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STRUCTURAL STUDIES IN THE VREDEFORT DOME : PRELIMINARY INTERPRETATIONS OF RESULTS ON THE SOUTHERN PORTION OF THE STRUCTURE.

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INFORMATION CIRCULAR No. 229

UNIVERSITY OF THE WITWATERSRAND
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by

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December, 1990

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ABSTRACT

Detailed and reconnaissance mapping of the southern part of the Vredefort structure has led to the recognition of a migmatitic basement complex. Deformational episodes in this basement fall into two main groups: events and structures pre-dating the 3,07 Ga Dominion Group and those post-dating the Dominion Group. Pre-Dominion Group events comprise an early Archaean anatexis and migmatisation of the basement with subhorizontal fabric development, followed by pervasively developed NE- and NW-trending, subvertical conjugate ductile shear zones. The shear zones are truncated by the Dominion Group - thereby revealing their involvement with tectonic events in the basement which predate the deposition of the late-Archaean/Proterozoic cover sequence. This implies that the shear zones pre-date the ca. 2,0 Ga Vredefort structure and could not possibly be part of a structural argument in any crypto-explosion hypothesis for the origin of this structure.

Post-Dominion Group events consist of: (1) a phase of subvertical shearing at Broodkop (SE Vredefort Dome) associated with a ca. 2,0-2,3 Ga thermal event; (2) mafic dyke intrusions at 1,62 Ga; (3) pseudotachylite development, of which two ages of generation are recognised; and (4) a joint/fracture event. The 2,0-2,3 Ga thermal event coincides with thermal and compressional activity in the Witwatersrand and younger Proterozoic strata and is possibly related to these activities. The 1,62 Ga mafic dyke post-dates the development of the ca. 2,0 Ga Vredefort structure. Pseudotachylite veins, some containing xenoliths of an earlier pseudotachylite generation, transect this dyke and surrounding gneisses, and represent an event which post-dates the Vredefort structure. These findings support previous results suggesting multiple pseudotachylite generation in Vredefort rocks during the period from 1,1-2,2 Ga. Several generations of pseudotachylite and mylonite along faults and shears in the Witwatersrand Basin have also been reported for this time span.

Preliminary results across the basement/late Archaean-early Proterozoic cover contact in the northwest of the Vredefort Dome include the development of foliations in lower Witwatersrand rocks and a shear zone at the basement/cover contact. These structures post-date the intrusion of the ca. 2 Ga alkali granite intrusions and the associated contact metamorphism, and are provisionally interpreted to be related to the final evolution of the dome.

Considerable geometric agreement of pre- and post-Dominion shear zones, joints and pseudotachylite younger than 2,0 Ga occurs in the basement, with NE and NW trends being most common. The coincidence of these structures suggests a geometric control on their development possibly by basement anisotropy. It is inferred that stress regimes in the basement varied through geological time, with easterly and northerly compressive trends common.

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STRUCTURAL STUDIES IN THE VREDEFORT DOME: PRELIMINARY INTERPRETATIONS OF RESULTS ON THE SOUTHERN PORTION OF THE STRUCTURE

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Published by Economic Geology Research Unit
Department of Geology,
University of the Witwatersrand,
1 Jan Smuts Avenue, Johannesburg 2001
Republic of South Africa

ISBN 1 874856 09 5

1. INTRODUCTION

The Vredefort Dome is situated about 120 km south of Johannesburg, more or less in the centre of the Witwatersrand Basin as presently known, straddling the provinces of the Transvaal and the Orange Free State (Fig. 1). The Vredefort structure is horse-shoe shaped, being more polygonal rather than circular. The structure consists of a basement core of about 45 km in diameter which is enclosed by a collar of partially overturned Archaean metasedimentary and - volcanic strata. Detailed geological summaries of this structure can be found in the "Proceedings of the 1987 Workshop on Cryptoexplosion and Catastrophes in the Geological Record" edited by Nicolaysen and Reimold (1990).

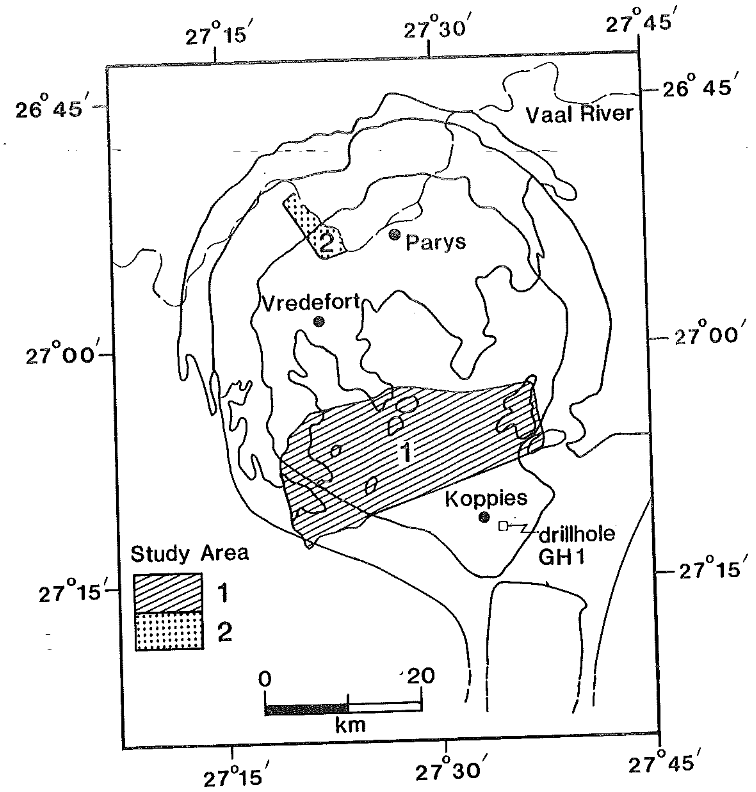


Figure 1: Locality map for the study areas in the Vredefort structure.

The Vredefort structure is considered to be unique for two reasons. Firstly, geochemical data documented by Slawson (1976) and Hart et al. (1981) on the exposed basement gneiss between the contact with the Archaean rocks and the centre of the dome is interpreted as representing a 15km deep crustal profile. Secondly, the structure is unique with respect to exceptional deformation phenomena, such as pseudotachylite, shatter cones, subplanar microdeformations in quartz grains of nearly all lithologies (cf. Nicolaysen and Reimold, 1985) and the occurrence of coesite and stishovite (Martini, 1978). Furthermore, the Vredefort structure has been the centre of much heated debate with respect to its origin. One school of thought (e.g. Nicolaysen, 1972; 1985; Lilly, 1981) favours an endogenous origin, possibly by catastrophic gas explosion. The second school of thought (e.g. Dietz, 1961; Hargraves, 1961; Martini, 1978; Grieve et al., 1990) prefers an exogenous origin in the form of a bolide impact. These hypotheses have induced some polarization and prejudice in the scientific community.

However, the results of a recently initiated multidisciplinary study (see summaries in Colliston et al., 1987; Reimold, 1987a; Reimold et al., 1988) strongly suggested the necessity of reviving an hypothesis, largely overlooked in recent expositions, namely that of a structural origin for the Vredefort Dome (e.g. Du Toit, 1954; Brock and Pretorius, 1964; Ramberg, 1967). The main incentive for a detailed comparative structural, geochemical, and isotopic study of selected areas of the early Archaean basement complex has been the dearth of published structural information, the lack of a structural data base on the dome and the strong bias towards geochemical studies.

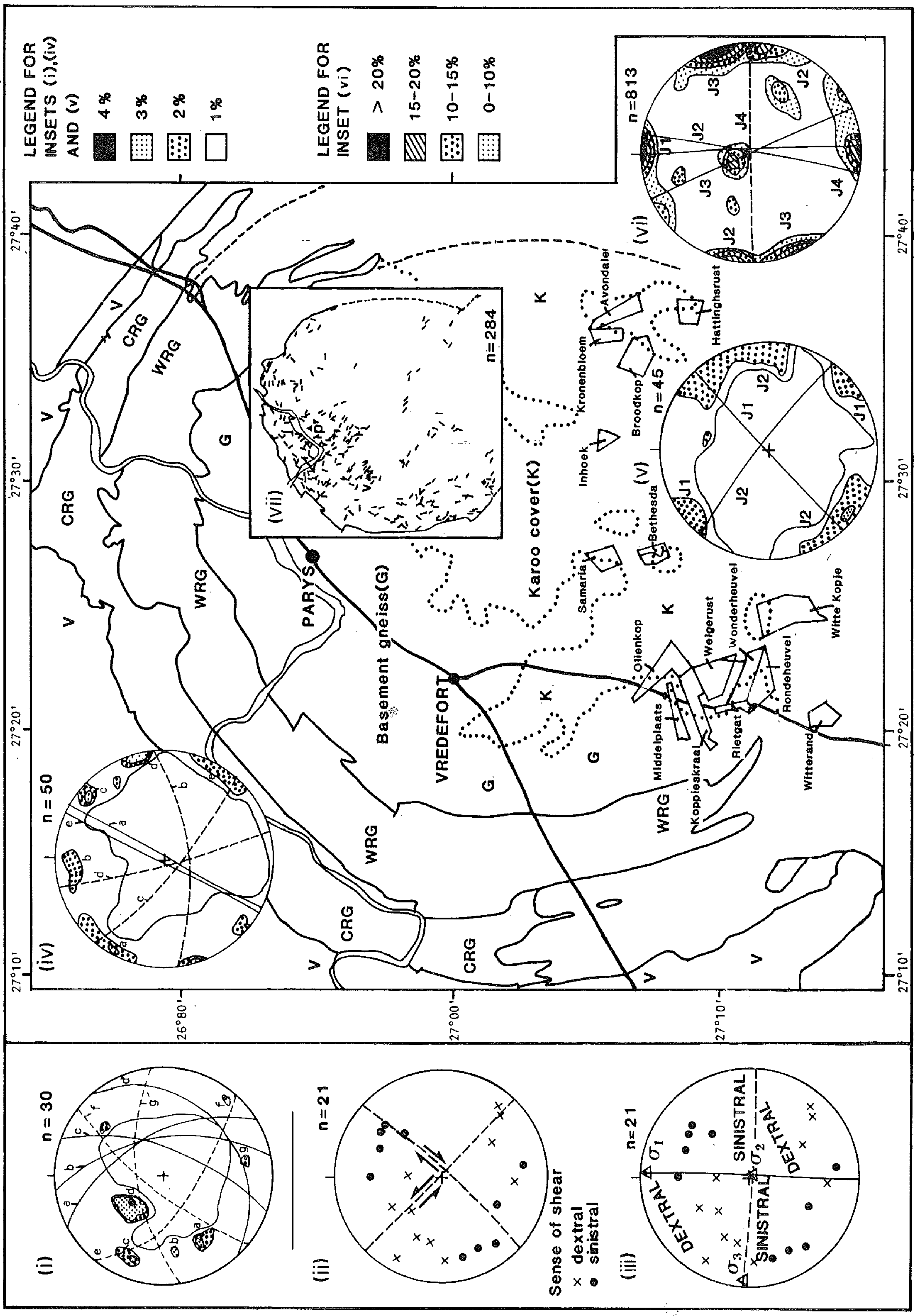
The area south of Vredefort was chosen as a primary target. This region (Fig.1) has, in the past, been neglected due to the extensive cover of Karoo Sequence rocks and the consequent lack of outcrop. Furthermore, a preliminary geochemical survey indicated that it was of anomalous composition with respect to the major lithologies of the basement, namely the Outer Granite Gneiss (OGG) and the Inlandsee Leucogranofels (ILG) (Colliston et al., 1987). A further important observation was that the collar rocks (Fig. 2), which are partly overturned in the northern parts of the Vredefort Dome, are not vertical or overturned in the south, thereby suggesting the possibility of a different structural control for the southern part of the Vredefort structure.

In this paper, a study is made of structures and events within the basement of the southern part of the dome. These deformational episodes are grouped into two main categories on the basis of relative structural dating and geochronological results: deformation episodes occurring prior to the deposition of the 3,07 Ga Dominion Group (Armstrong et al., 1990) and those that occur after. The variety of field, structural, and geometric characteristics are then discussed. An attempt is made to show the relevance of the various deformational episodes to the evolution of the Vredefort structure and a proposed ca. 2.0 Ga Vredefort event, and also to the regional tectonic evolution in this part of the Kaapvaal Craton.

2. OBSERVATIONS ON THE GENERAL LITHOLOGY OF THE VREDEFORT DOME

The granite-greenstone basement in the southern and southeastern parts of the Vredefort Dome (Fig.1, study area 1) is heterogeneous. It consists of various types of gneiss, and is extensively overlain by the Karoo Sequence. It was previously thought that the entire basement to the Vredefort structure consisted of two gneissic rock types, namely an inner core of felsic gneiss, the ILG, and an annulus of coarse-grained biotite-hornblende gneiss, the OGG (Hart et al., 1981). In this investigation a number of new outcrops were discovered which could not be classified geochemically as either ILG or OGG. A comparative mesoscopic description of these gneisses according to the existing classification, is given in Table I (for localities cf. Fig.2).

Figure 2: *Structural features of the Vredefort structure. Insets (1-V1) are synoptic equal area projections of poles to planar elements in the Archaean basement: (1) stereogram of regional Archaean gneissic foliation showing the eight planar orientations, a to g, recognised in study area 1; (11) stereogram of Archaean-age shear zones, differentiated into sinistral and dextral shear sense in the horizontal plane and showing subvertical NE- and NW-trending shear planes (study area 1); (111) stereogram of principal stress planes and axes for shear zones in (11), determined from the change in sense of shear directions; (1V) stereogram of pseudotachylite veins showing the five orientations observed - a to e, (study area 1); (V) stereogram showing the two dominant joint sets, J1 and J2, recognised in study area 1; (V1) stereogram synthesising joint data from Poldervaart (1962); four joint orientations are recognised, J1 to J4, north of study area 1; (V11) average strike of gneissic foliation (Reimold et al., 1985) deformed by dominant NE- and NW- trending Archaean shear zones. In simplified geological map of the Vredefort structure (modified after Nel, 1927): V = Ventersdorp Supergroup, CRG = Central Rand Group, WRG = West Rand Group, G = Basement Complex, K = Karoo Sequence.*


LEGEND FOR INSETS (i),(iv) AND (v)
4 %
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Sense of shear
× dextral
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PARYS
VREDEFORT
Basement gneiss(G)
Karoo cover(K)
CRG
WRG
V
G
K
Middelplaats
Koppieskraal
Rietgat
Witterand
Rondeheuvel
Wonderheuvel
Welgerust
Ollenkop
Samaria
Bethesda
Inhoek
Broodkop
Kronenbloem
Avondale
Hattingsrust
Witte Kopje

Table 1. Classification of gneiss-types in the study area

LOCALITY	GNEISS TYPE	OTHER
Rietgat	OGG	
Wonderheuwel	OGG	Lenses of medium-grained quartz-feldspar gneiss
Rondeheuwel	OGG	
Welgerust/ Olienkop	ILG	
Wittekoppies	---	Quartz-biotite-plagioclase gneiss
Samaria	ILG	Enclaves of amphibole-magnetite gneiss; quartz-feldspar gneiss; amphibolite
Bethesda	ILG	Enclaves of banded quartz-feldspar gneiss; charnockite
Broodkop	OGG	Quartz-feldspar-biotite gneiss; enclaves of amphibolite
Avondale	---	Rare pegmatitic-type gneiss
Kronenbloem	---	Rare pegmatitic-type gneiss

Selected sections of drill core samples of basement gneisses from south of the Vredefort Dome were also studied and were found to be texturally and compositionally heterogeneous (AAC hole GH1, Goedehoop 180; AAC hole Kroonstad NG1, Nooitgedacht 2242). The geochemical results indicate that the southern and southeastern parts of the central core are chemically distinct with regard to OGG and ILG, and are distinguished from the latter by being more enriched in HREE, Cs, Rb, U, Th, Ta and depleted in Se, Co, and Ni (Colliston et al., 1987; Reimold et al., 1988; M. Meyer, pers. comm., 1987). In general, the schlieric-heterogeneous nature of the central core gneisses as well as the results of macro and microscopic examinations of rocks from the study area and from other localities in the granitoid basement leads to the conclusion that the central basement of the Vredefort Dome represents a complex migmatite terrane.

3. STRUCTURAL FEATURES OF THE SOUTHERN PART OF THE DOME

The main mesoscopic structures affecting the entire basement gneisses in the south (Fig.2, study area 1), may be sequentially subdivided as follows (see also Table 3): (1) a subhorizontal 'early' regional foliation, Sg, (2) recumbent isoclinal folds and upright folds; (3) shear zones; and (4) singular and multiple fracture sets. The geometric data presented in Figure 2 with the exception of Poldervaart's (1962) data, represents some 167 fabric measurements from the study area.

This limited data base is a reflection of the paucity of outcrop in the southern part of the Vredefort Dome. Vast areas are covered by Karoo Sequence and heterogeneous erosion gives rise to metre - and decametre-scale flat-lying suboutcrop with hardly any three-dimensional exposures. Obtaining a statistical number of measurements from outcrops such as these is not only difficult, but also meaningless, as more measurements from any one outcrop would create a bias in the data distribution. The geometric distribution of data as recorded in the inset figures of Figure 2 are representative of the structural elements observed in the suboutcrop$_2$ on the farms named in Figure 2, with approximately 3 to 4 readings per 20 m where possible. The data is contoured for ease of interpretation.

A. Foliation

In the gneisses, the foliation is defined by the planar re-orientation of biotite and/or by subparallel, elongated feldspathic augen and stretched quartz grains. The foliation shows a change in orientation across the study area (Fig.2, inset i). This is supported by the strike-variation diagram of Reimold et al. (1985), which shows the variation in strike of the foliation in both the study region and the region northwards towards the contact with the collar rocks (Fig.2, inset vii). The variation in strike is mainly brought about by rotation through the horizontal into the subvertical by later-developed shear zones, as indicated by the great circles representing the foliation (Fig.2, inset i). The great circles broadly define the dominant strike for the shear zones, namely northeast, northwest and east-west.

The original subhorizontal nature of the regional foliation in the basement gneiss was recognised in low strain areas which are mainly located in the southernmost part of the study area. The subhorizontal nature of the regional fabric as seen on surface outcrop has subsequently been confirmed at depth by the study of diamond drill boreholes encompassing the complete Government and Hospital Hill Groups and part of the granitoid basement rocks. For example, the study of drill core GH-1 from ca. 2 km south of Koppies (Fig.1) revealed that the foliation in the gneiss is flat-lying and that the orientation of Lower Witwatersrand strata overlying the basement gneiss is subhorizontal (angles at stratigraphic contacts are generally less than 30o) and definitely not overturned as in other parts of the collar. The only structural features recorded are low-angle faults which affect the sediments on a decimetre to metre scale. It is important to note that the Dominion Group strata are neither recorded in this drill core nor in drill core NG 1 from northeast of Kroonstad.

B. Folds

In the southwestern part of the area, mesoscopic folds are only to be seen in the gneisses, where the migmatite banding is well developed. Scarce recumbent folds as well as later upright folds which deform the regional foliation, have been observed at certain localities. At Bethesda (Fig.2) well developed recumbent isoclinal folds deform the regional foliation and have axial planes coplanar with the foliation. Their fold axes plunge shallowly to the north (Fig. 3).

Figure 3: Bethesda. Isoclinal folds in Archaean gneiss with axial planes coplanar with regional foliation.

C. Shear Zones

Subvertical ductile shear zones on a metre - to decametre scale are ubiquitously developed in the area, and deform the regional gneissic fabric. The shear zones post-date the phase of isoclinal folding and are often found as conjugate pairs with both sinistral or dextral displacement. The four strike directions are northwesterly, northeasterly, easterly and northerly, with the latter two directions being the least common (Fig.2, compare insets i and ii). Inset (ii) represents the geometrical relationship of poles to shear planes, where the sense of shear (sinistral or dextral) in the horizontal plane has been determined. The geometric data obtained are from randomly selected shear zones in the study region. The dominant northeasterly and northwesterly strike orientations are also reflected in the regional foliation pattern north of the study area (Fig.2, inset vii).

The subvertical shear zones also deform the Archaean granulite facies rocks of the Steynskraal metamorphites (Stepto, 1979, 1990) but were not observed to transect the Dominion or Witwatersrand strata of the collar; the contact between the basement gneiss with shear zones and the Archaean cover rocks is an angular unconformity. Thus a minimum age for this shearing event can be inferred at › 3,06 Ga, which is the accepted age for the deposition of the Dominion Group (Walraven et al., 1990).

The only mega-scale shear zone with associated cataclasites and mylonites present in the area is the northeasterly trending Broodkop shear zone (Fig.2), situated close to the southeastern boundary of the structure. This subvertical shear zone, ca. 500 m wide, has an indeterminable strike extent due to Karoo cover. The present outcrop has a strike extent of ca. 600 m. Whereas the previously described subvertical shear zones were formed prior to the deposition of the Dominion Group, the Broodkop shear zone was developed later than 2,7 Ga ago (cf. see later section on the Broodkop migmatite complex and shear zone). Another difference between the two ages of subvertical shear zones is that the younger Broodkop shear is characterised by displacement in the vertical, while the older shear zones are characterised by horizontal displacement.

The orientation of the maximum and minimum stress axes for the older shear zones in the southern part of the Vredefort Dome (Fig.2, inset iii) was determined from a technique described by Davidson and Park (1978). It involved the construction of principal stress planes and stress axes on a best-fit basis from the change in the sense of shear as seen in a horizontal plane. The minimum and maximum compression directions as obtained by this model, are sigma 1 with a sub-horizontal plunge on a bearing of 272° and sigma 3 with a sub-horizontal plunge on a bearing of 002°.

D. Brittle Deformation: Pseudotachylite

Minor outcrops of pseudotachylite veins (Pt), developed on millimetre to centimetre scale, transect the regionally developed shear zones, pegmatites and quartz veins, as well as some early fractures. At least two generations of Pt are present Part 2 in the area. The geometrical arrangement of these veins (Fig.2, inset iv) shows that the poles to Pt are grouped close to the periphery of the net, reflecting their predominantly vertical attitude. The average great circles (a to e) represent the planar orientations of Pt, which vary in strike from northeast to northwest and east-west, with dips towards the southwest, southeast and south. The dominant strike directions recorded for the Pt are similar to the strike of the shear zones, and sheared gneissic foliation trends to the north of the study area (Fig.2, insets ii and vii respectively).

Although Pt is quite abundant in the north and northwest of the Witwatersrand Basin and the Vredefort collar (Fletcher and Reimold, 1989; Killick and Reimold, 1990), only mylonite in limited amounts could be detected in the drill core GH1 from south of Koppies. It is important to note from a shock metamorphic viewpoint, that no planar features were observed in quartz in GH1. From the above, together with other documented data (Fletcher and Reimold, 1989; Killick and Reimold, 1990) and the observations made in the study region, it may be inferred that there is an increase in Pt development from south to north in the basement core (cf. also Stepto, 1990).

E. Brittle Deformation: Fractures

Brittle fractures commonly cross-cut all existing structural elements as well as basement, collar, and intrusive rocks and including pseudotachylite. Data collected from basement gneiss in the study region (Fig.1, study area one) are plotted on a synoptic equal area projection in Figure 2, (inset v). Notwithstanding the limited data set, a regular pattern exists. Most of the joint poles are distributed around the periphery of the net, and illustrate the sub-vertical to vertical attitude of the joint planes. Two major groups are distinguished and are numbered J1 and J2, with the average great circles representing the two joint plane attitudes. The data spread is small for J1 and much larger for J2, but both broadly define northeast to northwest strike orientations.

Similar strike orientations for brittle phenomena in the basement rocks were obtained by Poldervaart (1962) north of this study area (north of a line between Vredefort and Parys - Fig.1) and a synthesis of his data is given in inset (vi) of Figure 2. From the synoptic projection, five major concentrations of poles to joints are recognized, and are numbered J1 to J5. The average great circles to these maxima represent the orientations of the joint planes. All but the east-northeasterly striking joint planes are vertical to near vertical; they in turn represent a subhorizontal joint set.

The grouping of these joint sets and interpretation of the groups is difficult as field relationships were not documented by Poldervaart (1962). However, two sets are apparent: an orthogonal set J1 and J4, and a diagonal set J2 and J3. The subhorizontal joint set J5 is possibly also associated with the diagonal set. The genesis of these sets is probably related to the dynamic development of the dome (see also Poldervaart, op. cit., p.237 for other reasons and discussion). In terms of this, the diagonal joint set and the orthogonal set are interpreted as shear joints and extensional joints, respectively.

Using this interpretation to define the principal stresses, the maximum compressive stress direction sigma 3 bisects the acute dihedral angle between J2 and J3, and the minimum tress direction sigma 1 bisects their obtuse angle. The intersection of J2 and J3 defines the intermediate stress direction sigma 2. This dynamic interpretation suggests northerly compression for the Vredefort Dome.

F. The Broodkop Migmatite Complex and Shear Zone

This migmatite complex is located some 35 km southeast of Parys and 10 km north-northeast of Koppies on the farm Broodkop. It is situated on the southeastern part of the Vredefort Dome, forming part of the Archaean basement and is in close proximity to greenstones which outcrop to the southeast (Fig.1, study area 2 & Fig.2) (definition of the term "migmatite" is after Mehnert, 1968).

(i) Lithology: migmatite and other

The lithological components of the migmatite are complex and reflect a variety of rocks of different size, shape and composition intermingling with each other on centimetre to metre scales. Major element chemistry shows that most samples taken are similar to typical OGG, but there are others that vary considerably (Colliston et al., 1987). The migmatites trend northeasterly and are subdivided from southeast to northwest into the following domains (Fig. 4):

(1) a *neosome domain,* which can be subdivided into quartz-feldspar-biotite-muscovite gneiss and a quartz-feldspar-hornblende-biotite gneiss. Biotite and hornblende vary between 1 and 3 vol. %; (2) a

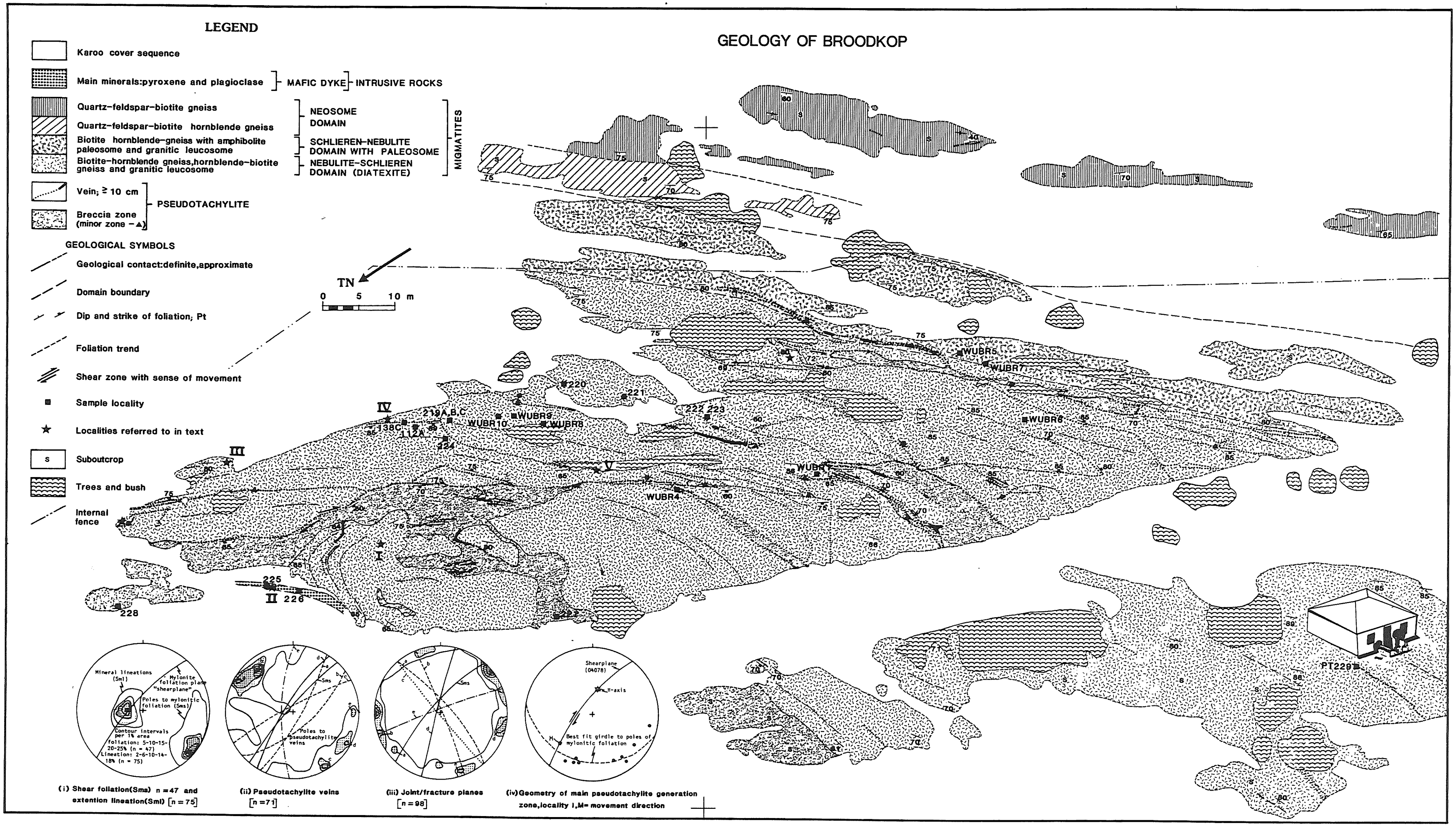


Figure 4: Geological map of Broodkop. Insets - equal area projections of: (1) Contoured intervals of poles to mylonite foliation (Sm) and mineral extension lineations (Sm2); (2) Contoured intervals (2-3-5-6-7%) of poles to pseudotachylite veins with planes (a) to (e) drawn to peak density domains; (3) Contoured intervals (2-4-6-7-8%) to poles of fracture planes; planes (a) to (e) drawn for domains of maximum clustering; (4) Geometry of main pseudotachylite generation zone - locality (I). The dashed pi-girdle is drawn through poles to rotated mylonitic foliation. M is the likely movement direction.

palaeosome domain (Fig. 5) where the matrix is a schlieric to nebulitic migmatite. In this zone, the amphibolite paleosome is distributed on a centimetre to metre scale; and (3) a *diatexite domain* where the paleosome is only recognisable as millimetre - to centimetre - wide mafic schlieren, and the lithological components vary compositionally from granitic to granodioritic types (Fig. 6; locality (V), Fig.4).

The entire migmatite sequence is pervasively intruded by pegmatitic leucosome, quartz veins, and pseudotachylite (Pt) - the Pt forming an orderly arterial network (Fig. 4). A mafic (gabbroic) dyke intrudes the diatexite domain in the northwest (locality II, Fig. 4). This dyke postdates the major shear deformation event which has affected all other lithologies at Broodkop, but predates a Pt-forming event which transects the undeformed dyke. Several Rb-Sr whole rock data define an isochron age for this dyke of 1.62 ± 0.12 (2 S) Ga for an initial ratio of 0.7141 ± 1. This age is interpreted as the minimum crystallization age for the dyke (Reimold et al., 1988), and consequently gives the minimum age for the Broodkop brittle shear event and a maximum age for the later Pt event. The relatively high initial ratio could lead to the suspicion that the dyke is contaminated by pegmatitic components. However, the detailed chemical data available on the dated dyke specimens do not substantiate this. Nevertheless, an attempt was made to date the dyke by the U-Pb method as well, an attempt that failed due to excessive chemical homogeneity with regard to U and Pb concentrations (Robertson, 1988).

Rb-Sr analyses of mineral separates from the Broodkop migmatite samples resulted in the recognition of a major thermal event having affected this area at approximately 2,2 Ga ago (Colliston et. al., 1987; Reimold et al., 1988). This thermal event is tentatively interpreted as representing the formation of the Broodkop shear zone. At least two Pt-forming events can be distinguished in outcrop (Figs.7, 8; locality (IV), Fig.4). The different compositions of these pseudotachylites are presented in Table 2, where it may be inferred that the grey variety is similar in composition to many granitic samples analysed from Broodkop. The Fe and Mg-rich Pt inclusions seem to be derived from a melt formed by the mixing of felsic (high Al) and mafic components.

Figure 5: Broodkop palaeosome domain. The boudined palaeosome is amphibolite distributed within a schlieric-nebulitic matrix. Scale = 1m.

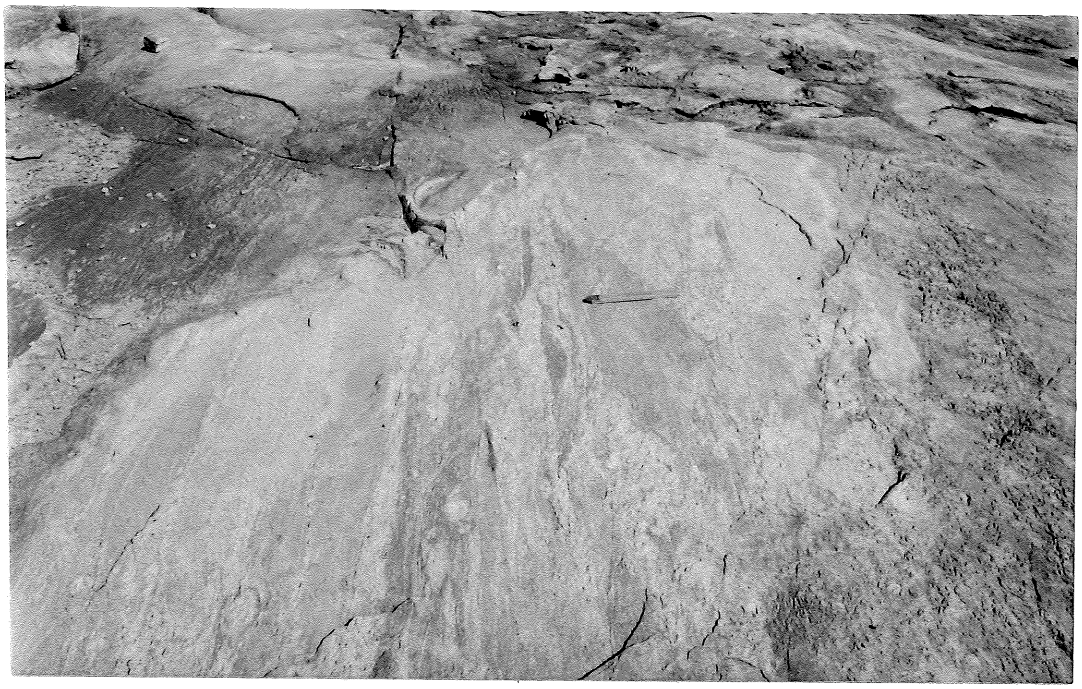


Figure 6: *Broodkop diatexite domain (Fig. 4 locality (V)); two components present, granitic (light grey) and granodioritic (dark grey). Scale = 40cm.*

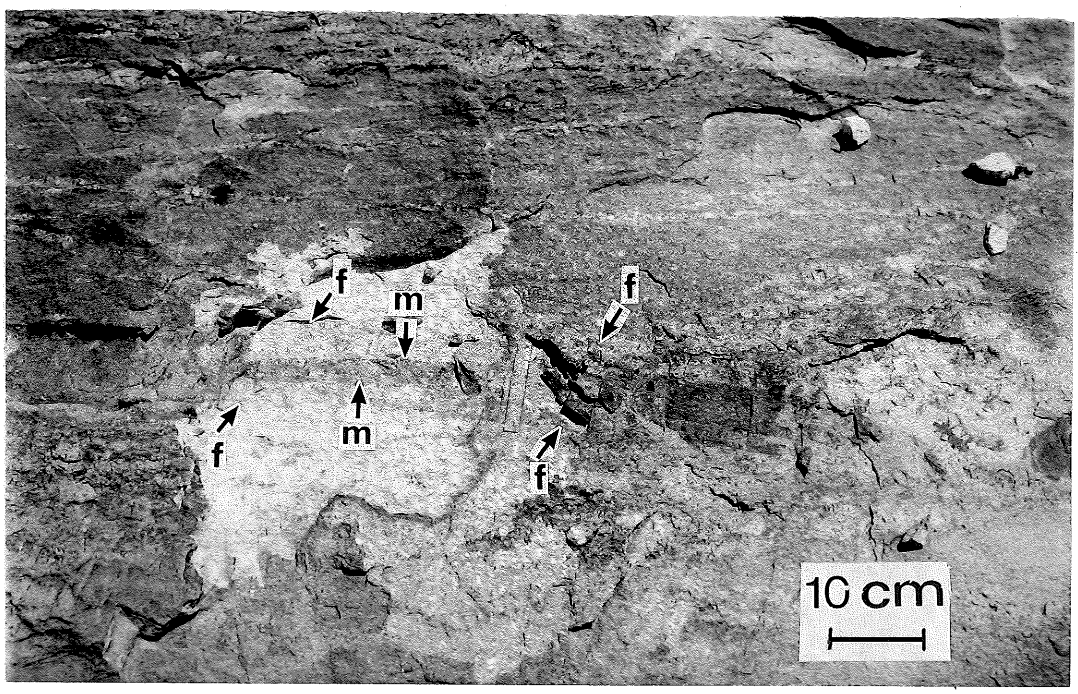


Figure 7: *Broodkop diatexite domain (Fig. 4 locality) (1V)). Occurrence of two pseudotachylite (Pt) generations: xenolith of a mafic Pt (m) within a felsic Pt (f) - see Table 2. Scale = 10cm.*

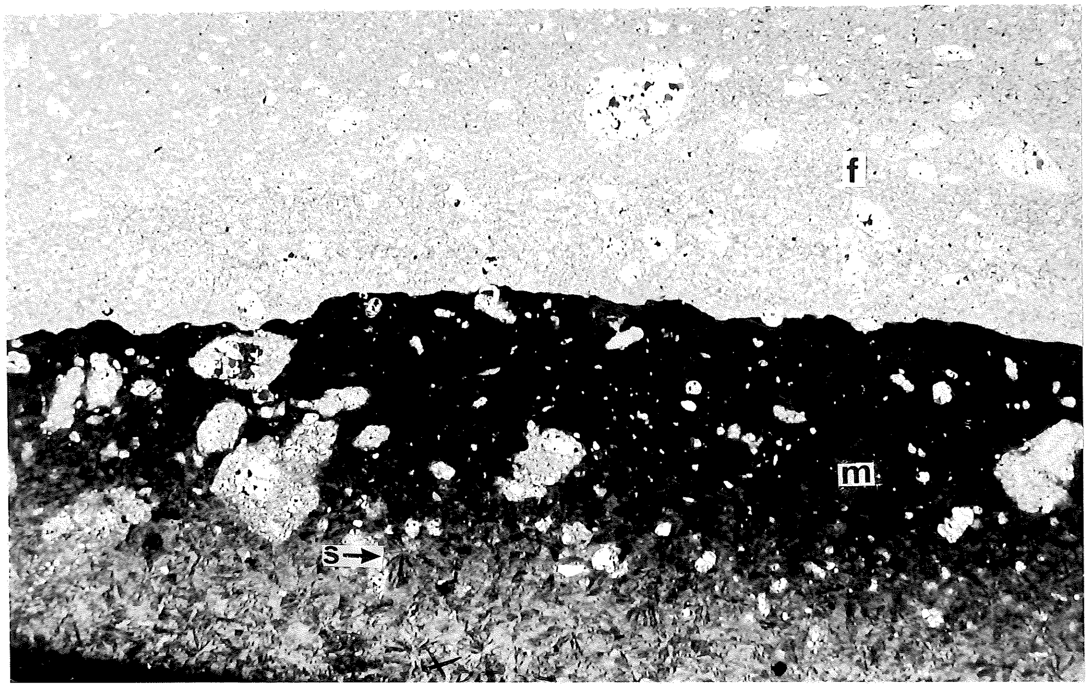


Figure 8: Broodkop diatexite domain (Fig. 4 locality (1V). Thin section across the contact between the felsic Pt (f) and mafic Pt xenolith (m) of Fig. 7; s = pyroxene spherulites. Field of view 4 cm.

(ii) Structural aspects

1. *Shear zone geometry*

The main structure affecting the entire migmatite complex is the northeasterly trending shear zone with a vertical to subvertical mylonitic fabric (Sms) which steepens from southeast to northwest, and a pervasively developed stretching ineation (Sml) trending 270°, plunging 72° (Fig.4 inset i). The fabric shows a textural variation from a macrofragmental crush breccia (cataclastic breccia) in the neosome domain (Fig.9), to mylonite in the palaeosome-containing domains and diatexite domains. The distribution of cataclastic and mylonitic rocks could either reflect zones of lower and higher strain, and/or preferred deformation in fluid-rich lithologies.

The geometry of the down-dip stretching lineation (Fig.4, inset i) indicates that movement was predominantly in the vertical. The sense of displacement is determined by the oblique relationship of s-c band structures (Simpson and Schmid, 1983) as depicted in Figure 10 resulting in downwards displacement of the southeastern block relative to the northwestern block.

2. *Pseudotachylite features and geometry*

Some of the more remarkable structural features developed at Broodkop are pseudotachylite bands, injection veins and breccia zones (Fig.4). The pseudotachylite forms a large network ramifying from a main pseudotachylite band which is situated on a mesoscopic movement surface and located towards the northernmost extremity of the outcrop. This surface is parallel to the shear foliation Sms, and may be traced laterally across the outcrop for some 180m. Shear phenomena are characteristic of this surface and a dextral sense of strike-slip movement may be inferred from the rotation of Sms (Fig.4, locality I).

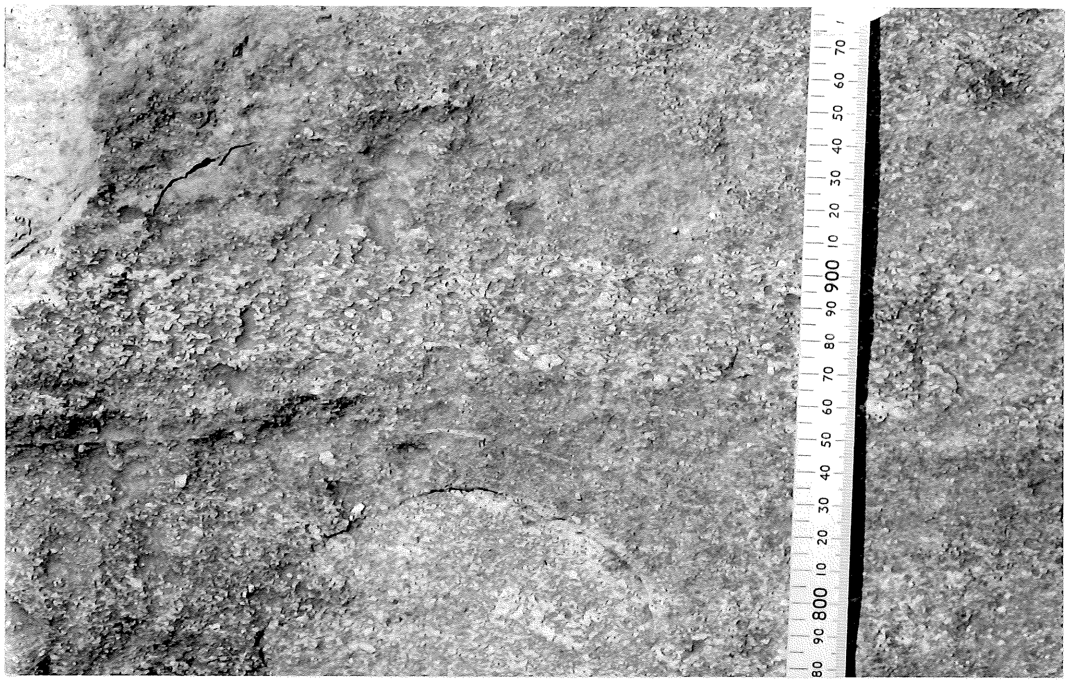


Figure 9: *Broodkop neosome domain. Macrofragmental crush breccia defined by trails of sheared and broken quartz and feldspar grains.*

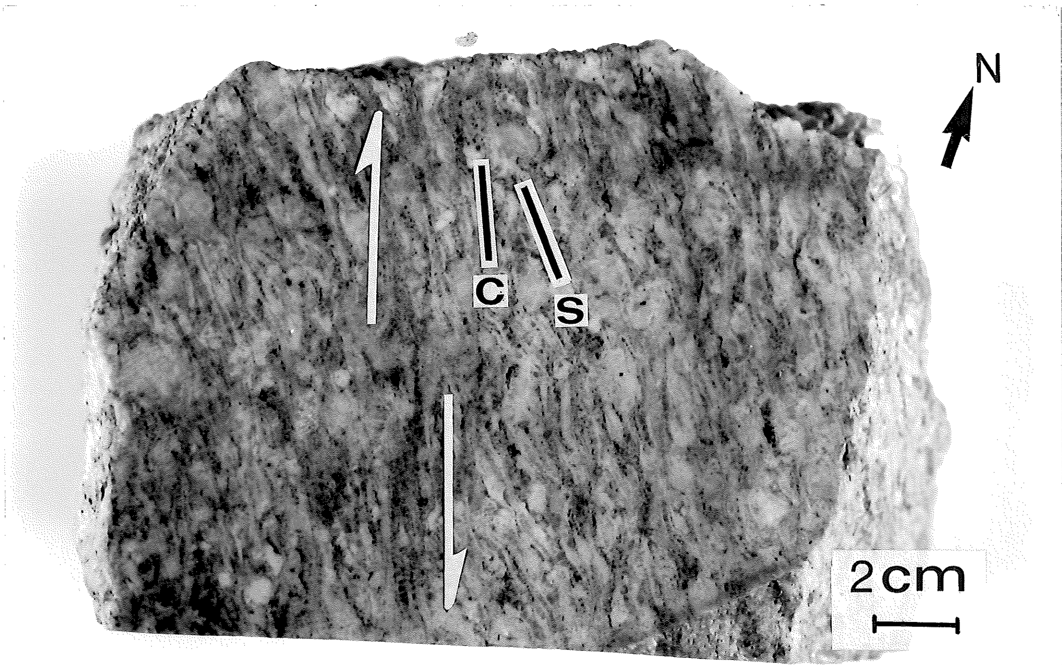


Figure 10: *Broodkop neosome domain. Polished surface of sheared gneiss (XZ- plane), with s and c-surfaces indicating shear in the sub-vertical.*

TABLE 2 : Pseudotachylite (Pt) analyses by XRF and microprobe in wt %; (No.)=No. of DFB analyses per thin section (ℓ=leucocratic Pt, d=Mafic Pt)

	USA 138c(ℓ)		USA 138c(d)	
	XRF	DFB(11)	XRF	DFB(11)
SiO_2	74.3	68.3	66.9	61.1
TiO_2	0.1	0.3	0.8	1.4
Al_2O_3	13.7	17.3	11.8	12.8
Fe_2O_3	2.5	1.1	8.5	9.6
MnO	0.03	0.1	0.1	0.2
MgO	0.3	0.2	3.3	4.2
CaO	0.8	1.0	2.1	2.8
Na_2O	2.9	5.4	0.1	3.0
K_2O	4.2	6.1	3.6	4.8
P_2O_5	0.1	-	0.2	-
LoI	0.9	-	2.5	-
TOTAL	99.83	99.8	99.9	99.9

The movement surface, with associated pseudotachylite band and injection veins containing flow textures and minor shear fractures (Fig.11), is similar to the pseudotachylite generation zones described by Sibson (1975) and Grocott (1981). These generation zones are shear fractures and have a more or less clear relationship between the generation (slip) surface and injection veins, with pseudotachylite being generated along the slip surface. At Broodkop pseudotachylite veins are rarely thicker than 1 to 20mm and individual veins can be traced for a few metres (occasionally for a few decametres), though the large network of veins linked to the main generation zone, can be followed for up to 180m along its trend. In some areas secondary shears and finally breccias with angular or rounded fragments occur (Figs.4 and 12).

The secondary shears also have associated pseudotachylite and have the same sense of shear as the main generation zone (Figs.12 and 14). The breccias occur on a mesoscopic scale as matrix within veins or as zones between pairs of veins formed either by a process of melt injection which separates blocks of gneiss or by a process of hydraulic bursting (Phillips, 1972). Spectacular but complex re-orientation of gneiss blocks and fragments which often show the effects of attrition and rounding commonly occur in the breccia zones (Fig.13 and Fig.4, locality (I)). A second pseudotachylite generation zone with a sinistral shear sense occurs

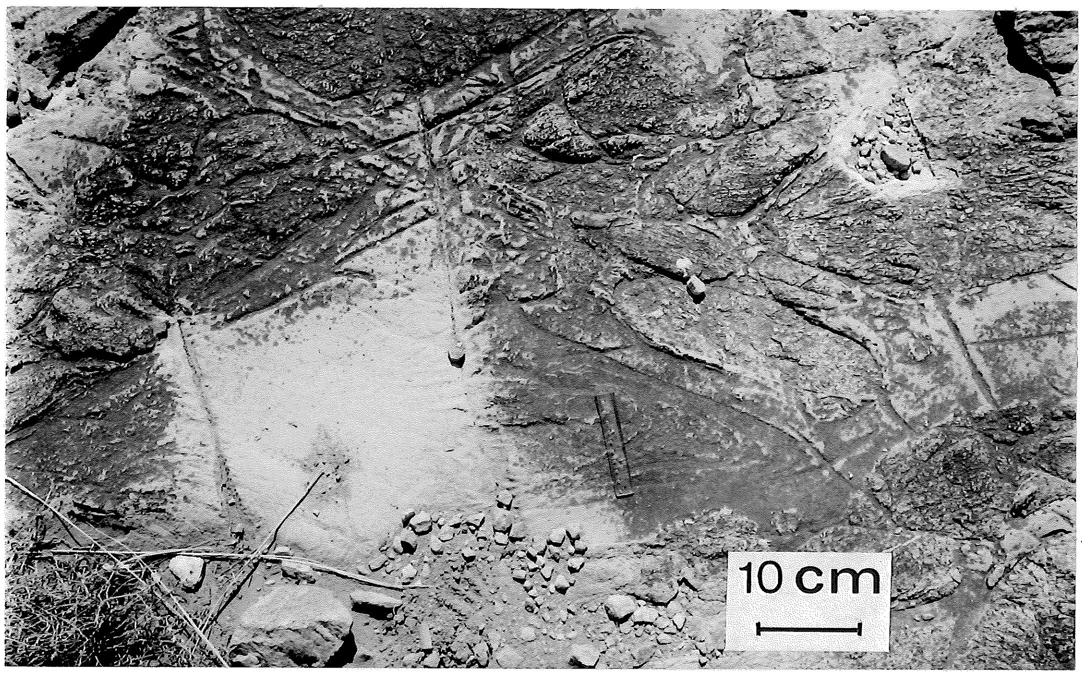


Figure 11: *Broodkop diatexite domain. Shear system of minor shear fractures and flow textures (folds) in Pt. Scale = 10cm.*

Figure 12: *Broodkop palaeosome domain. Dextral displacement of a quartz vein by Pt and the development of a breccia zone. Scale = 40cm.*

Figure 13: *Broodkop diatexite domain. Rotation and abrasion of 3m gneiss block by Pt which envelops this block (Fig. 4. locality (I)).*

Figure 14: *Broodkop diatexite domain. Dextral shear movement of Pt indicated by the rotation of mylonite fabric in gneiss. Note the development of post-Pt fractures.*

towards the southern end of Broodkop and is situated near the contact with the schlieren - nebulite migmatite domain (Fig.4). This zone shows many of the features recognised in the main Pt generation zone namely, the rotation of shear foliation (Sms), injection veins and breccia zones (Fig.4), but differs in the sense of shear - the main generation zone being dextral.

Measurement of the orientation of veins and generation zones throughout the Broodkop outcrop reveals the geometrical pattern illustrated in inset (ii) of Figure 4. Here five dominant clusters of poles, marked a to e, are defined and the planes for maximum clustering are drawn. The planes vary in strike from north to northeast with vertical to subvertical dips to the west, northwest and southeast. The majority of these planes are subparallel to the mylonite foliation. It is apparent that a close relationship exists between the well-developed foliation in the gneiss (high anisotropy) and the pseudotachylite and it is thus suggested that the high degree of rock anisotropy exerts a fundamental control on pseudotachylite generation and geometry.

The geometry of the main pseudotachylite (Pt) generation zone (Fig.4, locality (I)) is illustrated in inset (iv) of Fig. 4 and shows that the movement is mainly oblique, with the northerly block up and the southerly block down. A dextral sense of shear is apparent on outcrop. Pt veins initially intrude at a high angle from the generation zone into the surrounding gneiss, but gradually curve away becoming subparallel to the mylonite foliation (Fig.4) and commonly exhibit geometric features such as tapering, forking and branching (Fig.15).

3. *Joint/fracture geometry*

Joints/fractures are prominent on microscopic to mesoscopic scales. At least two ages of fractures were identified on outcrop, namely, those predating quartz vein and Pt formation (locality (III), Fig.4; Fig.16) and those postdating Pt formation and quartz vein development (Figs.14 and 16). The geometrical arrangement of poles to fracture planes shows a distribution around the periphery of the equal-area net and five cluster maxima (a-e) may be distinguished, which reflect the subvertical to vertical attitude of the fracture planes. The average planes to the clusters vary in strike from northwest to northeast, with sub-vertical dips in the same direction (Fig.4, inset iii). The planes may further be grouped into a diagonal set (a,c) and (d) reflecting northwesterly and northeasterly trends, respectively, and an orthogonal set (b,e) with north-northeasterly and east-northeasterly trends. All sets are oblique to the shear foliation (Sms), and are apparently not mechanically influenced by it.

(iii) Summary of deformational events

The following sequence of structural events were established from field relationships:

An early Archaean migmatite event is followed by pegmatitic intrusion and retrogressive metamorphism to amphibolite facies for the migmatites. The migmatites and pegmatites and the early shear fabric were deformed by a later brittle-shear event. Subsequently, quartz and quartz/K-feldspar veinlets intruded together with the first generation of Pt. Early fractures are developed, which are then transected by a second

Figure 15: *Broodkop diatexite domain. Forking and branching geometries of Pt injection veins, characteristic of hydraulic shear fractures.*

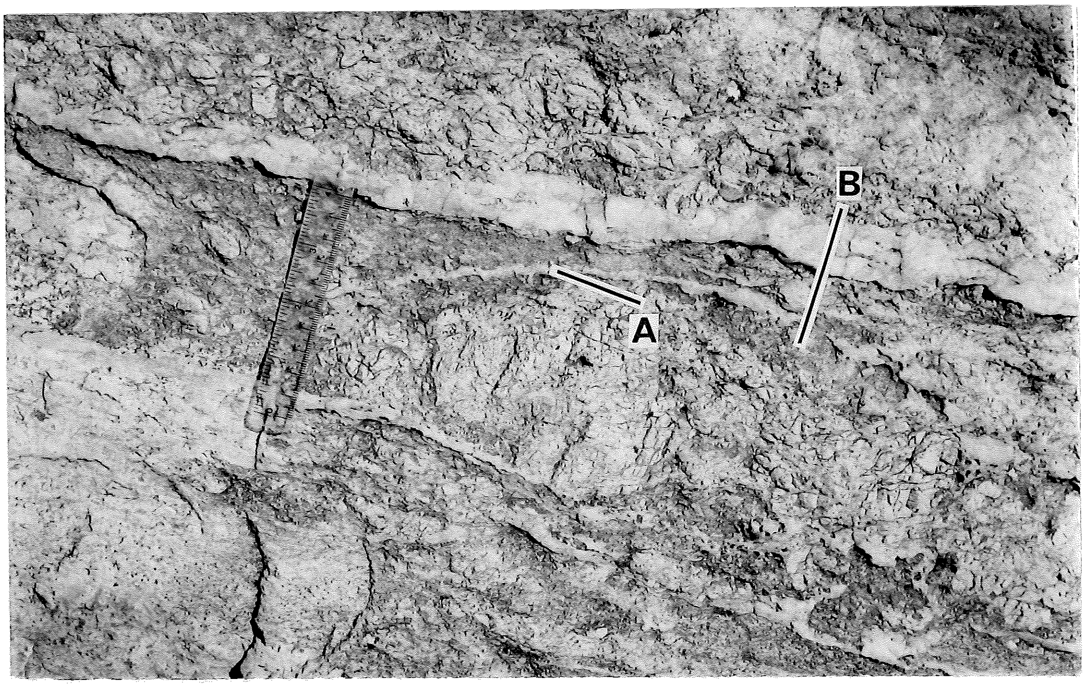


Figure 16: *Broodkop diatexite domain. Quartz vein transecting pegmatite and early fractures (A) and being cross-cut by ubiquitous later fractures (B), (Fig. 4 locality (111)). Scale = 10cm.*

generation of quartz veins. All of these are cross-cut by the gabbroic dyke which in turn is transected by Pt. The final structures developed are younger fractures.

(iv) Brittle deformation: Principal stress directions for (1) Broodkop shear zone and (2) Pseudotachylite zone

Equal area plots of the data for the shear zone and pseudotachylite (Pt) are shown respectively in insets (i) and (ii) of Fig. 17. The technique employed to calculate the stress directions for the structures is described in Ramsay and Huber (1987). The geometric data required to infer principal stress directions from a single fault plane are: the orientation of the fault plane, the slip vector (usually indicated by a mineral stretching lineation), the displacement sense across the fault plane and knowledge of the dihedral angle, for which an assumption has to be made. The assumed dihedral angles for the Broodkop shear zone and pseudotachylite generation zone are 20° and 62° respectively. The chosen angle for the Broodkop shear is based on values for conjugate shears in brittle rocks and the angle for the Pt zone is from values for shear fractures in a brittle regime (Hancock, 1985).

The interpreted directions of principal stress for the two structures are illustrated in Figure 17. The sense of stress for the Broodkop shear zone shows a steep east-west plunging direction of maximum compression (sigma 3) and a southeasterly direction of minimum compression (sigma 1) (maximum extension) (inset (i)). The sense of stress for the Pt zone shows a west-southwesterly direction of maximum compression and a southeasterly minimum compression. The trends of the stress regimes for the two structures are similar, but differ for instance in plunge for the direction of maximum compression which is steeper (subvertical) for the Broodkop shear in comparison to the Pt zone, which is shallow plunging.

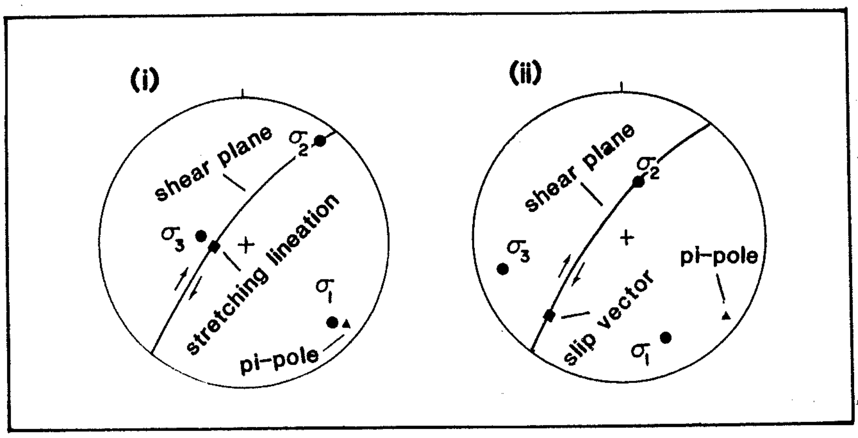
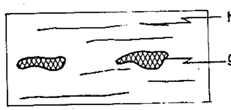
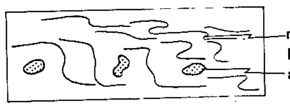


Figure 17: Equal area data plot. The calculation of principal stress directions for the Broodkop shear zone and the pseudotachylite generation zone are shown in insets (i) and (ii) respectively.

4. SUMMARY AND CONCLUSIONS

Any researcher, when addressing the problematics of the origin and evolution of the Vredefort structure, has to bear in mind that this terrain has experienced multiple geological events during long periods of

Table 3: Evolution diagram for the Vredefort structure and environs. Chronological information based on data by Walraven et al. (1990) and Armstrong et al. (1990). AE = Ga

STAGE	METAMORPHIC GRADE	FABRICS AND SHEAR ZONES	TECTONIC MECHANISM	OTHER EVENTS
(A) >3.8 AE CONSOLIDATION OF CRUST				GREENSTONE FORMATION IN KAAPVAAL CRATON
(B) ca .3.3-3.8 AE EARLY GRANULITE METAMORPHISM  	GRANULITE FACIES	SUBHORIZONTAL FABRIC	DUCTILE LOW ANGLE SHEAR SYSTEM (COMPRESSION)	TABLE 3 Working model of geological events for the Vredefort structure and environs
(C) GRANULITE METAMORPHISM AND ANATEXIS MIGMATITIZATION OF OGG AND ILG  		? ARCHAEAN SUBVERTICAL SHEAR ZONES		
(D) 3.10 AE COMPLETION OF ANATEXIS, (CLOSE ISOTOPIC SYSTEM IN OGG) ca. 3.07 AE DEPOSITION OF DOMINION GROUP,& WWR SUPERGROUP.	RETROGRESSIVE AMPHIBOLITE EVENT(OGG)		EXTENSION (DOM.REEF, INITIAL WWR COMPRESSION)	
(E) 2.8 AE DEPLETION OF ILG FOR LIL'S (CLOSE ILG ISOTOPIC SYSTEM) 2.7 AE	? GREENSCHIST FACIES(WWR)		POST 2.7AE TECTONIC ACTIVITY (RE-PEATED SHEARING,FRACTURING EVENTS) EXTENSION ? COMPRESSION ? DUCTILE SHEARING AND THRUSTING AT DEEP LEVELS UPLIFT	EXTRUSION OF VENTERSDORP LAVAS HYDROTHERMAL AND TECTONIC ACTIVITY(SHEARING) IN WWR
(F)2.4-2.2 AE Thermal Event (RESETTING OF OGG,IGG MINERALS) ca. 2.4 AE MAFIC INTRUSIVES (EPIDIORITES?) 2.2-2.3 AE FIRST PSEUDOTACHYLITE DEVELOPMENT SUBVERTICAL BROODKOP SHEAR ZONE 2.1-1.96 AE INTRUSIONS OF ALKALI GRANITE COMPLEXES AND ASSOCIATED MAFIC ROCKS ca. 2.0 DOME DEVELOPMENT: OVERTURNING, WITH CLEAVAGE DEVELOPMENT MULTIPLE JOINTING, PSEUDOTACHYLITE, RIM FAULT DEVELOPMENT	CONTACT METAMORPHIC EVENT	LATE SUBVERTICAL SHEAR ZONES	RAPID UPLIFT	2.2-2.5 COMPRESSION EVENT IN WWR, THRUSTING TO N! EXTRUSION OF HEKPOORT ANDESITES (!) ca. 2.25 DEPOSITION OF TRANSVAAL SUPERGROUP EARLY BUSHVELD INTRUSIONS
1.93 AE BRONZITE GRANOPHYRE (BG) INTRUSION		SUBVERTICAL FABRIC	TECTONIC READJUSTMENT	
1.4 to 1.1 AE? POST – BG PSEUDOTACHYLITE DEVELOPMENT. FURTHER MULTIPLE JOINTING				ca. 1.2 AE ALKALI MAGMATIC ACTIVITY (PILANESBERG AND PIENAARSRIVER COMPLEXES)

geological time. This time span extends from the Archaean to post Bushveld (ca. 2,0 Ga) times (Walraven et al., 1990). It is therefore necessary to separate those events that have affected the basement only, from those that have affected both the basement and the overlying Dominion, Witwatersrand, and Transvaal strata. This investigation contributes information on some of the events that have occurred in the basement of the hitherto lesser known southern part of the Vredefort structure.

The results of this study can, however, be subdivided on structural and geochronological grounds into events that have occurred prior to and after the deposition of the Dominion Group and will briefly be dealt with in that order. An attempt is made in Table 3 to synthesize all of these results together with available information on deformational and magmatic events and chronology for the Vredefort structure and environs. It is obvious from the large number of question marks that the scheme of Table 3 should be treated as a working model.

A. Pre-Dominion Group Events

Migmatites. During the investigation of all the exposures in the southern part of the Vredefort Dome, it became apparent that the basement rocks were migmatites. Detailed mapping of lithologies at Broodkop in the southeastern portion of the dome revealed a complex mixture of migmatitic rock types that included portions of mafic gneiss palaeosome, granitic and granodioritic leucosomes and nebulitic structures in the form of rafts and schlieren. Reconnaissance work to the north of the southern study region confirmed the migmatitic nature of the basement in other areas of the dome and led to the conclusion that the exposed basement in the Vredefort structure, which is generalized as Outer Granite Gneiss and Inlandsee Leucogranofels represents part of a vast migmatite complex. The migmatite event is associated with stage (C) in Table 3 , for which a minimum age of 3,1 Ga (Armstrong et al., 1990) is suggested.

Regional foliation and folds. In areas of lower strain, the early structures developed in the migmatitic basement gneiss were recognised as being predominantly subhorizontal. These structures comprise a regionally pervasive sub-horizontal foliation with co-planar migmatite lithological units and axial planes of mesoscopic recumbent isoclinal folds. The folds deform the migmatite foliation. Outside of the lower strain areas and northwards of the southern study region, the subhorizontal attitude of the foliation is not at all apparent, as the foliation is deformed by subvertical shear zones of Pre-Dominion Group age. The general co-planarity of the early structures is interpreted as representing the result of shear movement during the migmatite event (Table 3, stage (C)).

Shear zones. Mesoscopic, subvertical conjugate shear zones are commonly observed throughout the basement. The shear zones are characterised by both a dextral and sinistral sense of shear and horizontal displacement. They deform the regional migmatite foliation and associated co-planar elements, giving rise to persistant northeasterly and northwesterly trends. The angular unconformity between the basement and the overlying Archaean strata is defined by the truncation of the shear zones by the ca. 3,07 Ga Dominion Group (Table 3, stage (C)). The inferred minimum age for the shear zones is thus pre-Dominion. The importance of the shear zones lies in their being related to tectonic events which predate the Dominion Group and later Archaean strata (Table 3, stages (C & D)). Consequently, the subvertical fabrics and lithologies in the basement, e.g. as seen in the Steynskraal metamorphites situated in the central core of the structure, cannot be employed as evidence in either the impact or internal explosion hypotheses for the genesis of the ca. 2,0 Ga Vredefort structure.

B. Post-Dominion Group Events

The Broodkop shear event. The Broodkop shear zone exemplifies a later phase of subvertical shearing in the basement and is the only macroscopic scale shear zone recognised in the study region. The shear zone is characterised by mainly brittle deformation and predominantly vertical movement and contrasts with the pre-Dominion age, mesoscopic, ductile conjugate shears characterised by horizontal displacement. The age of this shearing event is tentatively associated with thermal events identified on Broodkop, in other parts of the Vredefort structure , and the Witwatersrand Basin at ca. 2,2 - 2,3 Ga ago (Reimold et al., 1988). It is also linked in time to a post-Ventersdorp (ca. 2,7 Ga) compressional event involving northwards overthrusting in the Witwatersrand rocks at about this time (Table 3, stage (F) and Roering et al., 1990).

Brittle deformation: pseudotachylite (Pt). The evidence obtained from the Broodkop Complex suggests that Pt is either coincidental with the above-mentioned late shear event or younger (as exemplified by the Pt cross-cutting the 1,62 Ga gabbroic dyke on Broodkop. Ages on the Pt from localities in the northern part of the dome (Reimold et al., 1990) are in agreement with this statement. The ages obtained by the 40Ar - 39Ar step heating technique, range from 2,2 Ga to 1,1 Ga and are interpreted by the authors as representing more than one generation of Pt. This is supported by the present study, where at least two generations of Pt have unequivocally been recognised at Broodkop (and by other evidence summarised in Reimold et al., 1990).

In the entire study region of the southern dome, Pt generally occurs as lenticular single veins and networks which post-date all of the previously mentioned events. The geometry of Pt is controlled by the degree of rock anisotropy and commonly follows the regional northeasterly and northwesterly structural trends. This is a general feature throughout the basement in the Vredefort structure (e.g. Reimold et al., 1985). In the Witwatersrand Basin, it has been demonstrated that Pt development is structurally controlled (e.g. Killick et al., 1988; Fletcher and Reimold, 1987). Field relationships of Pt at Broodkop suggest that the dyke-like occurrence there was controlled by the shear zone foliation with brittle failure occurring on shear fractures, along which most melt was generated. A similar mode of origin is suggested for the other Pt occurrences in the Vredefort basement.

When the various ages of generation of Pt in the Vredefort Dome and Witwatersrand Basin are compared ((Fletcher and Reimold, 1990; Roering et al., 1990; Table 3, stage (F)), the following observations may be made :

(1) Pt was generated prior to, syn and post the development of the dome;
(2) Pt was also generated in the Witwatersrand Basin at the same time as on the Vredefort dome; and
(3) Pt generation spans periods of tectonic activity on the Kaapvaal Craton consisting of both contractional and extensional events.

The significance of these observations is that Pt is, firstly, not an isolated occurrence which is restricted to the Vredefort structure only, secondly, that Pt is associated with tectonic processes, and thirdly, that it was not developed in a single event but over a long geological time span. It is therefore suggested that tectonic processes may be a viable alternative to the endo - and exogenic shock hypotheses that have been suggested to explain this phenomenon and the existence of the dome.

Intergranular planar microdeformation in quartz, previously associated with a catastrophic shock event postulated for the formation of the Vredefort structure, were only rarely seen in samples from the southern study areas (some micropetrographic characteristics of the Broodkop rocks are shown in Figs. 18 - 22). The occurrence of these features is restricted to samples that were in direct contact with Pt and therefore suggests a genetic relationship to Pt formation. This was also concluded by Reimold (1987a,b; 1990) from microdeformation studies along radial traverses through the northern and eastern sectors of the basement.

Brittle deformation: fractures. Fractures occur ubiquitously throughout the southern part of the structure, as well as all other areas of basement. They form the final structures developed in the sequential history of events that occurred after the rise and subsequent overturning and faulting of the Vredefort structure (Table 3, stage (F)). The general geometry of fractures in the basement consists of a dominant diagonal fracture set with northeasterly and northwesterly trends and an orthogonal set with easterly and northerly trends. The fracture pattern is interpreted to be related to a later period of extension and readjustment in the Vredefort Dome (Table 3, stage (F)).

C. Other Aspects Related to the Study

The following aspects are pertinent to the discussion:

(1) general interpretations that can be made from the study of planar structures, namely the geometry of structural trends and related stress directions;

(2) certain structural observations across the basement collar contact (Fig.1, study area 2; Fig.23);

(3) the deformation of pre-Dominion shear zones and the structural control at the southern end of the structure; and

(4) final comments.

General geometry of planar elements and stress directions.

There is considerable agreement in strike orientation of planar structural elements of both pre- and post-Dominion age (compare insets (i, ii, iv, v, vi) of Fig. 2 with insets (i, ii, iii) of Fig.4), with northeasterly and northwesterly trends being more common. The co-planarity and geometrical control of structures of different ages is tentatively explained in terms of basement anisotropy.

The preliminary interpretation of principal stress directions from available data suggests that the general sense of the directions for the pre-Dominion (3,07 Ga) shear event, the ca. 2,2 Ga Broodkop shear

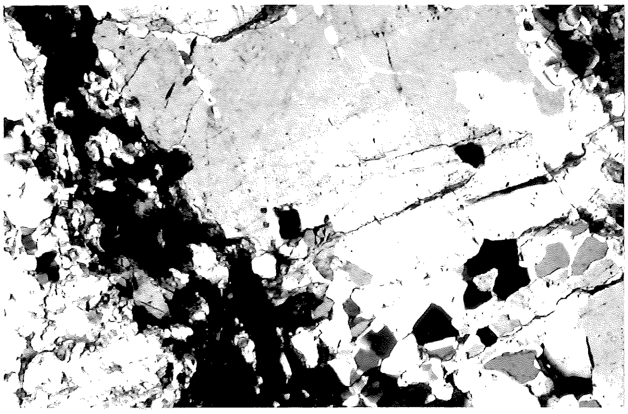
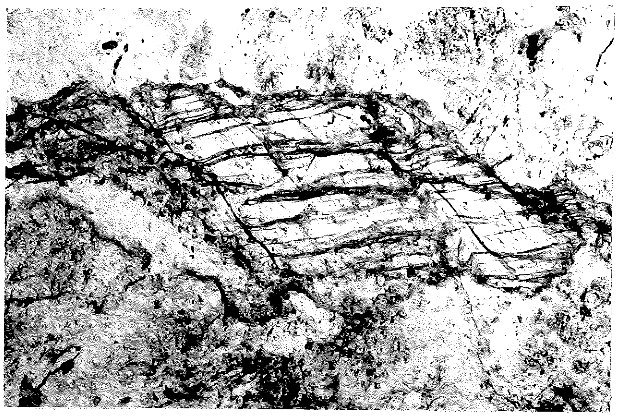
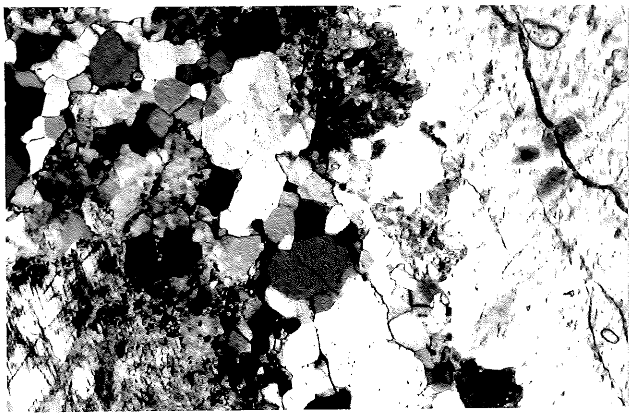
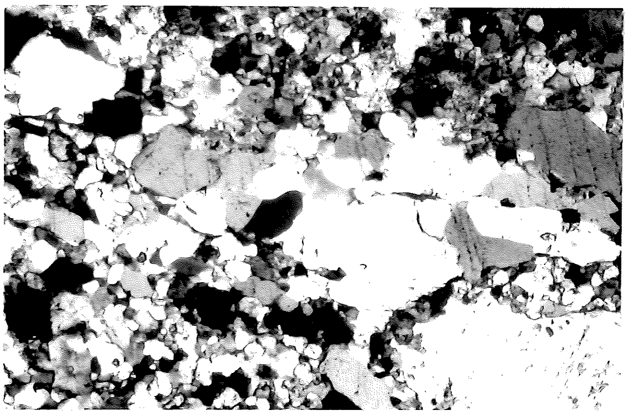
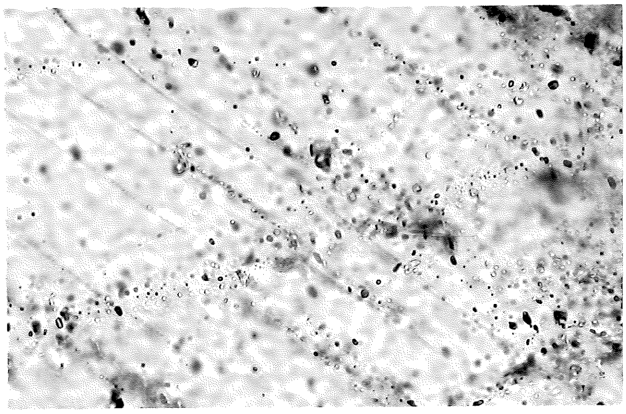






Figure 18: *Pegmatitic leucosome: Sm defined by recrystallized quartz ribbons; the large grain is quartz with planar fractures of varying orientation. Field of view 3,4mm (WU-Br10).*

Figure 19: *Sheared pegmatite: kinked muscovite, with post shear planar and curved microfractures, surrounded by fluid inclusion-rich K-feldspar. Field of view 2,7mm (193).*

Figure 20: *Sheared migmatite: Mylonite foliation defined by quartz ribbons with large microcline phenocrysts; limited fracture formation. Field of view 3,4mm (221).*

Figure 21: *Sheared migmatite: Planar fractures in quartz ribbons perpendicular to long axes of the ribbons. Field of view 2mm (193).*

Figure 22: *Fractures and trails of fluid inclusions in a quartz grain. Field of view 3,4mm (16)..*

event and the post 1,62 Ga pseudotachylite generation at Broodkop are fairly constant with an east-west maximum compression and a southeasterly direction of minimum compression (compare Fig.2, inset (iii) with Fig.4 insets (i & ii)). In contrast to the easterly trending direction of maximum compressive stress for the above events, the direction of maximum compressive stress for the youngest regionally developed structural event, namely fractures, trends northerly (interpreted from inset (vi) of Fig.2). It is interesting to note that measurements on present-day stresses for southern Africa (Gay, 1977) indicate a similar orientation for the principal compressive stress direction.

An interpretation of supposed stress directions during the development of the Vredefort Dome of ca. 2,0 Ga, is afforded by the asymmetry of the structure, namely with the collar overturning in the north and subhorizontal stratification in the south. It is suggested that southeasterly compression could explain this asymmetry. Further credence to the compressive nature of the stress and its northwards orientation is independently given by geophysical evidence which suggests the presence of lower crust along the southeasterly trending Vredefort axis (Corner et al., 1990).

Notwithstanding the limited data base on the basement and data gaps during the late Archaean and early Proterozoic, the different directions of compressive stress determined allow for an interpretation of changing stress fields with geological time. However, the subsequent effect of changing stress fields is best illustrated by the orogenic history of the late Archaean to early Proterozoic cover rocks which have been subjected to various periods of compression and extension and during which the Vredefort Dome evolved (Table 3).

Some structural aspects of study area 2 in the NW section of the dome (Fig.1; Fig.23).

Preliminary structural results from an ongoing study in the northwestern part of the structure particularly at the contact between collar and basement, have been summarised in Figure 23. Together with results from previous studies (e.g. Bisschoff, 1969, 1988) they suggest the following deformation sequence:

(1) intrusion of the epidiorites at $>$ 2,1 Ga;

(2) intrusion of the alkali granites and thermal metamorphism - ca. 1,96 to 2,17 Ga (Nicolaysen et al., 1963; Hargraves, 1987 in Walraven et al., 1990), prior to overturning of collar rocks (Hargraves, 1987);

(3) main domal uplift and overturning; occurrence of two ages of foliation in the late Archaean cover rocks and in the alkali granite (this study); development of a dextral shear zone at the contact between the basement and the Dominion Group (this work); some pseudotachylite and mylonite (especially at bedding plane contacts) possibly generated during this event;

(4) rim faulting/multipli-striated joint surface (shatter cone) forming event;

(5) formation of granophyre dykes ca. 1,93 - 2,0 Ga, and pseudotachylite development; and

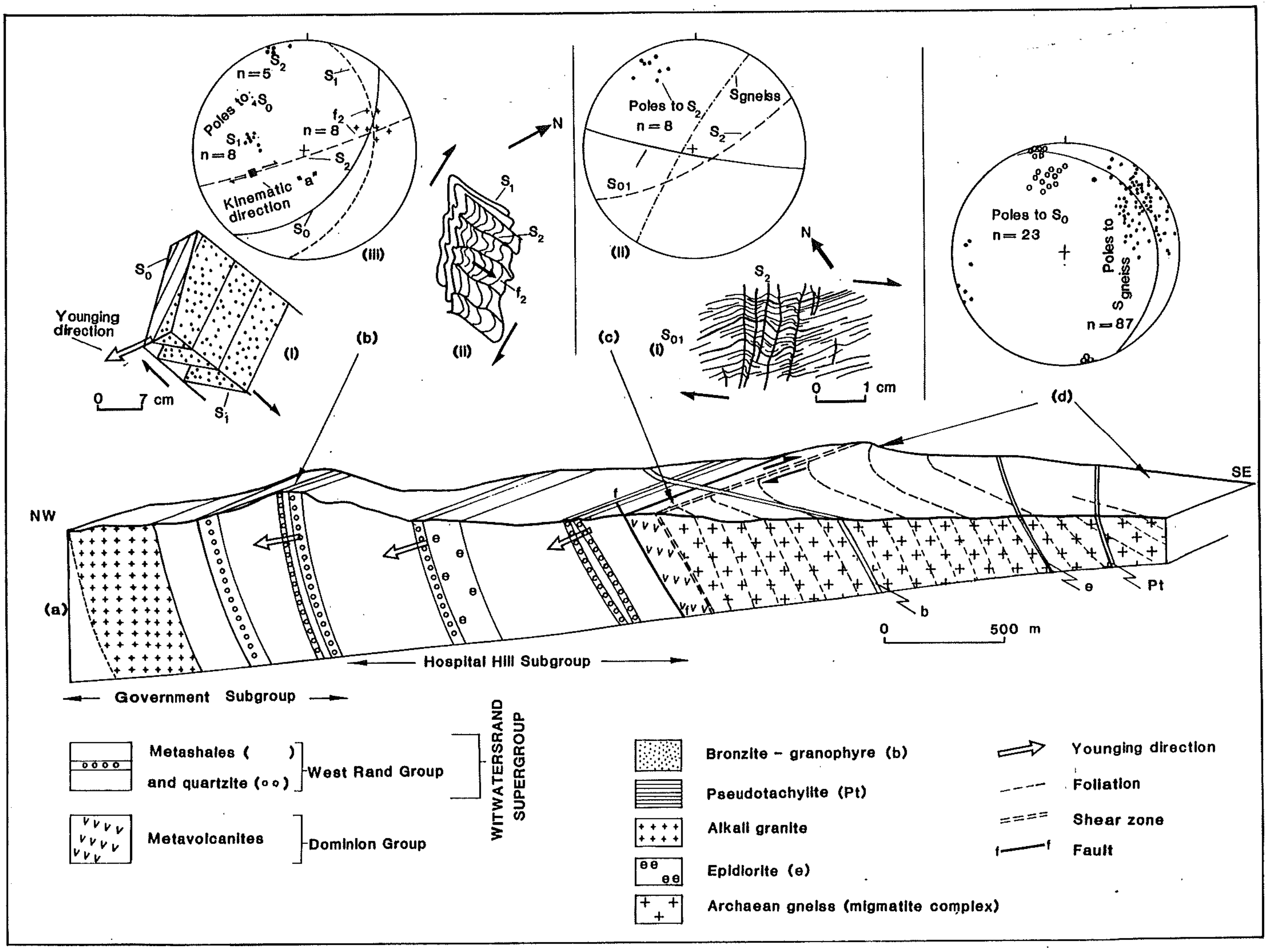


Figure 23: *Field and geometric data from study area 2. (a) controlled section through part of the basement and basal Archaean cover rocks; (b) (1) First cleavage/bedding relationships; (11) second cleavage development - refoliation; (111) geometric relationships of cleavage and bedding; (c) Basement/Archaean cover contact relationships - development of a shear zone; (1) cleavage relationships and (11) geometric relationships; (d) Geometric relationship of pre-Dominion Group late shear fabrics in basement and bedding in the Archaean cover sequence.*

(6) a fracture event.

The geometry of the two foliations (Fig.23 b,c) suggests that they are related to the evolution of the dome, although this still remains to be tested in other localities around the structure. The first foliation (Fig.23b i,ii, iii) is interpreted to be associated with vertical flexural slip movement and the second foliation (Fig.23c i, ii) with subhorizontal stretching around the structure. The shear zone at the basement/cover contact (gneiss/Dominion Group rocks) (Fig.23 a, d) may also be associated with the latter movement or alternatively, with northwards thrusting (Colliston, 1990).

The occurrence of multipli-striated joint surfaces (shatter-cones; Nicolaysen and Reimold, 1985) transecting the alkali granite, the foliation and the late rim faults suggests that this deformation event post-dates overturning and faulting (Ramsay, 1961; Simpson, 1981; Reimold et al., 1988; Colliston and Reimold, 1989a). The implication for the genesis of the Vredefort Dome is that this event post-dates the development of the structure and may thus not be necessarily related to a single catastropic origin as previously proposed (e.g. Dietz, 1961; Manton, 1965; Albat, 1988), but instead may be associated with purely tectonic mechanisms as suggested by others (e.g Ramsay, 1961; Brink and Knight, 1961; Colliston, 1990).

Deformation of pre-Dominion shear zones and structural control of the southern part of the Vredefort structure

These phenomena, cannot be fully explained on the basis of this first detailed investigation and therefore require further study. However, some information from this study and from the literature allows for tentative interpretation.

The shear zone identified at the upturned basement/cover contact (Fig.1, study area 2;) and interpreted to be associated with the upturning of the collar, rotates the subvertical shear zones in the migmatitic basement through at least 70° into the horizontal (Fig.23 a, d). The subhorizontal attitude of the strata to the south of the dome may be explained by considering a model recently proposed for the evolution of the Vredefort Dome by Colliston (1990); cf. also Colliston and Reimold, 1989a, b).

Final comments and recommendations

This contribution emphasises the necessity of continuing detailed structural investigations in other parts of the Vredefort structure. The aim of such studies would be to establish a broad data base which would:

(1) assist in the multidisciplinary task of unravelling the origin(s) of this geologically unique structure,

(2) allow for the structural placing of the structure in the context of its setting within the economically important Witwatersrand basin,

(3) allow for the verification of interpretations made and the testing of hypotheses such as the preliminary inter-interpretations presented here and the various models (impact, internal explosion or orogenic) presented to date.

ACKNOWLEDGEMENTS

The authors would like to thank colleagues at the University of the Orange Free State, the University of the Witwatersrand and those associated with the mining industry for valuable discussions and advice. H. Albat, C. Simpson, L. Nicolaysen, C. Roering, D. Strydom, M. Watkeys, L. Wolhuter and Prof. Hatton S. Yoder, Jr. provided most appreciated, detailed critical comments on earlier versions of this manuscript. WUR acknowledges research support from the following institutions, namely the BPI, CSIR-FRD and Schonland Research Centre.

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