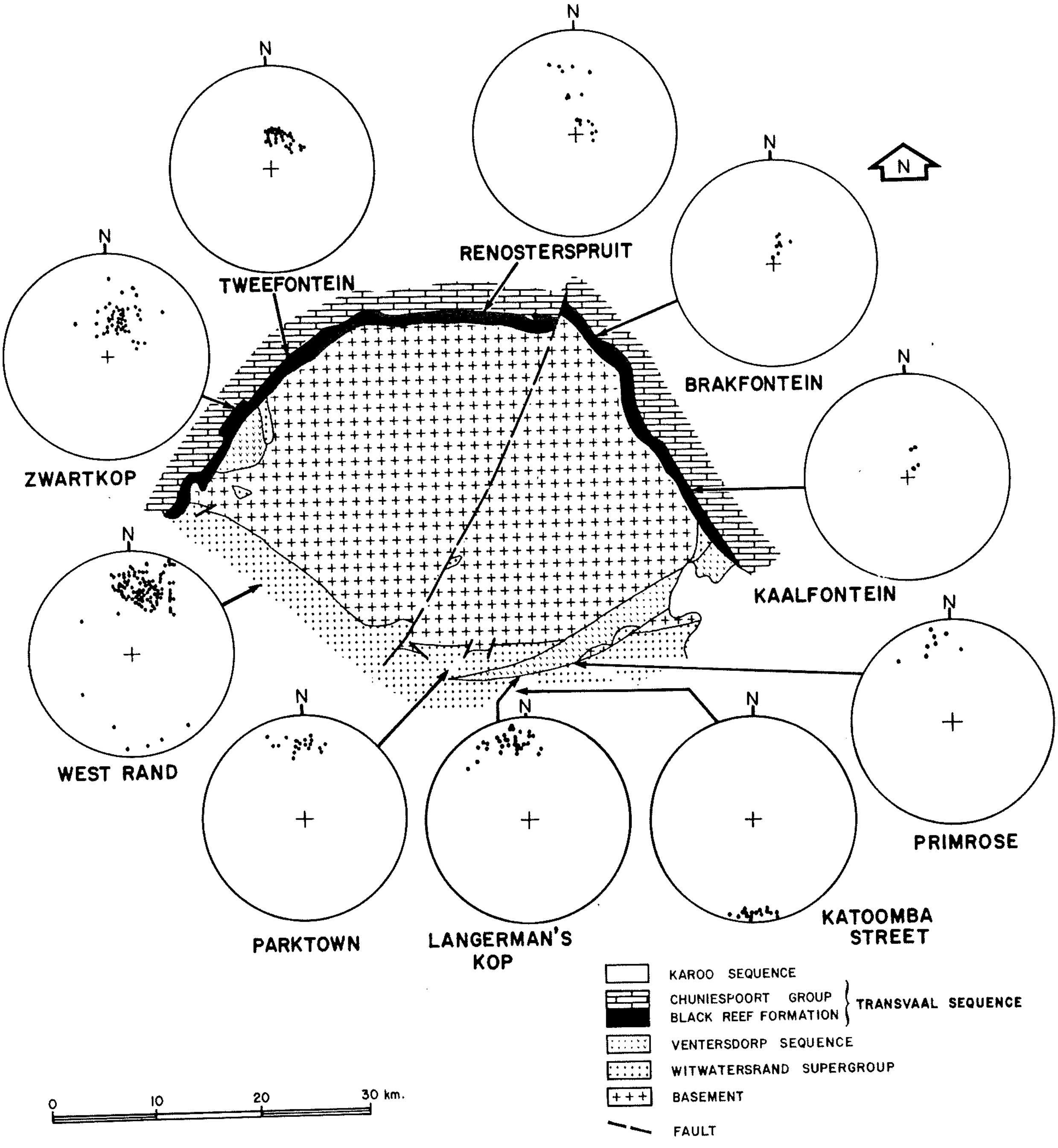


Figure 8 : *Variation of cleavage-orientation around the Johannesburg Dome (lower-hemisphere, equal-area projection).*

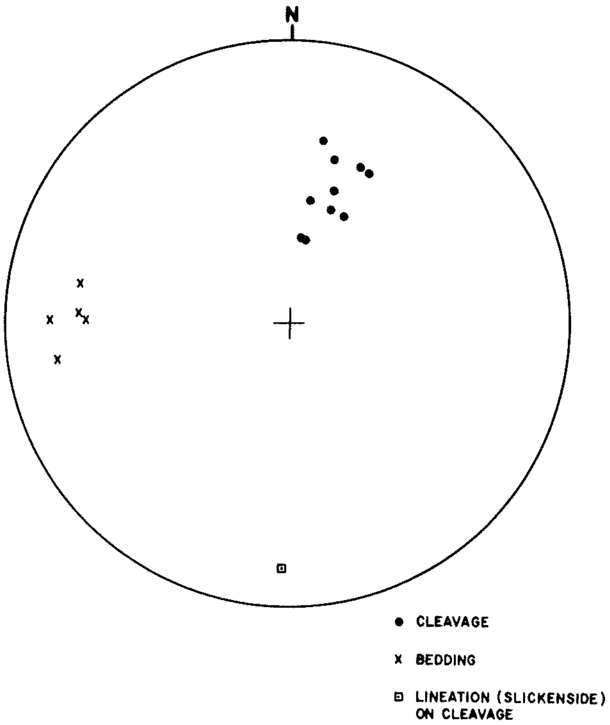


Figure 9 : *Cleavage- and bedding-orientations in the steeply-dipping, western limb of the West Rand syncline (lower-hemisphere, equal-area projection).*

Since the cleavage is considered to be post-Transvaal in age, measurements were taken in Black Reef Formation, Ventersdorp, and Witwatersrand Supergroup rocks in this regional study. The distribution of cleavage in the study-region at large is shown in Figure 10. In general, the strike of the cleavage has an arcuate distribution. Lineations in the cleavage in the Heidelberg area plunge southwest, while a single lineation in the Randfontein area plunges south (Fig. 10).

There is a definite relation between the cleavage and the minor folds described previously. At the Rietfontein locality, the strike of the cleavage is essentially parallel to the strike of the axial-planes of the folds (Fig. 5), but the dip of the cleavage is, generally, considerably shallower than that of the fold axial-planes (Fig. 5). This relation is clearly displayed at the Tweefontein locality (Fig. 3), where a fold is developed in the Black Reef Formation in which one of the limbs is, in part, overturned and dips steeply southwards. The fold axis strikes 290° and plunges at 15° to the northwest. The cleavage strikes 290° and dips 20° to the south. Minor folds of identical geometry are exposed in a road-cutting through Pretoria Group rocks in the Skeerpoort, to the north of Tweefontein. These folds are asymmetric, plunge to the west, and are associated with a shallow, southerly-dipping cleavage (Fig. 11). The Tweefontein structure appears to be a larger-scale fold of this type. At the Skeerpoort locality, the cleavage is also developed in a sill of Bushveld (2 100 Ma) age.

Although the cleavage is generally well developed in Witwatersrand and Ventersdorp Supergroup rocks and is sporadically developed in the Black Reef Formation surrounding the Johannesburg Dome (Fig. 8), the greenstone lithologies within the basement are essentially devoid of cleavage and certainly do not reflect the post-Transvaal deformation which produced the widespread cleavage, except where suitable basement lithologies lie in close proximity to the cover.

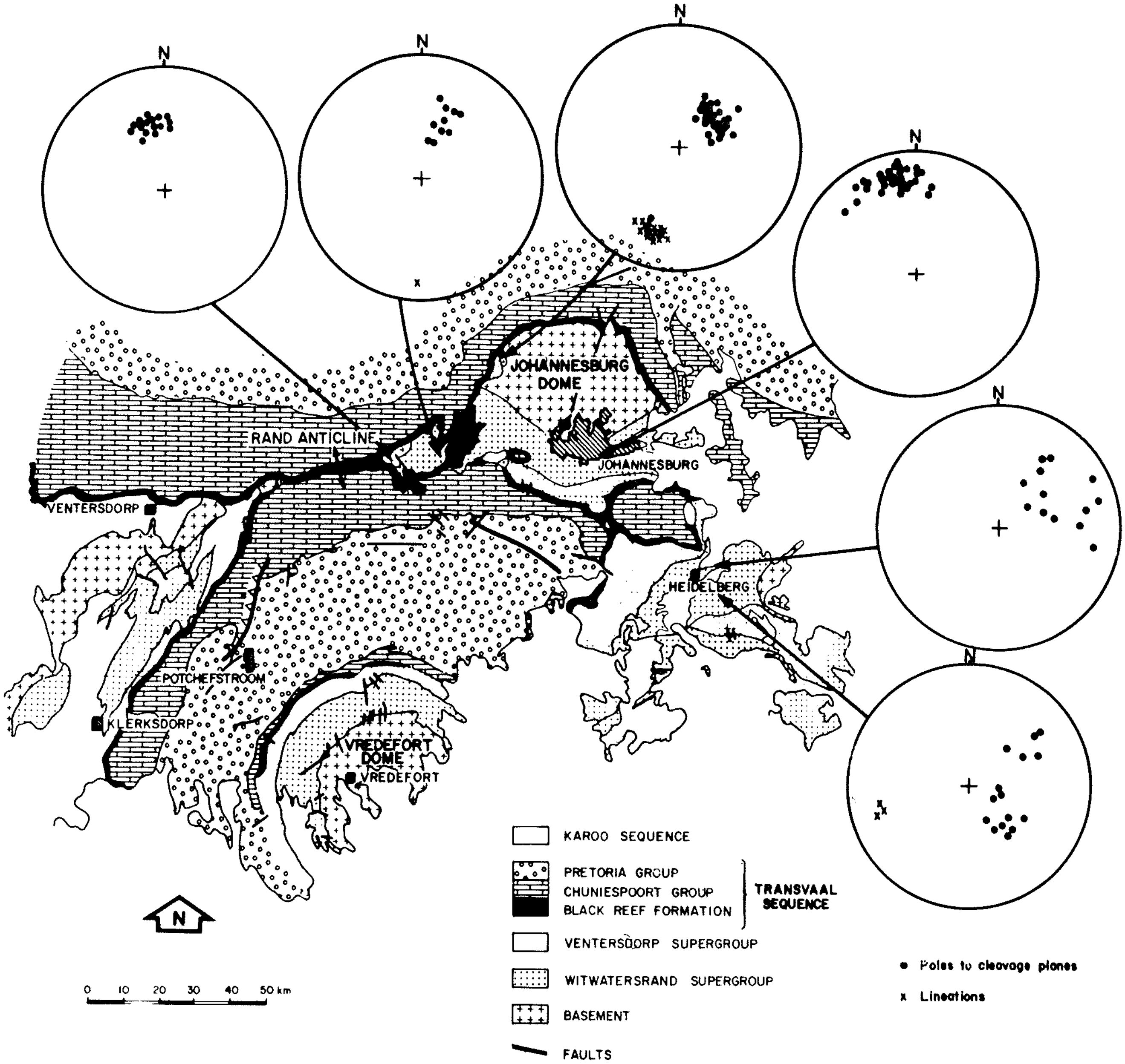


Figure 10 : *Regional variation of orientation of cleavage and associated lineation through the study-region (lower-hemisphere, equal-area projections).*

Figure 11 : Minor folds in interbedded mudstones and siltstones in the Pretoria Group at Skeerpoort. The shallow, southerly-dipping cleavage is approximately parallel to the axial-planes of overfolds.

Faults.

In general, faulting appears to have had only a minor effect on the distribution of the Black Reef Formation in the study-region, and this is the subject of a more-detailed investigation. However, certain major faults have been described, which affect the Transvaal Sequence, particularly the Pretoria Group, and which may have relevance to the present study.

Foremost amongst these faults is the Master Bedding Plane Fault described by de Kock (1964) and Fletcher and Gay (1971). This fault is extensively developed in the mines of the Carletonville area, but its surface expression has not been identified positively. It is essentially a bedding-parallel fault and generally occurs within the Jeppestown Subgroup. This fault is of post-Transvaal age, as it displaces the Ventersdorp-age Gerhardminnebron graben at the western end of the West Wits Line and passes from Witwatersrand Supergroup strata into the overlying Transvaal Sequence rocks (Fletcher and Gay, 1971). The fault is characterized by thick, mylonite- and breccia-development. An enigmatic aspect of this breccia, reported by both de Kock (1964) and Fletcher and Gay (1971), is the presence of fragments of Transvaal Sequence dolomite within host, Jeppestown Subgroup, sedimentary rocks.

Cousins (1962) described the results of deep drilling in faulted ground lying to the south of Western Areas Gold Mine, where the Malmani Dolomite Formation and portion of the overlying Pretoria Group have been duplicated by east-west striking faults. These faults apparently do not displace the underlying Black Reef Formation. Although Cousins (1962) suggested that sinkhole-induced subsidence was responsible, this seems highly improbable.

Truter (1936) described a major, northwesterly-dipping thrust which caused the dolomites to over-ride the Pretoria Group in the area west of Potchefstroom. This fault is associated with folding along north-northeasterly-striking axes and with the development of extensive, imbricated faulting. According to Truter (1936), the fault is of post-Bushveld (2 100 Ma), but pre-Pilanesberg (1 500 Ma), age.

In addition to these faults, a period of post-Transvaal, right-lateral wrench-faulting has been recognized in the East Rand basin by Antrobus and Whiteside (1964). These faults strike east-west and parallel an older set of left-lateral wrench-faults (Vogels Tear-Fault) (Ellis, 1943; Antrobus and Whiteside, 1964; Stanistreet *et al.*, 1985). Their post-Transvaal age is indicated by the fact that they displace post-Transvaal dykes. De Jager (1964) also records the presence of such faults in the southern portion of the East Rand basin, although the age in this area cannot be determined. Mapping by Mellor (1917) in the West Rand Syncline provided evidence for right-lateral, post-Transvaal displacement in what he regarded as the western termination of the Rietfontein Fault. Roering (1968) also noted that the Witwatersrand Supergroup strata have been affected by such faults, although, again, their age is uncertain.

DISCUSSION

Classification of Structures

The structural features presented above can be divided into several sets, on a basis of their orientation. The most important set, which comprises all of the major structures, includes: large-scale folds, the axes of which change orientation around the basin, from northwest, in the east, through east-west,in the north, to northeast, in the west (Fig. 2); small-scale folds, the axes of which parallel those of the major folds (Fig. 4); and cleavage, the strike of which parallels that of the fold axes (Fig. 10). Included with this set of structures are all of the major faults, viz. the Master Bedding Plane Fault, the Potchefstroom thrust, and the strike-faults south of Western Areas Gold Mine.

A second set of structures comprises north-to-northeasterly-striking folds which are developed in the northwestern portion of the study-region. A third set of structures are east-west-striking, right-lateral wrench-faults of relatively small displacement, which have been well documented in the East Rand basin (Antrobus and Whiteside, 1964), but which probably also occur on the West Rand and elsewhere. Finally, it is believed that the cleavage relations around the Johannesburg Dome are indicative of yet another tectonic event.

Relations Among Major Structures

Reference to Figures 2 and 4 indicates that, with minor, local exceptions, the minor and major fold-axes are parallel in any particular area. The spectrum of fold-profiles is also similar: for example, the fold-structure at Tweefontein (Fig. 3) has minor-fold counterparts in the Skeerpoort (Fig.11) and a macroscale counterpart on Vogelstruisfontein, to the south of Durban Roodepoort Gold Mine. All the asymmetric folds verge outward from the main Witwatersrand Basin, i.e. axial-planes dip basinwards. It is pertinent to note that minor folds in the Contorted Bed in the Central Witwatersrand area also verge northwards, and the axes of these folds strike east-west (Fripp and Gay, 1972). A comparable spectrum of fold-shapes occurs in the Contorted Bed and in the Pretoria Group rocks in the Skeerpoort (Fig. 11) (Fripp and Gay, 1972).

In general, the cleavage is not axial-planar to the folds, but dips at a shallower angle. Exceptions occur where folds are overturned, when the cleavage may be axial-planar. The strike of the cleavage is parallel to the strike of the axial-planes of the folds, and cleavage dips towards the centre of the main Witwatersrand Basin. This relation has also been noted by Fripp and Gay (1972) in the case of the Contorted Bed.

The orientation of both the folds and cleavage changes systematically through the study-region (Figs. 2, 4, 5), and, therefore, it is concluded that they are genetically related. On a regional scale, these structures are seen to lie tangentially to the Vredefort structure.

Similar fold geometries, i.e. open folds with shallow plunges, were recorded by Simpson (1977) in the Potchefstroom synclinorium (Fig. 12), which she attributed to the emplacement of the Vredefort structure. She reported that the rocks within the Potchefstroom synclinorium were devoid of cleavage, however. A cleavage which is apparently axial-planar to the overfold in the upper Witwatersrand rocks in the collar of the Vredefort structure was noted by Ramsay (1961) and Manton (1962).

The three sets of linear fabrics measured all plunge in the direction of the Vredefort structure (Fig. 10). Although faults have not been included in this study, it has been noted that major faults in the general area also lie tangentially to the Vredefort structure (Fig. 2).

The nature of deformation of the mineral spots at the Rietfontein locality, i.e. close to plain strain, is indicative of an origin by simple shear. A similar conclusion applies to the Swartkop syncline to the south of the Rietfontein locality. Fripp and Gay (1972) also proposed a simple-shear model to account for the development of folds and cleavage in the Contorted Bed in the Central Rand area. In their case, the deduced shear was from south to north, but it is evident from the regional distribution of structures that the stress-field must have acted radially to the Vredefort structure. These various structural features, therefore, must be genetically related to the emplacement of the Vredefort Dome.

Structural Mechanisms

It has been shown that the structures described are tangential to the Vredefort Dome. However, there appears to be a variation in structural style radial to the dome. Close to the dome,the rocks are intensely folded (Manton, 1962), shattercone- and striated-joint-surfaces are common, and a

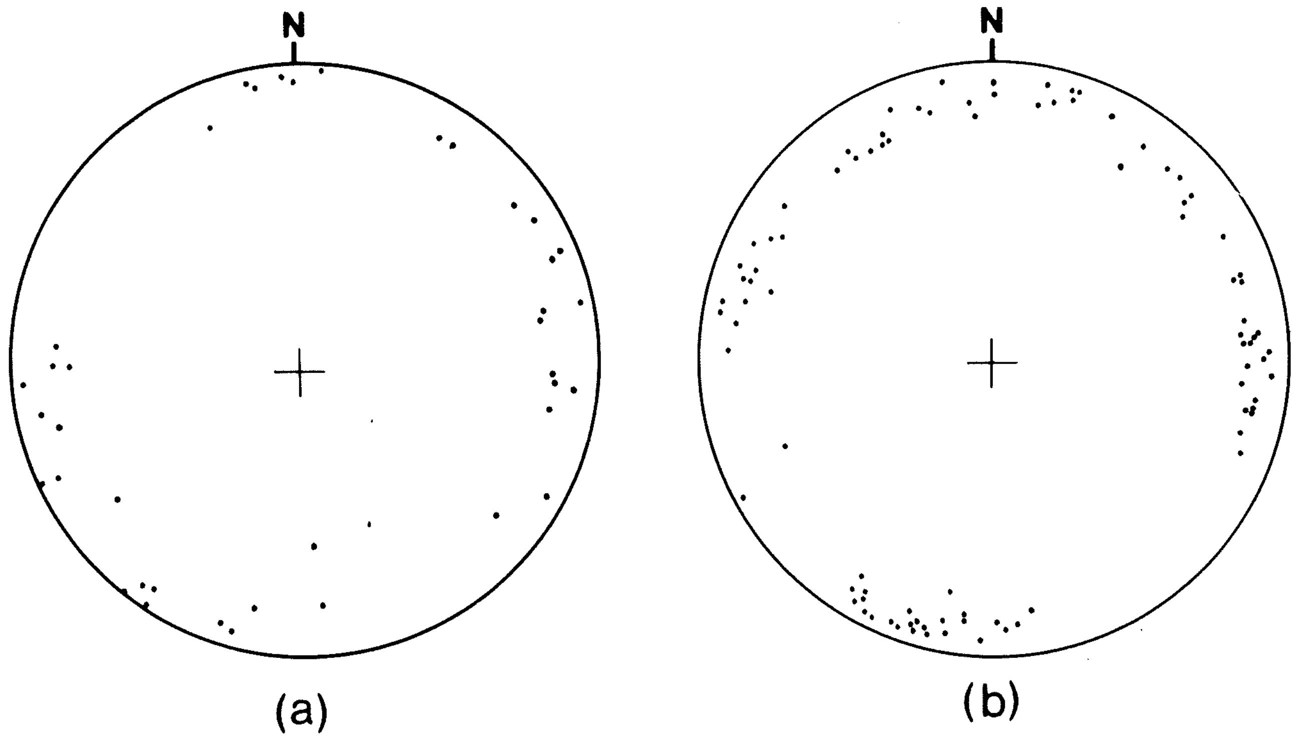


Figure 12 : Orientations of minor-fold axes in the Potchefstroom (rim) synclinorium (after Simpson, 1977) (lower-hemisphere, equal-area projection).

tangential cleavage is locally developed (Manton, 1962; Ramsay, 1961; Simpson, 1977). In the Potchefstroom synclinorium, open folds with large amplitudes are common, but cleavage is poorly developed or absent (Simpson, 1977). With increasing distance, the folds decrease in amplitude and wavelength. Shear-induced cleavage is developed, but is variable in intensity. It appears anomalous that cleavage is well developed in a region one hundred kilometres from the dome centre, and yet is weakly developed close by. This must imply that different deformational mechanisms were operative in different regions.

There appears to be a relation between the deformation-style in the Transvaal Sequence and the nature of the sub-outcropping geology. Where the Transvaal Sequence is underlain by the very homogeneous and competent Klipriviersberg Group volcanics, deformation is confined to folding. However, where sedimentary rocks underlie the Transvaal Sequence, a cleavage is often developed, sometimes associated with folds, particularly over Witwatersrand Sequence rocks. Since the cleavage is induced by simple shear, it is inferred that shear-stresses were transmitted through the Witwatersrand Sequence, outwards from the dome, along the layered, less-competent units. In contrast, it appears that the homogeneous and competent, Klipriviersberg Group volcanics simply moved bodily on top of the underlying, layered rocks, with a minimum of internal shear. The Transvaal Sequence overlying the lava appears to have been shortened by simple, lateral compression. In this regard, Manton (1962), following Ramsay (1961), noted a decrease in strike-length of the Witwatersrand strata in the collar-rocks around the Vredefort structure. Manton (1962) interpreted this as the result of an inward and upward movement of the basement and Witwatersrand strata through a constriction. At a higher level, mass was moved outward, causing folding of the Transvaal Sequence. Such movements would have resulted in shearing parallel to bedding.

This model emphasizes differential shear in the Witwatersrand Sequence. Locally, this might be expected to manifest itself as dislocation along planes of weakness, such as major, lithological boundaries, forming bedding-sub-parallel faults. This phenomenon is frequently encountered in the mines of the Witwatersrand Basin, particularly along shale-quartzite interfaces. The Master Bedding Plane Fault may provide a major example of this phenomenon. Simpson (1977) considered the Potchefstroom thrust to be a Vredefort Dome-related structure, possibly a back-thrust related to folding in the rim synclinorium. Strike-faulting on the northern portion of Western Areas Gold Mine (Cousins, 1962) may also be related to this deformation. Although Cousins (1962) interpreted this as solution-slumping, reverse-faults, lying sub-parallel to bedding, could have produced similar effects, i.e. duplicating portion of the Malmani Dolomite Formation and Pretoria Subgroup, without displacing the Black Reef Formation.

The folds in the study-region verge outwards from the Vredefort structure and indicate tectonic transport away from the dome. However, Simpson (1977) observed a zone of normal faulting in the Potchefstroom synclinorium, with downthrow towards the dome, which post-dates the folding, but which she, nevertheless, regarded as related to the doming. These faults indicate a late, extensional phase which operated radial to the dome. This phenomenon may explain an enigma associated with the Master Bedding Plane Fault. De Kock (1964) and Fletcher and Gay (1971) recorded the presence of dolomite fragments within the breccia associated with this fault, where it is located within Witwatersrand Supergroup rocks, well away from the Transvaal Sequence unconformity. A single stage of movement, in no way, can account for this relation. The presence of these dolomite fragments is interpreted as signifying an initial, outward phase of movement, during which Witwatersrand Supergroup rocks were thrust over Transvaal Sequence rocks. This was followed by a return movement, during which blocks of Transvaal Sequence became detached and were transported to their present position within the Witwatersrand Supergroup as a fault-breccia. It is concluded that the emplacement of the Vredefort Dome induced an initial, outward mass-movement, which was followed shortly after by an inward movement.

The Effect of the Johannesburg Dome

The shear-induced cleavage discussed above is not consistent in strike and dip around the Johannesburg Dome (Fig. 8). In general, the dip of the cleavage is steeper on the southern side of the dome, and strikes are dispersed around the dome.

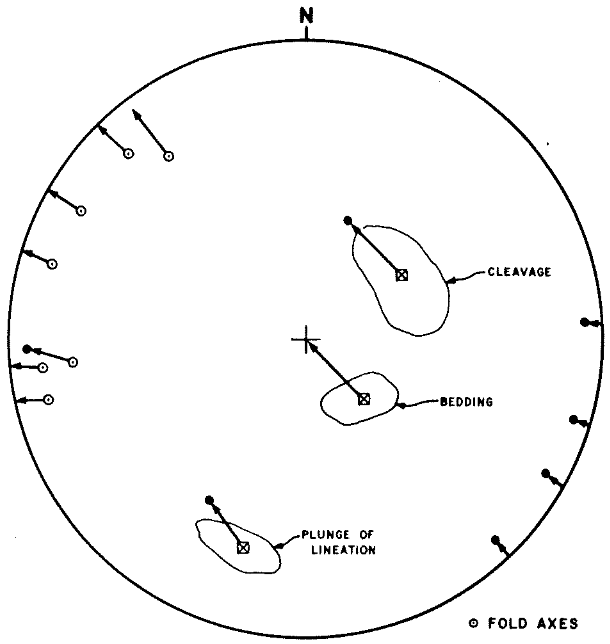
Figure 5 shows that the lineation at the Rietfontein locality, on the edge of the Johannesburg Dome, does not plunge down the dip of the cleavage. If, however, the cleavage- and plunge-data are corrected for the local dip of the Black Reef Formation off the Johannesburg Dome, the lineation moves to the exact downdip position, as might be expected to be the case with a shear-induced lineation and cleavage. The axes of the minor folds assume an horizontal disposition and scatter about the perpendicular to the plane containing the poles to the cleavage and the plunge of the lineation (Fig. 13). If the cleavage-data around the Johannesburg Dome (Fig. 8) are corrected for local dips on the Black Reef Formation, the cleavage dispersion is greatly reduced (Fig. 14). These observations suggest that the emplacement of the Johannesburg Dome post-dates cleavage-development and, therefore, occurred later than the Vredefort event. The data suggest that dome-emplacement locally caused folding of the cleavage (Renosterspruit, Fig. 8). Furthermore, at one locality investigated on the Central Rand, situated in overfolded Government Subgroup shales, south of the Rietfontein fault (Katoomba Street, Fig. 8) (McCarthy *et al.*, 1982), the cleavage dips northwards. This may indicate that a rise of the Johannesburg Dome caused local reactivation of the Rietfontein Fault, overturning the cleavage. The fact that the cleavage dips more steeply than the bedding in the overfolded limb, nevertheless, suggests that the strata were already overturned or, at least, steeply-dipping prior to reactivation of the Rietfontein Fault. No data bearing on the origin of the Rand Anticline were forthcoming.

Other Structural Events in the Region

In addition to the two structural events described above, which are considered to be related to the emplacement of domes, two other, minor features were noted during the course of gathering data, viz. a set of north-to-northeasterly-striking folds in the northwestern portion of the region and a set of east-west-striking, right-lateral wrench faults. The regional significance of these structures, or their ages, could not be determined from the present data-base.

CONCLUSIONS

This study has shown that the Black Reef Formation is deformed by heterogeneous development of folding and a penetrative cleavage. These structures strike tangentially to the Vredefort Dome and are genetically related to it. Deformation in the Contorted Bed may be related to this event. The cleavage is best developed away from the Vredefort Dome, where Witwatersrand Supergroup lithologies are in close proximity to the base of the Transvaal Sequence. Witwatersrand lithologies are also cleaved. In contrast, cleavage does not occur in Transvaal Sequence lithologies overlying the homogeneous, Klipriviersberg Group volcanics, suggesting that shear-movements were transmitted outward from the Vredefort structure, through the Witwatersrand strata. Elsewhere, folding occurred by simple compression.



<u>*Figure 13*</u> *: Pi-diagram illustrating the effect of correction of the orientation of cleavages, lineations, and plunges of fold-axes for the local dip of the Black Reef Formation at the Rietfontein locality (from Fig.5) (lower-hemisphere, equal-area projection). After correction, lineation-plunges down the cleavage and fold-axes assume an essentially-horizontal attitude and scatter about the strike of the cleavage.*

Shearing in the Witwatersrand Supergroup sedimentary rocks probably also led to the development of major, bedding-parallel faults, such as the Master Bedding Plane Fault. These faults appear to have experienced two phases of movement: an initial phase outward from the dome, followed by subsequent retraction.

The study has shown that cleavage is dispersed in the vicinity of the Johannesburg Dome, which indicates that the emplacement of this dome occurred after the Vredefort event. This illustrates the potential value of the cleavage as a time-reference in establishing a chronology of structural events in the vicinity of the main Witwatersrand Basin. In

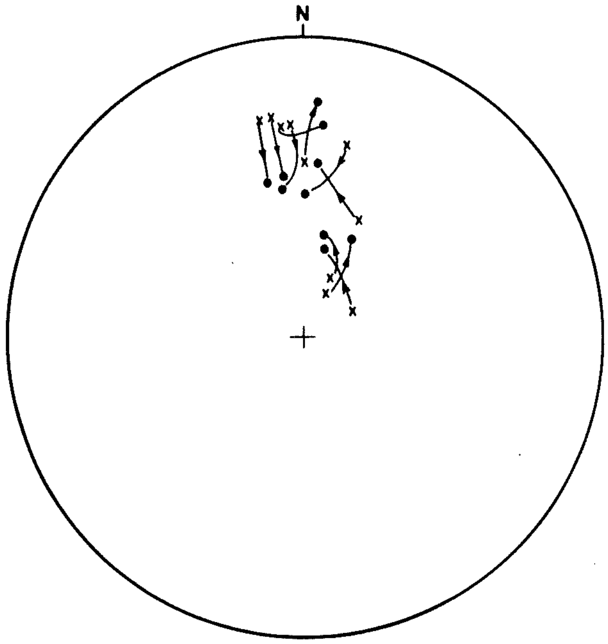


Figure 14 : Diagram illustrating the effect of correction of cleavage-orientation, around the Johannesburg Dome, for local dips of the Black Reef Formation. Crosses refer to centroid of cleavages for various areas (from Fig. 8), while dots refer to position after correction (lower-hemisphere, equal area projection).

addition to these events, northerly-to-northeasterly-striking, gentle folds in the northwestern portion of the study-region and right-lateral wrench-faults of small displacement reflect post-Transvaal Sequence events of uncertain affinities.

In this communication, there have been described one major and three minor, post-Transvaal Sequence deformations, all of which affected the Witwatersrand Supergroup, to a greater or lesser degree. It is possible that further, minor deformations will become apparent as a result of on-going work in the Transvaal Basin.

ACKNOWLEDGEMENTS

The writers gratefully acknowledge financial support from the Senate Research Committee of the University of the Witwatersrand, the Atomic Energy Corporation, and the C.S.I.R. and technical assistance from Mesdames D. du Toit, P. King, and J. Palmer and Messrs. M. Hudson,

K. Palmer, and T. Hewitt.

REFERENCES

Antrobus, E.S.A., and Whiteside, H.C.M. (1964). The Geology of Certain Mines in the East Rand. In Haughton, S.H. (ed.), The Geology of Some Ore Deposits in Southern Africa, Vol. I, Geol. Soc. S. Afr., 125-160.

Cousins, C.A. (1962). The Stratigraphy, Structure and Igneous Rocks of the Transvaal System at Western Areas Gold Mine. Trans., Geol. Soc. S. Afr., 65, 13-40.

De Jager, F.S.J. (1964). The Witwatersrand System in the Springs-Nigel-Heidelberg Section of the East Rand Basin. In Haughton, S.H. (ed.), The Geology of Some Ore Deposits in Southern Africa, Vol. I, Geol. Soc. S. Afr., 161-190.

De Kock, W.P. (1964). The Geology and Economic Significance of the West Wits Line. In Haughton, S.H. (ed.), Geology of Some Ore Deposits in Southern Africa, Vol. I, Geol. Soc. S. Afr., 323-386.

Ellis, J. (1943). A Tear Fault in the Far East Rand. Trans., Geol. Soc. S. Afr., 45, 75-88.

Fletcher, P., and Gay, N.C. (1971). Analysis of Gravity Sliding and Orogenic Translation: Discussion, Bull., Geol. Soc. Am., 2677-2682.

Fripp, R.E.P., and Gay, N.C. (1972). Some Structural Aspects of the Hospital Hill Series on the North-Central Margin of the Witwatersrand Basin. Trans., Geol. Soc. S. Afr., 75, 187-196.

Manton, W.I. (1962). The Orientation and Implication of Shattercones in the Vredefort Ring Structure. Unpubl. M.Sc. Thesis, University of the Witwatersrand, Johannesburg, 162pp.

McCarthy, T.S., Cadle, A.B., and Horrocks, P.C. (1982). Thrust Faulting in Witwatersrand Rocks at Langerman's Kop, Johannesburg. Trans., Geol. Soc. S. Afr., 85, 189-201.

Mellor, E.T. (1917). The Geology of the Witwatersrand: Explanation of the Geological Map. Spec. Pub. 3, Geol. Surv. S. Afr., 46pp.

Nel, L.T. (1935). The Geology of the Klerksdorp-Ventersdorp Area: Explanation of Geological Map. Geol. Surv. S. Afr., 168pp.

Papenfus, J.A. (1964). The Black Reef Series within the Witwatersrand Basin, with Special Reference to Its Occurrence on Government Gold Mining Areas. In S.H. Haughton (ed.), The Geology of Some Ore Deposits in Southern Africa, Vol. I, Geol. Soc. S. Afr., 191-218.

Ramsay, J.G. (1961). Comment on paper "Shatter Cones in the Rocks of the Vredefort Ring" by Hargreaves, R.B. Trans., Geol. Soc. S. Afr., 64, 156-157.

Roering, C. (1968). The Tectonics of the West Rand Syncline: a Field Study of Brittle Failure in the Witwatersrand Basin. Econ. Geol. Res. Unit., University of the Witwatersrand, Inf. Circ. 48.

Rogers, A.W. (1922). The Geology of the Country around Heidelberg. Spec. Pub. 4, Geol. Surv. S. Afr., 84pp.

Simpson, C. (1977). A Structural Analysis of the Rim Synclinorium of the Vredefort Dome. Unpubl. MSc. Thesis, University of the Witwatersrand, Johannesburg: 1, 257pp.

Stanistreet, I.G., McCarthy, T.S., Charlesworth, E.G., Myers, R., and Armstrong, R.A. (1985). Wrench Tectonics as the Major Pre-Transvaal Structural Control on the Northern Portion of the Witwatersrand Basin. Submitted to Precambrian Research.

Truter, F.C. (1936). Observations on the Geology and Tectonics of a Portion of the Potchefstroom District. Trans., Geol. Soc. S. Afr., 39, 441-456.

——— oOo ———