

**AN OVERVIEW OF THE EARLY - PROTEROZOIC, AURIFEROUS
BLACK REEF PLACER IN THE TRANSVAAL BASIN**

By

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ABSTRACT

Recent, successful, local and international, opencast gold mining operations, has led to renewed interest in the Black Reef as an exploration target in parts of the Transvaal Province. This has resulted in renewed research activity on the Black Reef over the last few years. No recent attempt been made, however, to collate available information on the Black Reef, past and present. The purpose of this dissertation, therefore, is to collate relevant data with special reference to the historical and present areas of Black Reef palaeoplacer mining in the Transval Basin.

The Black Reef is a sporadically developed, sometimes auriferous basal conglomerate, of the predominantly siliclastic Black Reef Quartzite Formation, that occurs at the base of the early Proterozoic, 2460 - 2050 M.a. Transvaal Supergroup, over much of its distribution in the Transvaal Province of the Republic of South Africa. It overlies Archaean basement rocks, the Witwatersrand and Ventersdorp Supergroups and the 'proto-basinal' Wolkberg and Buffelsfontein Groups of the Transvaal Supergroup, which may alternately, be correlates of the Ventersdorp Supergroup. The Black Reef Quartzite Formation is transitionally and conformably overlain by the carbonates of the Transvaal Supergroup.

The Black Reef in the Transvaal basin, has an extensive, but intermittent history, of surface and underground mining activity, covering the late 1800's to the present day. At present, successful, opencast operations (Lindum Reefs) are ongoing on the West Rand near Randfontein and underground mining is taking place at Consolidated Modderfontein Mines on the East Rand. Past activities have taken place in the Klerksdorp - Venterdorp area of the southwestern Transvaal, in the Dedepoortrant area of the west - central Transvaal and in the Kaapsehoop area of the eastern Transvaal.

It is found that economic Black Reef, is predominantly associated with proximal, footwall, auriferous Central Rand Group sediments of the Witwatersrand Supergroup and occurs in localised palaeochannels, which may be many kilometres in length, up to 600 m wide and up to 13 m deep. Morphology of these channels, is controlled by the footwall palaeotopography at the time of deposition of the Black Reef. The palaeotopography was, in turn, shaped by the strike, dip and differential erosion features of the footwall successions. Channels tend to overlie the topographically negative, softer formations, such as the Booyens Shale Formation and mostly trend parallel to the strike of these formations. In the southwestern Transvaal, the Black Reef developed as braided streams in post-Ventersdorp graben structures, whilst on the East Rand, northwest trending faulting controlled the general direction of the Black Reef channels.

Deposition of the Black Reef took place on an erosional surface, in channels incised into pre - Black Reef basement. The overlying, siliclastic, sheetlike facies was deposited in a prograding or braided plain environment. This was terminated by transgressive conditions and the onset of minor shale deposition, followed by deposition of the carbonates of the Chunniespoort Group of the lower Transvaal Supergroup.

It is concluded that the economic potential of the Black Reef is confined to areas overlying or bordering the Witwatersrand Basin. Some soil covered areas, overlying the Rand Anticline, may not have been properly assessed in the past. Underground mining of unoxidised Black Reef is not a viable economic prospect at present. The best potential for exploitation of the Black Reef, is as small-scale, opencast operations, similar to the Lindum Reefs operation.

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CHAPTER 1

1 INTRODUCTION

The recent worldwide trend towards small and shallow, but highly profitable, opencast, gold mining operations, as well as the local successes of similar operations such as Lindum Reefs, has led to renewed exploration interest in the Black Reef over parts of the Transvaal (fig. 1.1) in recent years. This has resulted in renewed research activity, by Mining Houses and the universities, directly or indirectly related to this reef. As with other facets of geology, this does not necessarily always entail work that is directly related to mining and exploration efforts and research often tends to follow its own path.

Much information has been published over the last 100 years concerning the Black Reef. However, there has been no recent concerted effort to collate information on the historical mining activities, recent mining activities, relevant past and present research information available on the Black Reef except for an unpublished in-house report by Body (1988). As a result, the purpose of this dissertation is to collate relevant data with special reference to the historical and present areas of Black Reef palaeoplacer mining.

Because of time constraints, this dissertation does not discuss hydrothermal gold in the Black Reef, but concerns itself solely with palaeoplacer Black Reef in the Transvaal Basin. Research over the last decade, has however, indicated the presence of probable Black Reef - age equivalent palaeoplacers in South America and Australia. These occur in the Moeda Formation of the Minas Gerais Supergroup in Brazil (Renger and Minter, 1986; Minter et al, 1990) and in the Jeerinah Formation of the Hammersley Group (Hickman and Harrison, 1986; Cheney, 1996).

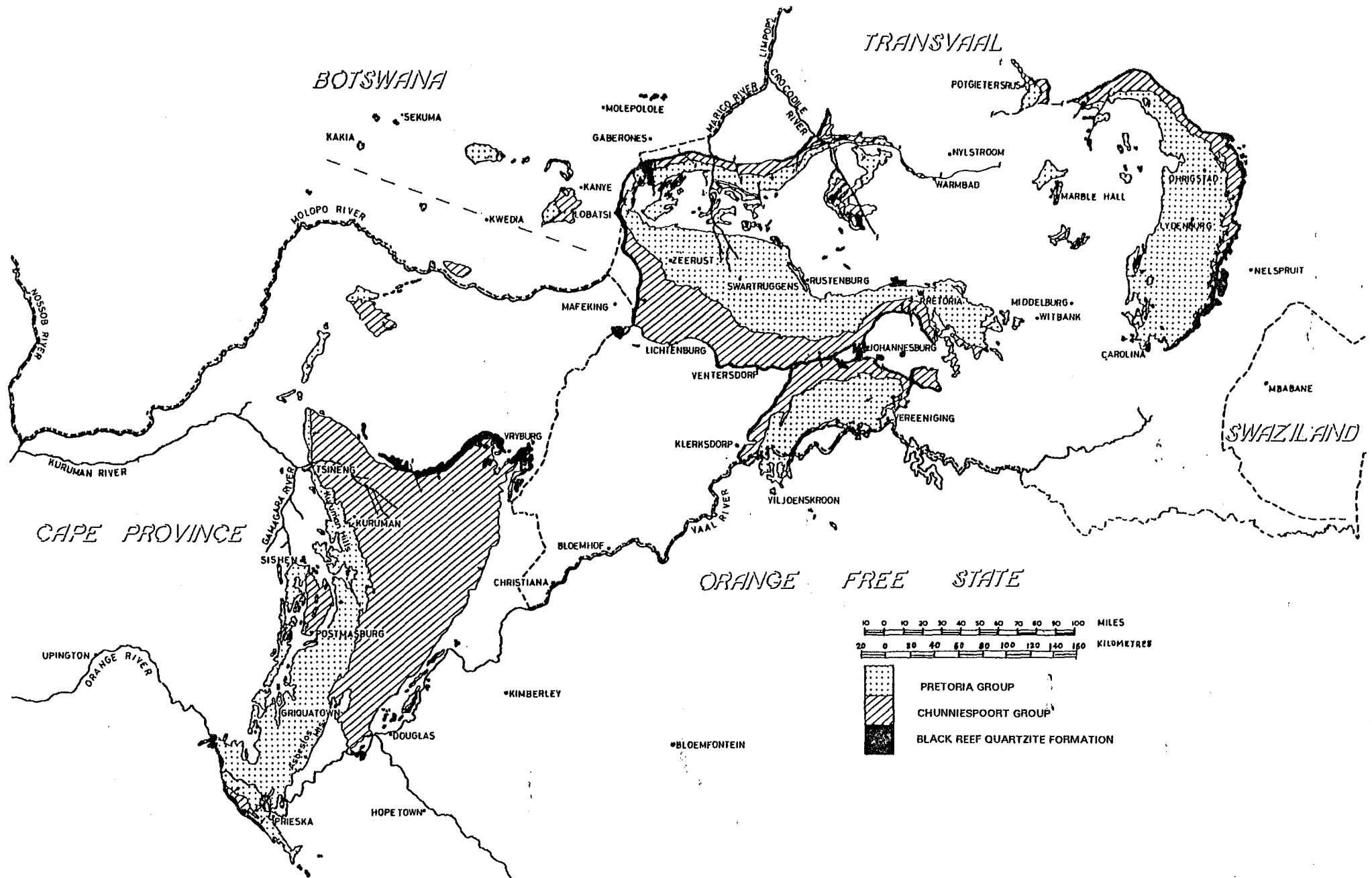


Fig. 1.1. Distribution of the Transvaal Supergroup and Black Reef Quartzite Formation (Truswell, 1976).

Note: A copy of Plate I from Papenfus's 1964 map of the Black Reef in the Witwatersrand basin is included in the pocket at the back of this dissertation. A general stratigraphic column of the Transvaal Supergroup is shown in figure 1.2.

1.1 Definition of the Black Reef

The Black Reef is a sporadically developed, sometimes auriferous conglomerate, that occurs at the base of the BRQF (fig. 1.2). This formation in turn forms the basal unit of the Proterozoic, 2460 - 2050 Ma (SACS, 1980) Transvaal Supergroup over much of its distribution (fig. 1.1 and Plate 1). The basal conglomerate contains the youngest, significantly gold bearing placer deposit in South Africa (Els et al, 1995). It has similar lithological characteristics to the Witwatersrand placers and may indicate "a brief return to depositional conditions" similar to the latter (Els et al, 1995).

The BRQF is conformably and transitionally overlain by the dolomitic Malmani Subgroup of the Chuniespoort Group of the lower Transvaal Supergroup (fig. 1.3). It comprises predominantly quartzite with lenses of grit and conglomerate. Shale horizons are always present, occurring mostly towards the top of the succession (SACS, 1980). The formation lies conformably on the Wolkberg Group where it is present and unconformably where it is not (SACS, 1980). This is disputed by Clendenin et al, 1989) who identified an unconformity between the BRQF and the underlying Wolkberg Group in the eastern Transvaal which is considered a correlate of the older Ventersdorp Supergroup.

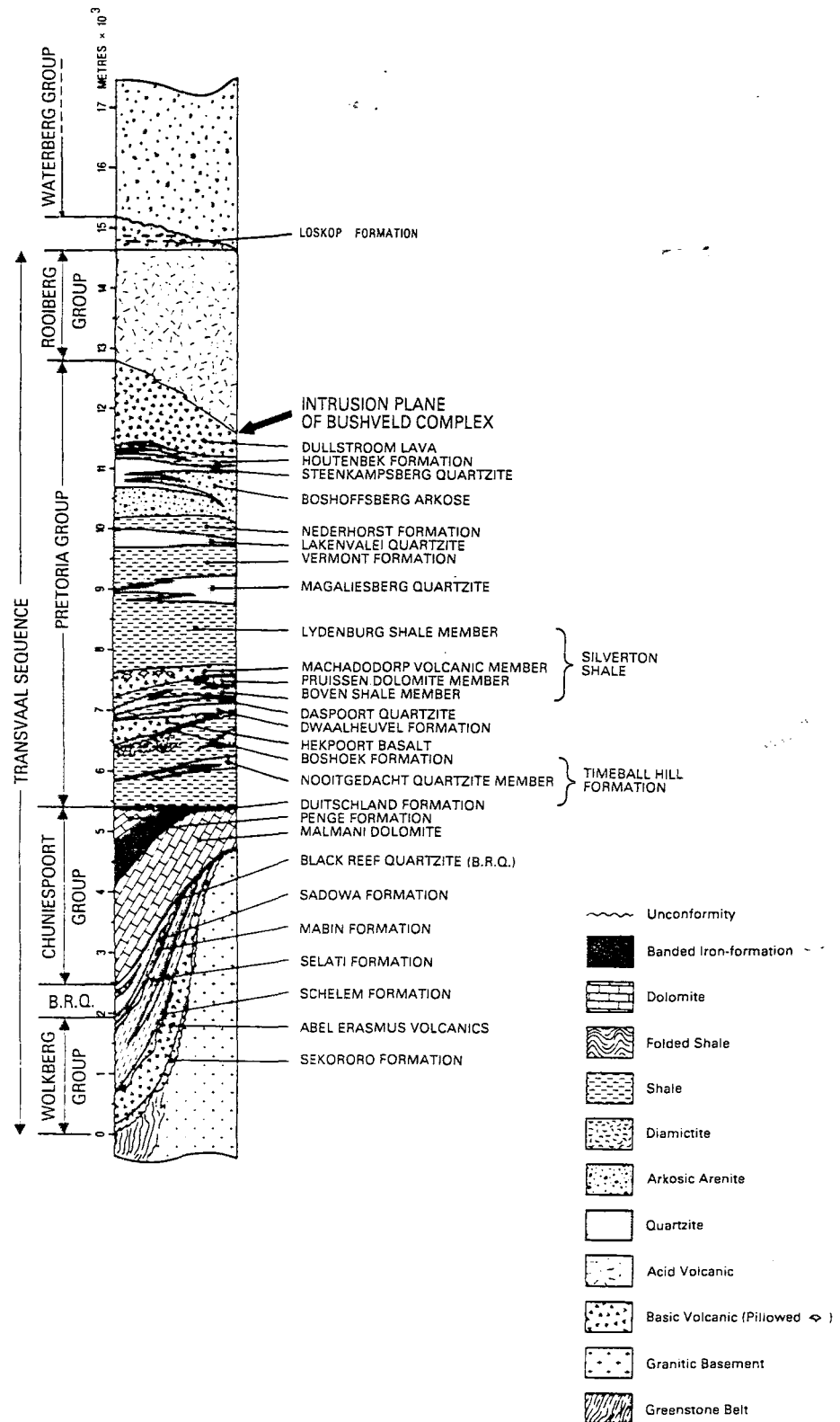


Fig. 1.2. General stratigraphy of the Transvaal Supergroup in the Transvaal (Bushveld) basin (SACS, 1980).

		WESTERN TRANSSVAAL	CROCODILE RIVER	MARBLE HALL	EASTERN TRANSSVAAL
		FORMATION	FORMATION	FORMATION	FORMATION
ROOIBERG GROUP	Schrikkloof				Selons River
	Kwaggasnek				Damwal
PRETORIA GROUP					Dullstroom Basalt
					Houtenbak
					Steenkampsberg Quartzite
					Nederhorst
	Rayton	Smelterskop Quartzite	Maekkaan Quartzite	Lakenvalei Quartzite	
		Leeuwoort			Vermont Hornfels
	Mogaliesberg Quartzite				
	Silverton Shale				
	Daspoort Quartzite				
	Strubenkop Shale				
CHUNIESPOORT GROUP					Dwaalheuwel Quartzite
					Boshoek
					Rooihoogte
					Duitschland
					Penga
					Frisco
					Eccles
	Lyttelton				Lyttelton
MOLLMANI SUBGROUP					Monte-Christo
	Oaktree				Oaktree
	Black Reef Quartzite				
BUFFELS-FONTEIN GROUP	Tygerkloof Quartzite				Sadowa Shale
	Witfonteinrante				Mabin Quartzite
	Waterval				Selati Shale
	Hampton				Schaalem
					Abel Erasmus Basalt
					Saxororo
ARCHAEAN BASEMENT / WITWATERSRAND SUPERGROUP / VENTERSDORP SUPERGROUP					

Fig. 1.3. Regional correlations in the Transvaal Supergroup (modified after SACS, 1980).

For most recent work on the BRQF, as with this dissertation, the Formation is divided into two informal units. These are the "Black Reef" or "Black Reef Conglomerate" and the "Black Reef Quartzite". The term Black Reef is used for the gold-bearing conglomerate located at the base of the BRQF and the Black Reef Quartzite is used for the lowermost quartzite unit which overlies or "caps" (Pouroulis, 1988) the Black Reef where present.

1.2 Historical Nomenclature

The name Black Reef is a historical mining term for a dark coloured, gold-bearing quartzite and conglomerate occurring in the central Transvaal (SACS, 1980) and was a term used by Penning in 1891 (see Haughton, 1938), to describe the unit conformably underlying the Dolomite Series and unconformably overlying the earliest Proterozoic and Archaean formations of the Transvaal (Button, 1973a). It has been used in the literature by Stonestreet in 1897 (SACS, 1980).

A variety of names such as Kromdraai Quartzite, Berg or Kantoor Sandstone have been applied to parts of the Black Reef by early authors such as Molengraaff (1898) and Dorffel (1904) (SACS, 1980). In the eastern Transvaal, terms such as Berg Sandstone (Nicol Brown, 1896), lower Lydenburg series (Wilson - Moore, 1896) and Black Reef Series by other early workers were used to describe the BRQF (Button, 1973c). Haughton (1938) first officially used the name "Black Reef Series".

Defining the base of the BRQF has raised difficulties. In the eastern Transvaal, the upper parts of the Wolkberg were often included as part of the lower Black Reef Series, and vice versa (Button, 1973c). The position of the upper contact of the BRQF is conventionally taken as the top of the upper quartzite bed (Body, 1988).

1.3 Black Reef Mining Areas

The Black Reef in the Transvaal basin has a long history of intermittent mining activity spanning the late 1800's to 1945. Renewed underground exploitation occurred in the late seventies on the East Rand and successful opencast operations were undertaken in the 1990's in the Randfontein area of the West Rand. This history is inextricably intermingled with the history of the Witwatersrand gold fields.

As with all outcropping conglomerates in the Transvaal Province, the Black Reef has been extensively prospected, sampled and trenched almost everywhere where it is exposed at surface. Most of this has been economically unsuccessful, except on a very minor scale.

In total, three major and two minor areas have been exploited to a greater or lesser extent (fig. 1.4). These are:

- (1) The southwestern Transvaal in the Klerksdorp - Ventersdorp - Potchefstroom area.
- (2) The West Rand area in the vicinity of Randfontein and Krugersdorp.
- (3) The East Rand Goldfield in the vicinity of the present Consolidated Modderfontein Mines 1979 Ltd.
- (4) The west - central Transvaal between Rustenburg and the Botswana border (minor activities).
- (5) The eastern Transvaal in the vicinity of Kaapsehoop (fairly minor).

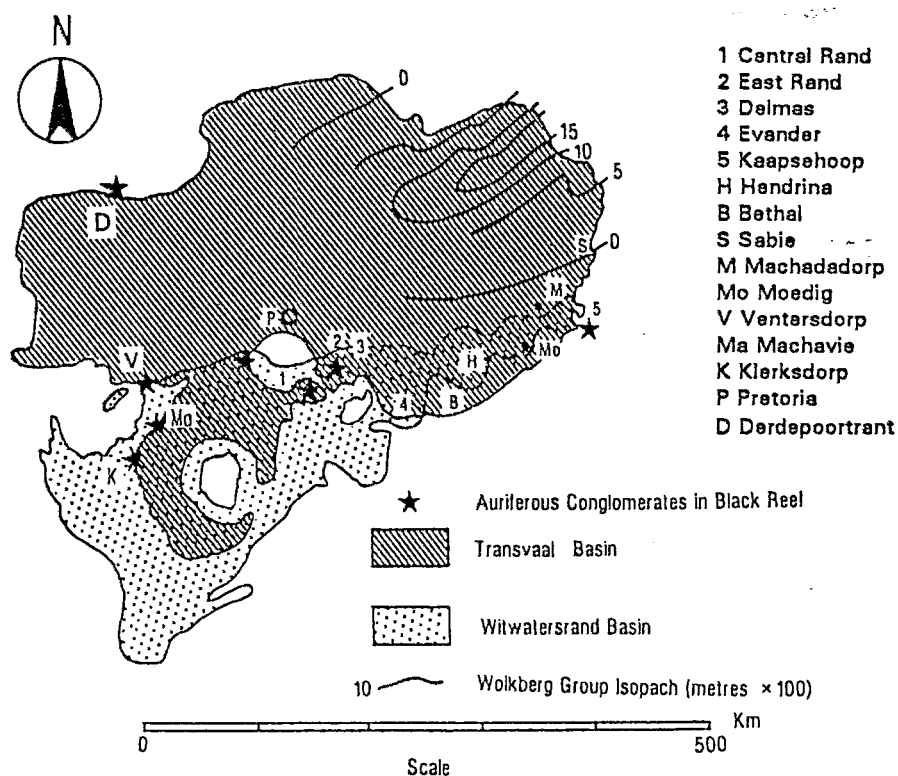


Fig. 1.4. Map showing distribution (known and inferred) of Witwatersrand and Transvaal basins, and location of mineralised conglomerates in the Black Reef (Button, 1978).

These areas are discussed individually in chapters 3 to 8 of this dissertation, starting with the west - central Transvaal and moving in an anti - clockwise order around the boundary of the Transvaal Basin to the eastern Transvaal. In some areas, such as the West Wits Goldfield, much information is unavailable for publishing, due to inhouse confidentiality.

1.4 Previous work

This is discussed in more detail in the sections dealing with each individual area listed above.

Information has been published on the Black Reef since the 1890's. According to Du Toit (1954), Penning was the first to describe the Black Reef in the Witwatersrand area. Stonestreet (1897), described the rolling nature and erratic mineralisation of the Black Reef in the Natalspruit area of the East Rand. Molengraaff (1904) collated available data in the Transvaal Province and applied the name "Black Reef Series" over the full known areal extent of the formation, as did Du Toit (1926 and 1954).

Swiegers (1938: 1939) studied the geology and mineralogy of the Black Reef and concluded that it was at least partly hydrothermal. Frankel (1940) found the gold at Machavie mine to be of placer origin with some later remobilisation. Liebenberg (1955) concluded from his detailed mineralogical work on the Witwatersrand rocks, Dominion Reef and the Black Reef, that the gold and uraninite were both detrital and that the modified placer theory was therefore correct. Papenfus (1964), from his studies of the Black Reef in the Witwatersrand basin, concluded that it was detrital in origin. Frey and Germs (1986) found that the uranium content of the Black Reef is always less than 500 ppm U_3O_8 . The sphalerite and galena in the reef are epigenetic in origin.

Subsequently, after these early researchers, a large body of literature on the Black Reef has accumulated. A number of these have entailed comprehensive research. Button (1973a and c) investigated the BRQF and its depositional history in the eastern and northeastern Transvaal, whilst Tyler (1979) similarly investigated the west - central Transvaal. Pouroulis (1988) studied the sedimentology of the BRQF at Consolidated Modderfontein Mines on the East Rand whilst van den Berg (1994) undertook research on the outcropping BRQF of the southwestern Transvaal. Shaw (1994), described the geology and assessed a gold evaluation study on the Black Reef opencast mining operations on the West Rand.

CHAPTER 2

2 REGIONAL GEOLOGY

2.1 Geographical Distribution

The Transvaal Supergroup extends for 1600 km across the Transvaal and Northern Cape Provinces (Truswell, 1977) (fig. 1.1). Two major sub-basins are recognised; the Transvaal or Bushveld basin and the Griqualand West basin. The Transvaal basin covers much of the southern and central parts of the Transvaal, parts of the Northern Cape Province and Orange Free State and southeastern Botswana (Button, 1986). The Griqualand West basin is located over the eastern parts of the Northern Cape Province and adjoining parts of Botswana (Button, 1986). The two major basins are separated by an archlike structure east of Vryburg, which exposes the older, underlying Ventersdorp Supergroup (Clendenin et al, 1988; Duane et al, 1991).

The Transvaal Supergroup is an erosional / tectonic remnant and covers a total area of 250 000 km². The original areal distribution was probably of the order of 500 000 km² (Button, 1986). The narrow, less than 30 m thickness of the BRQF limits its outcrop distribution to a narrow ribbon around the rim of the basin (Els et al, 1995).

2.2 Morphology of the Transvaal Basin

The Transvaal Supergroup is one of a series of Proterozoic, intracratonic, sedimentary basins overlying the Kaapvaal craton (Eriksson, 1972).

The Transvaal succession occupies a continuous, west - east trending, elliptical or "pear - shaped" (Truswell, 1977) inward dipping basin, encircling and forming the floor of the Bushveld Complex (De Kok, 1964). Some small uplifted areas of Black Reef shales and quartzites, such as the

Crocodile River fragment and Marble Hall inlier, crop out within the Complex (fig. 1.1). Separated from this main basin by a gentle upwarp (Rand anticline) and the Johannesburg Dome, a subsidiary, northeast trending, synclinal trough (Plate 1) (Papenfus, 1964) (SACS, 1980) occurs along its southern boundary between Potchefstroom and Heidelberg, the southern side of which has been sharply overturned around the northern and western rim of the Vredefort dome (Truswell, 1977). This subsidiary trough overlies the northern and central parts of the Witwatersrand basin. In the Orange Free State, the Transvaal succession is mostly covered by near horizontal Karoo sediments (Papenfus, 1964).

2.3 Structural Framework of the Transvaal Basin

Button (1986) considers the geometry of the Transvaal basin and therefore the BRQF to have been controlled by the two, major, near contemporaneous, post - Transvaal Bushveld and Vredefort events, dated at 2050 Ma and 2006 Ma respectively (Trieloff et al, 1994). The huge volumes of mafic magma injected into the basin caused the inward tilting of the Transvaal succession, the increasing dip of the strata towards the middle of the basin, implying sagging of the strata to accommodate the weight of the magma. Diapirism is thought to have caused some of the domal features occurring within the Bushveld Complex (Button, 1986).

Grieve and Masaitis (1994) describe the Vredefort structure as "the central uplifted core of a very large, probably originally multi - ringed, impact structure" with an estimated, original rim diameter of 300 km (fig. 2.1). These structures resulted in the preservation of the underlying Transvaal and Witwatersrand successions in the annular depression surrounding the central dome (McCarthy et al, 1990).

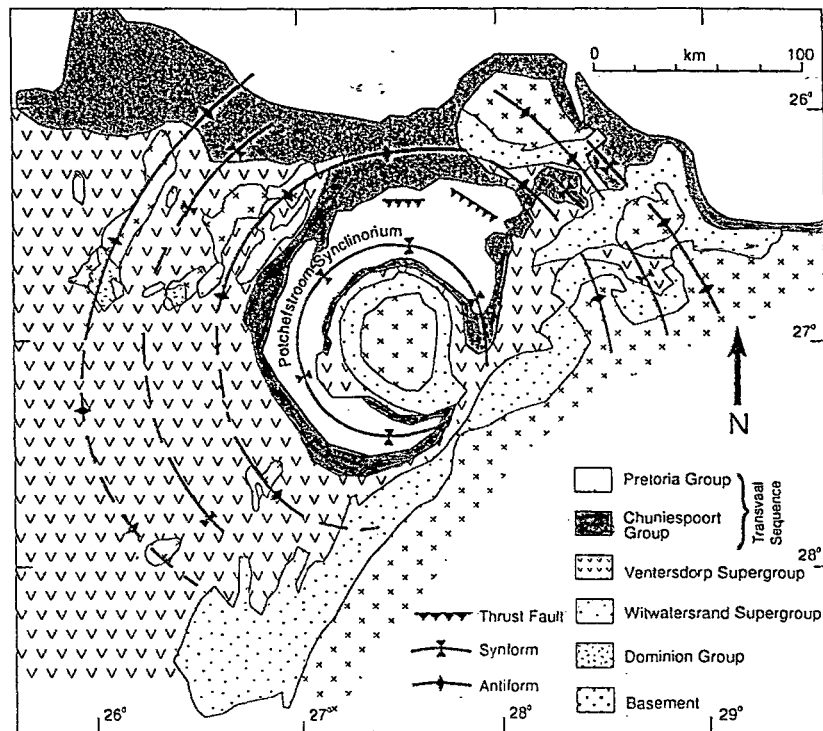


Fig. 2.1. Geological sketch map of the Vredefort structure, with the partially overlying Karoo Sequence removed. Indicated are the series of concentric antiform and synform structures surrounding and related to Vredefort (after McCarthy et al., 1990; Grieve and Masaitis, 1994).

The BRQF "broadly reflects the main structural features of the underlying Witwatersrand sediments" since it was also present at the time of Vredefort tectonics (Papenfus, 1964). The Vredefort event resulted in the development of a major rim synclinoorium in the Transvaal and underlying formations with overturning of strata around the collar of the Vredefort Dome (Simpson, 1978; Button, 1986). The BRQF outcrops around this collar (Plate I). According to McCarthy et al (1986), simple shear related, major and minor, open to overturned folding and penetrative cleavage occurs in the BRQF throughout the Witwatersrand basin. These parallel fold trends and cleavage strikes are tangential to the Vredefort dome and therefore may be associated with the Vredefort event. The cleavage dips at a shallow angle towards the dome. The fold trends turn from northwest

over the East and Central Rand, to due west over the West Rand and Rand anticline, to southwest over the Ventersdorp - Klerksdorp area (fig. 2.2). A northwest and a second northeast fold trend is present over the West Rand. According to Mellor (1917) in McCarthy (1986) this interference folding (fig. 2.3) resulted in the preservation of the numerous outliers of BRQF in the area. In the southwestern Transvaal, outcrop patterns are influenced by warping of the footwall, and minor, often intense folding and faulting does occur (Els et al, 1995). Folding, both pre- and post - Black reef times, has affected the East Rand to a much greater extent than the rest of the Witwatersrand basin (Pouroulis, 1988).

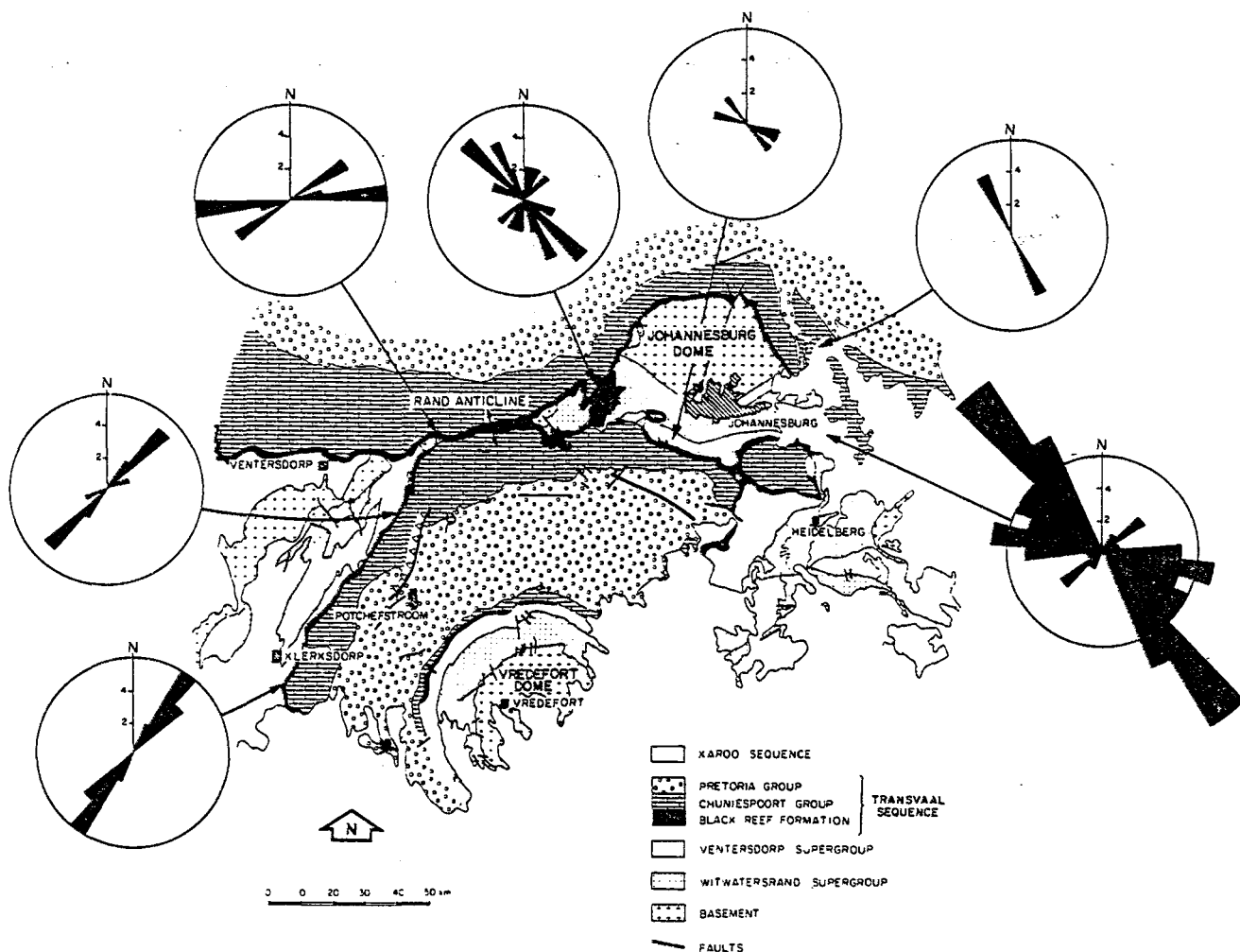


Fig. 2.2. Regional variation of the strike of major folds in the Black Reef Formation through the study area. Data obtained from Mellor (1917), Nel (1935) and Papenfus (1964). Extracted from McCarthy et al. (1986).

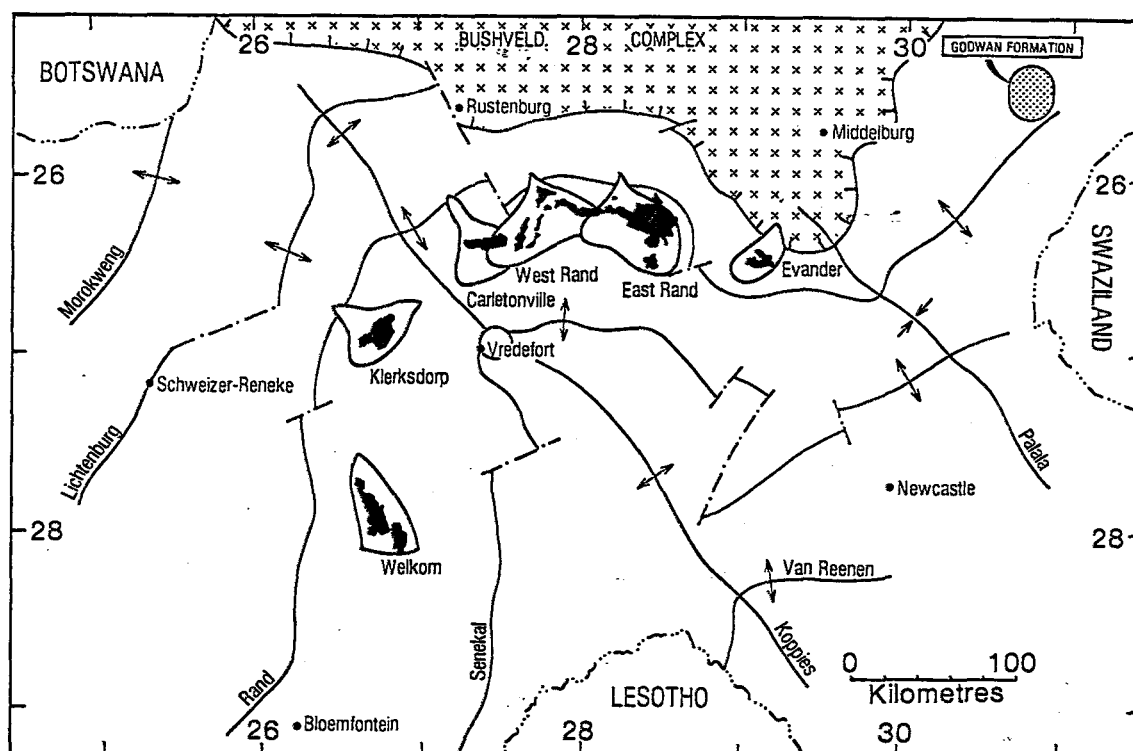


Fig. 2.3. Interference fold trends in the Witwatersrand basin which also affect the Black Reef Quartzite Formation (modified after Pretorius, 1974) (after Button, 1978).

The small scale folds commonly found in the BRQF, which generally trend parallel to the large scale folding, are described by McCarthy et al (1986) as shallowly plunging, gently warped to slightly overturned, with fold wavelengths of metres to tens of metres. Interference folding, as found in the major folds, is well developed locally.

In the eastern Transvaal, intense north - northeast trending folding of the lower Transvaal sediments occurs, overlying a projected extension of the Murchison greenstone belt. Movement of competent basement granite blocks, relative to the soft greenstones, caused this deformation (Button, 1973a).

Els et al (1995) considers major faulting to have had minimal influence on the BRQF, even when the footwall Witwatersrand and Ventersdorp rocks or overlying Transvaal succession (Papenfus, 1964) show large displacements. Post - BRQF tectonic stresses are considered to have been released by bedding parallel faults such as the Master Bedding Plane Fault (McCarthy et al, 1986) and folding on a large scale (Papenfus, 1964).

2.4

Pre - Transvaal/Black Reef Basement

The Transvaal Supergroup was deposited unconformably on floor rocks ranging from Archaean granites up to the youngest Ventersdorp rocks (De Kock, 1964). In the northwestern and western parts of the Transvaal basin, Ventersdorp lavas and sediments form the floor whilst Archaean granites, gneisses and greenstone belts occur in the eastern Transvaal. In its southern parts, the Transvaal Sequence laps across the Archaean basement onto Witwatersrand strata and Ventersdorp volcanics (Button, 1986). Within the Witwatersrand basin, the Transvaal Supergroup overlies Ventersdorp Supergroup rocks over most of the area (Plate 1) (Papenfus, 1964).

The BRQF usually lies at the base of the Transvaal Supergroup except where its proto - basinal facies is present. In the vicinity of Thabazimbi, in the west - central Transvaal, the BRQF conformably overlies the proto - basinal Buffelsfontein Group (Tyler, 1979b) and in the eastern and northeastern Transvaal, the proto - basinal Wolkberg Group (Button, 1973a). Recent basin analysis by Clendenim et al (1988b) and Cheney et al (1990) however, supports the view that the BRQF forms the base of the Transvaal Supergroup and that the proto - basinal Groups are "correlates of the Ventersdorp Supergroup" (Eriksson et al, 1993).

2.5 Pre - Black Reef Palaeotopography

The pre - Transvaal erosional surface had a varied topography. The Murchison greenstone belt underlying the Wolkberg proto - basin in the eastern Transvaal had broad, deep valleys. Palaeohills occurred in granitic areas (Button, 1986). The pre - BRQF depositional surfaces were relatively smooth and gently dipping over the proto - basinal sediments (Button, 1973a and c). Outside of the proto - basins e.g. on the East Rand, incised channels were cut into the footwall (Papenfus, 1964; Pouroulis, 1988). In the southwestern Transvaal, low relief (<30 m) palaeo - grabens controlled the paths of the channelised Black Reef (Van den Berg (1994). On the West Rand , negative topography has developed over the softer strata of steeply dipping Witwatersrand rocks, resulting in a trellis drainage pattern (Papenfus, 1964).

Chemical weathering formed a palaeosol, a few metres deep, in the pre - Transvaal basement rocks. Sericitisation is developed over basaltic terrain (Button, 1986) whilst predominantly quartz and sericite is developed in granitic areas (Button and Tyler, 1981) on the erosional unconformity (Button, 1986).

2.6 The Black Reef Quartzite Formation

"The BRQF can be traced throughout" the Transvaal basin of the Transvaal Supergroup. It is generally from a few metres to 500 m thick. It attains its maximum thickness over the Wolkberg proto - basin in the eastern Transvaal, which includes the 100 m thick, basaltic Serala Volcanic Member. Away from the proto - basin, the BRQF is usually less than a few tens of metres thick (Button, 1986).

The BRQF is intrinsically an arenaceous formation with lesser shales. The basal conglomerate, where present, is generally thin (Hamilton and Cooke, 1965) and gold - bearing when overlying auriferous Witwatersrand sediments (Papenfus, 1964). Clasts vary from small pebbles to cobbles and commonly consist of quartz, quartzite and lesser chert (Hamilton and Cooke, 1965). Clasts derived from the footwall are often present (Els et al, 1995; Papenfus, 1964; Tyler, 1979b).

The quartz arenites overlying the conglomerate are compositionally and texturally mature (Button, 1986). These are generally medium - grained and pale bluish, weathering to a creamy white (Hamilton and Cooke, 1965) or dark grey (Swiegers, 1940). These quartzites were probably subtidally deposited, on a "very wide, gently shelving, southwestward - deepening sea" which transgressed across the pre - Transvaal basement from west to east (Button, 1973a and c).

2.7 Malmani Dolomites

The BRQF grades transitionally into the overlying dolomitic Malmani Subgroup. The basal, 10 - 200 m thick Oaktree Formation consists of Fe- and Mn - rich dolomites, carbonaceous shales and quartzites and is a transition zone to the overlying succession. The Malmani Subgroup is nearly 2000 m thick in the middle of the Transvaal "Bushveld" basin and is present throughout the basin except where the overlying Pretoria group has truncated it (Button, 1973a; Eriksson et al, 1976).

2.8 Metamorphism

The Transvaal succession underwent contact metamorphism during intrusion of the Bushveld Complex. Intrusion of shales by sills, resulted in the development of fine-grained hornfels (Button, 1976). The convective cell, generated by the intrusion of the Complex, may be the heat source that generated the thermal gradient responsible for the migration of

hydrothermal gold into the shale horizons of the Transvaal Supergroup in the eastern Transvaal and elsewhere (Duane et al, 1991). This hydrothermal gold occurs in the transition zone at the top of the BRQF in parts of the eastern Transvaal as well as elsewhere (Duane et al, 1991).

2.9 Age

The base of the Transvaal Supergroup unconformably overlies rocks as young as the Ventersdorp Supergroup, dated at 2300 -2700 M.a. (U - Pb) (Van Niekerk and Burger, 1978). The proto - basinal Groblersdal Group is dated at 2460 M.a. (U - Pb) (Coertze et al., 1978). The Timeball Hill shales are dated at 2263 M.a. (Rb - Sr whole rock) (Burger and Walraven, 1980). The Black Reef Quartzite Formation is therefore probably 2500-2200 M.a. in age.

CHAPTER 3

3 BLACK REEF IN THE WEST - CENTRAL TRANSVAAL

In the west - central Transvaal, the BRQF is exposed for 175 km's along strike, from 12 km northeast of Thabazimbi to the Botswana border near Ramotswa in the west (fig. 3.1). In Botswana, the BRQF swings south "in the arc of country between Lobatse, Otse and Ramotswa" (Key, 1986) and then continues into South Africa (Tyler, 1979b). Eleven km's north of this belt and east of Derdepoort, a second, outlier belt of poorly exposed, 12 km long, roughly east - southeast trending BRQF occurs (Tyler, 1979b) in the Derdepoort "graben" (fig. 3.1).

3.1 Historical Background

This historical data is mainly derived from Tyler (1979b).

Hatch (1904) first reported the presence and geographic locality of the Black Reef Series in the west - central Transvaal. Kynaston (1911) described the Black reef Series in the area as " fine- to coarse- grained feldspathic quartzite, commonly containing pebbly bands" and recognised strike - fault duplication in the succession. In 1912, Kynaston noted that the Black Reef Series in the Derdepoort area was a " light coloured, hard quartzite with occasional thin bands of conglomerate and often with flaggy beds and sandy shales near the base" and " no more than 16 m (50 ft) thick". He assigned the series to the Ventersdorp Supergroup whilst Wagner and Ross (1925), recognising the unconformity at the base of the sporadically gold bearing conglomerate, correlated it with the Black Reef Series.

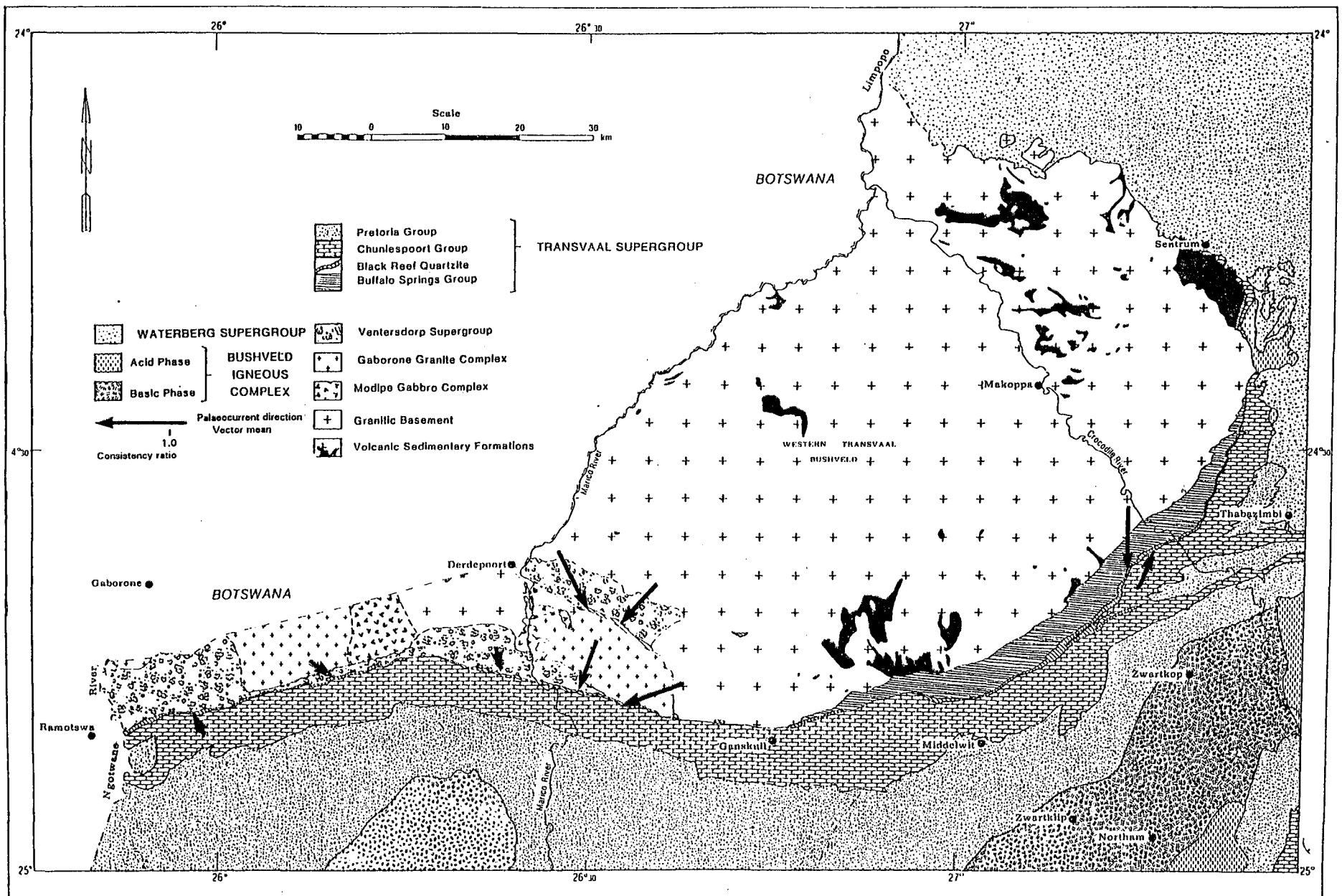


Fig 3.1. Location and geological setting of the Black Reef Quartzite in the west - central Transvaal showing palaeocurrent vector mean directions (after Tyler, 1979b).

Schutte et al (1960), returning to the area around the Crocodile River west of Thabazimbi, concluded that the Black Reef Series transgressed the underlying volcanics to rest on the basal sediments (which had previously been correlated with the Dominion Reef system). Tyler (1979b) disagreed with this interpretation and considered the Black Reef Quartzite to have been removed by pre - Chunniespoort erosion, the Chunniespoort dolomites lying directly on the Hampton Formation of the proto - basinal Buffelsfontein Group. Schutte et al (1960) considered the Black reef Series of the Derdepoort graben to have four possible correlatives: the Moodies or Dominion Reef Systems, the Wolkberg Formation or the Black Reef Series (fig. 3.2).

DERDEPOORTANT

	ANDESITIC LAVAS	ACID LAVAS	SEDIMENTS	
			LOWER	UPPER
TRUTER (1949)	OVERWACHT SERIES, SWAZILAND SYSTEM		DOMINION REEF FM.	
POLDERVAART & GREEN (1952)	ONVERWACHT SERIES, SWAZILAND SYSTEM	DOMINION REEF SYSTEM		
SCHUTTE (1963)	OVERWACHT SERIES, SWAZILAND SYSTEM	MOODIES SYSTEM	MOODIES SYSTEM, OR DOMINION REEF, OR WOLKBERG.FM. OR BLACK REEF SERIES	
GEOLOGICAL SURVEY (1974)	VENTERSDORP SYSTEM		BLACK REEF SERIES	
TYLER (1978)	VENTERSDORP SUPERGROUP		BLACK REEF FM.	

Fig. 3.2. The evolution of stratigraphic nomenclature in the Derdepoortant (King, 1995).

The distinction between the Black Reef and the pre - Black Reef Kransberg Quartzite in the Thabazimbi District was first recognised by Marais (1967; 1968). This was acknowledged by the Geological Society of South Africa on the 1974 Thabazimbi sheet. The accompanying explanatory note of Jansen (1974) states that "the Black Reef Series forms an almost

continuous belt along the northern boundary of the (Transvaal) basin". The presence of the series overlying the Ventersdorp beds along the Derdepoortrant was also accepted.

Tyler (1978)'s MSc thesis assessed the stratigraphy of the pre - Chunniespoort succession in the Makoppa Dome area of the west - central Transvaal. His 1979b paper interpreted the depositional environment of the BRQF in the west - central Transvaal.

3.2 Geology and Structure

The predominantly arenaceous Black Reef Quartzite is best exposed in the Thabazimbi area (fig. 3.1). Towards the west it forms a low relief escarpment of moderate outcrops, whilst in the middle (Ganskuil) area, outcrop is poor due to flat, sand covered terrain (Tyler, 1979b).

The BRQF comprises a laterally persistent 40 - 50 m thick sheet of south to southeastwards dipping, heterogeneous clastic sediments, conformably overlain by the dolomitic Chunniespoort Group (fig. 3.3). The upper contact, where exposed, is sharp. The Black Reef lies unconformably on rocks of the Archaean basement and Ventersdorp Supergroup but has a gradational contact with the underlying Kransberg Quartzite of the proto - basinal Buffelsfontein Group where present. Unconformable basal contacts are sharp and commonly overlie a thin palaeosol horizon. Northeast of Thabazimbi, erosional truncation of the BRQF has resulted in the Chunniespoort dolomites lying directly on the lower units of the Buffalo Springs Group (Tyler, 1979b).

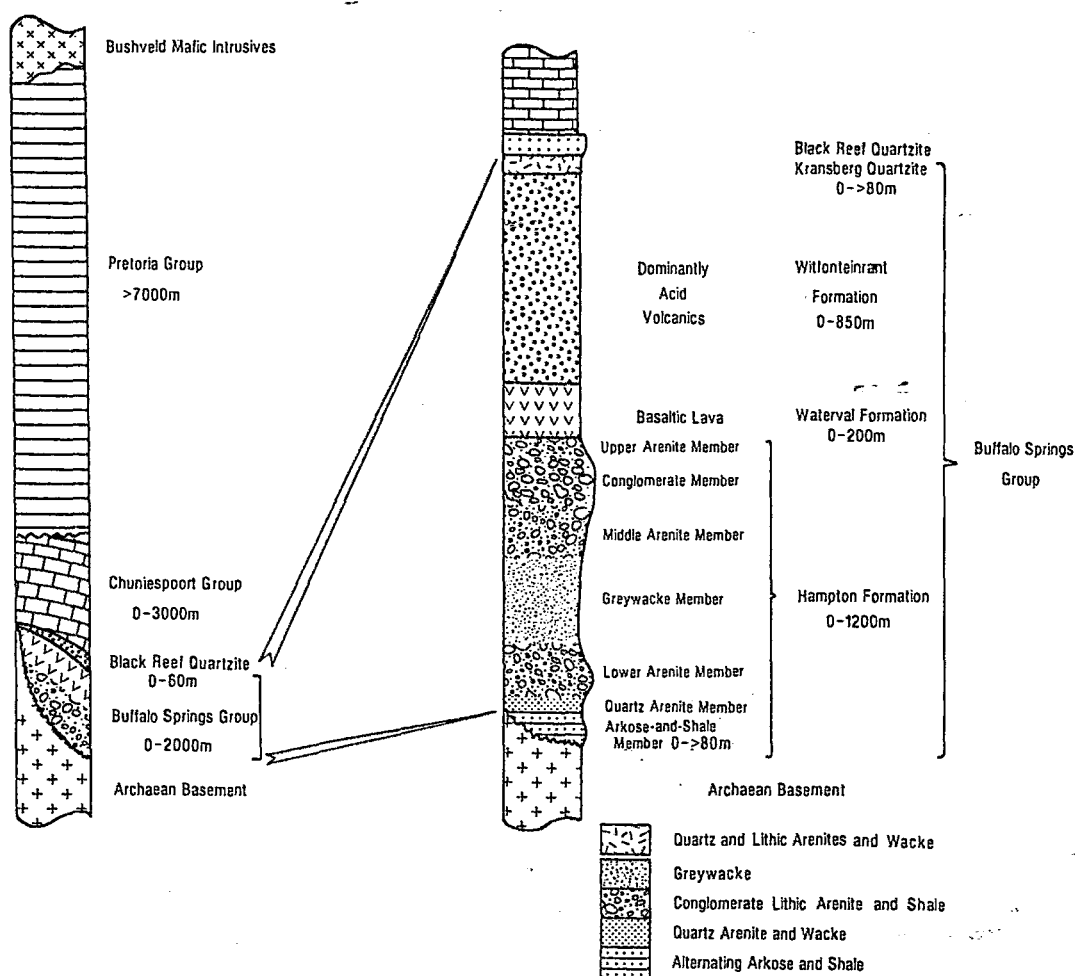


Fig. 3.3. Stratigraphic setting of the Black reef Quartzite in the Thabazimbi area of the west - central Transvaal (Tyler, 1979b).

In the Thabazimbi area, left - lateral faulting in the Black Reef Quartzite, with displacements of a few centimetres to hundreds of metres, is quite common. Both left- and right- lateral faulting have been observed in the area to the west of the Marico River (Tyler, 1979b).

The Derdepoort graben (figs. 3.1 and 3.4) is surrounded by basement granites and greenstone remnants (King, 1996) and consists of acid and basic Ventersdorp lavas with intercalations of tuffs, agglomerates, conglomerates, shales and quartzites overlain by conglomerates and quartzites of the Black Reef Series (Wagner and Ross, 1925). The formations extend west - northwestwards into Botswana and correlate with the Ventersdorp succession (Tyler, 1978).

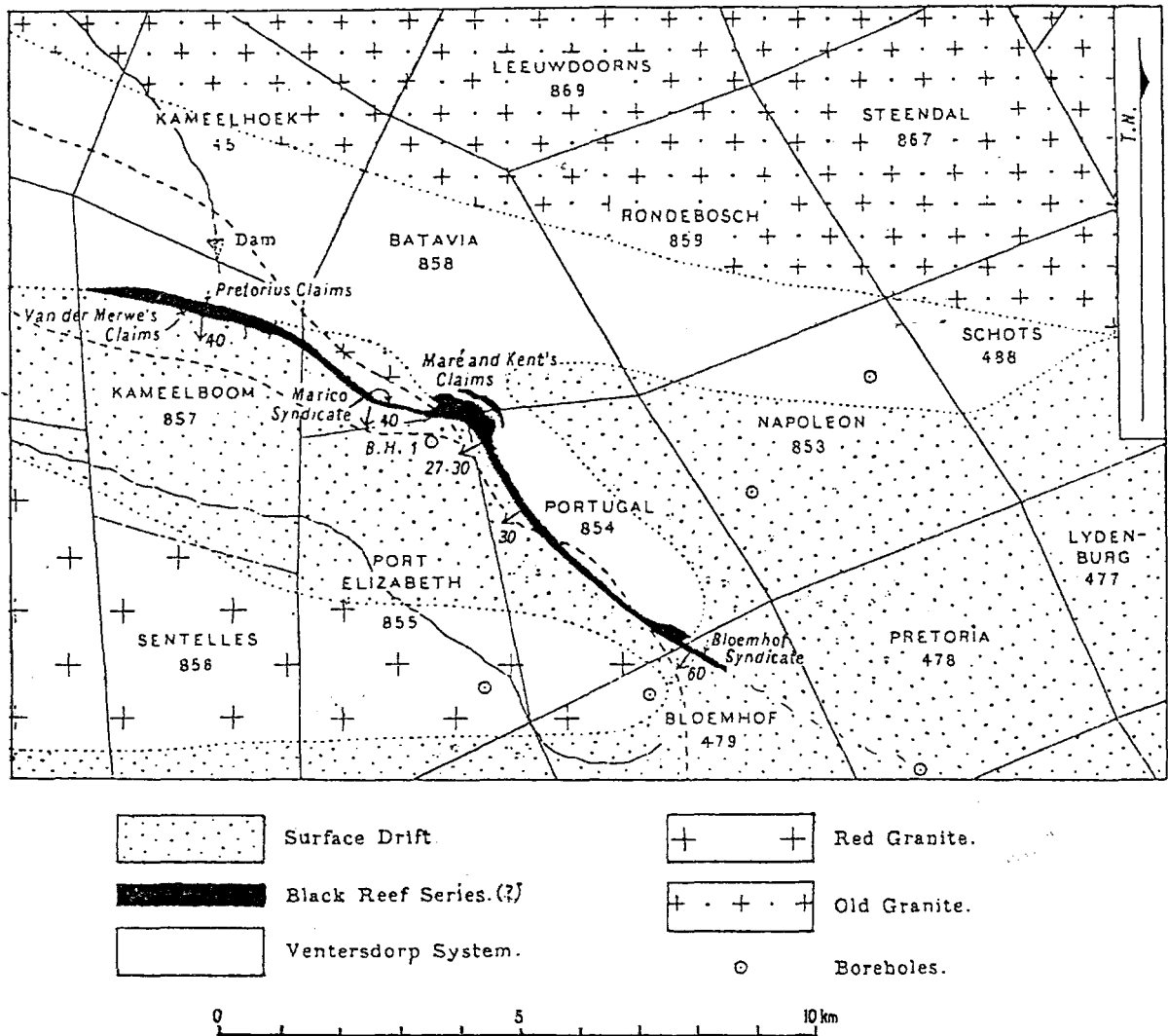


Fig. 3.4. Geological map of the Batavia Goldfield (Wagner and Ross, 1925).

The Ventersdorp rocks in the graben consist of a northern asymmetrical syncline, changing to a highly folded southern anticline, with parallel axes trending east - southeastwards along the graben. The gold - bearing conglomerate lies unconformably on the southern limb of the anticline. South of this on Batavia no. 858 the sedimentary package overlies granite basement. The general dip of the formations is to the south - southwest (Wagner and Ross, 1925). Folding is pre - Black Reef times whilst the graben is post - Transvaal (Tyler, 1978 in King 1996). Faulting in the Derdepoortant is mostly small scale thrust faulting resulting in duplication

and sometimes triplication of the Black Reef in places (Wagner and Ross, 1925)

3.3 The Black Reef

The conglomerates of the Black Reef occur at the base of the Formation or lie on thin, impersistent, granular sand (fig. 3.5). Intercalated, discontinuous, conglomeratic bands are, however, sometimes present in the overlying sediments. Clasts are predominantly vein - quartz (30%), are poorly sorted, well rounded and 1 - 4 cm in size. Some clasts are much greater than 15 cm in size. Volcaniclastic conglomerates are present locally (Tyler, 1979b). Both conglomerate types show crude, imbricate structures of the clasts (Tyler, 1979b; King, 1996). The generally sharp upper contacts of conglomerate bands are scoured into by overlying conglomerates. Upward fining sequences are rare. The matrix of conglomerates consists of poorly sorted, rounded, coarse quartz and lava grains. The composition of the Black Reef is strongly influenced by its footwall rock types (Tyler, 1979b).

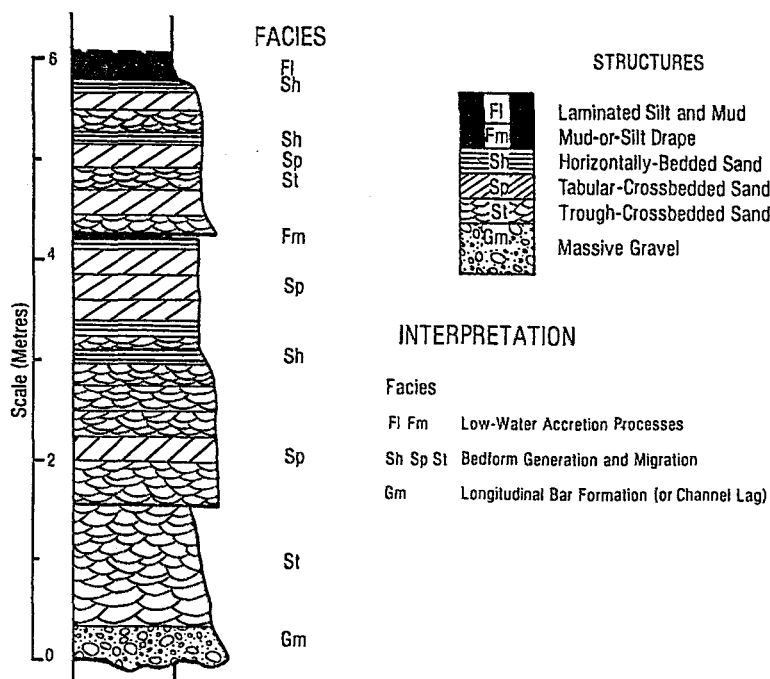


Fig. 3.5. Detailed measured section through the initial fluvial phase of Black reef sedimentation (Batavia 176 KP) (Tyler, 1979b).

Conglomerates are developed along the southern boundary of the Derdepoort graben (Wagner and Ross, 1925). Pebbles consist predominantly of 1 - 10 cm sized, grey quartz and quartzite clasts with a maximum size of 15 cm. Both vein - quartz dominated and volcanic - clast dominated types are present (King, 1996). Conglomerates grade vertically and laterally, over a few hundred metres, into quartzites with scattered pebbles which often grade laterally into siltstones and shales (Wagner and Ross, 1925; Tyler, 1979b). Gold bearing conglomerate consists mostly of a single band, occasionally split by quartzite partings, and is 3 - 130 cm thick. It was deposited on an uneven surface with the pebbles occupying depressions. The conglomerate reaches its maximum thickness on Kameelboom no. 857. On Batavia the thickest conglomerate is 46 cm (fig. 3.5). The conglomerates deteriorate rapidly away from Batavia southeastwards to scattered, isolated clasts lying on the footwall contact (Wagner and Ross, 1925).

3.4 The Black Reef Quartzite

The Black Reef Quartzite consists predominantly of poorly sorted, light weathering, fine to granular, quartz rich lith - arenites with scattered pebbles and common quartz - arenite bands. Coarse varieties are texturally mature. Volcanic grains, blue opalescent quartz and interstitial carbonaceous and pyrite specks are present. Common sedimentary structures are trough and planar cross - bedding, ripple cross laminations, swash laminations, planar beds with scattered pebbles and accessory mud - drapes. Finer varieties are texturally immature with common, interstitial carbonaceous laminae (Tyler, 1979b).

Fine - grained, reddish - brown weathering, texturally immature, planar bedded, dark grey wackes are common above the Buffelsfontein Group over the eastern sides of the area. Occasional, less than 1 m thick arenite units are present. Primary sedimentary structures such as 15 cm thick, low

- angle trough and planar cross - beds, symmetrical ripple marks and flat - topped asymmetrical ripples are common. Thin mud - drapes and coarser arenite lenses are present (Tyler, 1979b).

Finely laminated shales and ripple - marked siltstones are present at the top of the Black reef Quartzite. They are greyish - black, carbonaceous and sericitic. Near the top of the succession, rare, less than 1.5 m thick, planar - bedded lenses and thin (a few cm thick) bands of light coloured dolomites occur (Tyler, 1979b).

In the Derdepoort graben, the most characteristic Black Reef sediments are hard, greyish - white weathering, greyish to yellowish grey, cross - bedded quartzite and quartzitic grits. These are commonest on Batavia whilst mostly shales and sandy shales overlie the conglomerates on Kameeldoorn (Wagner and Ross, 1979b).

3.5 Palaeocurrent Directions

Tyler (1979b) measured palaeocurrent directions at 13 stations along the strike of the Black Reef between Thabazimbi and the Botswana border (fig. 1 and Table 1). The predominantly unimodal current directions indicated sediment transport was southwards into the centre of the Transvaal basin. Two exceptions to this had vector means oriented northwards out of the basin (fig. 3.1).

The low consistency ratios for some of the vector means "are a function of primary sedimentary structures in the near - shore environment" interpreted for the upper units of the Black Reef Quartzite in the west - central Transvaal (Tyler, 1979b).

3.6 Depositional Setting

The impersistent basal Black Reef conglomerate in the west - central Transvaal is considered to be deposited in a braided stream setting. A marine transgression followed which deposited the overlying quartzites as coastal sands in a high energy, near shore environment (fig. 3.6). Planar wackes were deposited (suspension sedimentation) in a lower - shore face environment whilst the upper shales were deposited in the transition zone between coastal sands and shelf muds (Tyler, 1979b).

In southeastern Botswana, south of Ramotswa (fig. 3.1), Key (1986) interprets a similar depositional environment for the Black Reef Quartzite Formation, of marginal beach deposits overlying conglomerates and deltaic sediments. Rivers flowed eastwards into the Transvaal basin from hills to the west.

3.7 Historical Mining Activity

The Batavia Goldfield (Northern Rustenburg District) is located across 5 farms (fig. 3.4) in the Derdepoort graben, east - southeast of Derdepoort. First discovered in May 1922, a thin conglomerate outcropping along a crest of low hills, the Derdepoort, on the southern parts of Batavia no. 858 was "in places rich in gold" (Wagner and Ross, 1925). The conglomerates were traced westwards onto Kameelboom no. 857 where they were found to "carry gold at several points". The two farms were proclaimed public diggings on 8 May 1923. A number of syndicates were formed by mutual agreement by the seven hundred gold seekers present and the ground was divided into blocks and lots drawn (Wagner and Ross, 1925). The conglomerates were later traced southeastwards across Portugal no. 854 onto a government farm, Bloemhof no. 479. Discovery rights were granted in July 1924 and the area proclaimed a public digging (Wagner and Ross, 1925). Most of the exploratory work was done on Batavia.

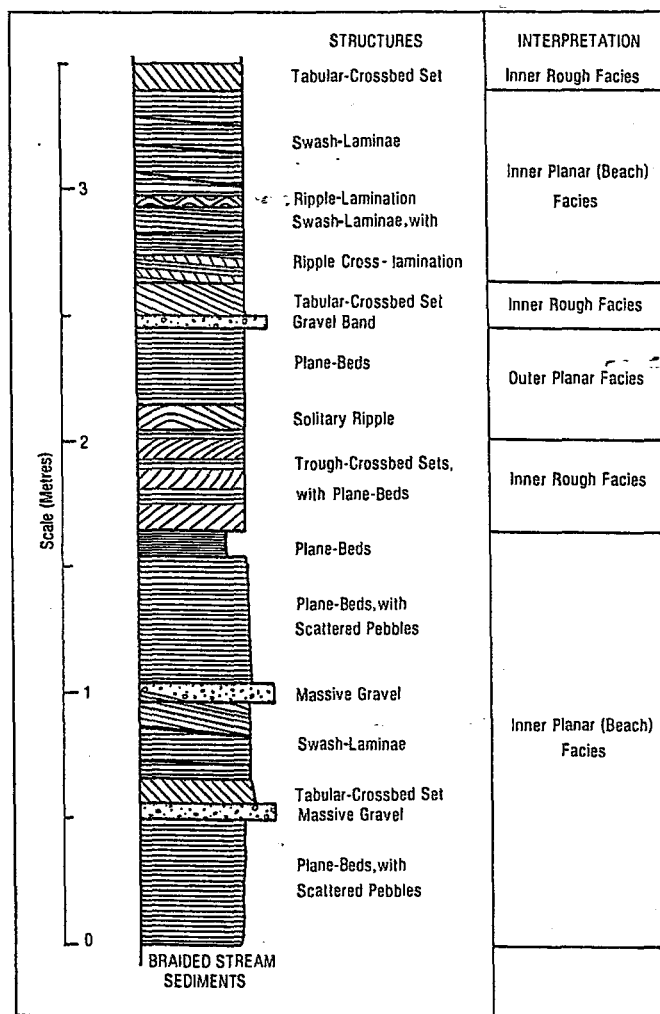


Fig. 3.6. Detailed measured section through the near - shore sediments of the Black Reef Quartzite Formation, south of the Derdepoortrant (Tyler, 1979b)

Many claims were actively worked in 1923 and 1924, positive results being insufficient to interest any of the large, Johannesburg based mining houses. A total of 7 inclined shafts were sunk with 2 tunnels developed along strike on the Black Reef and large numbers of cuttings and trenches were dug. All workings were abandoned by June 1925 when Wagner and Ross visited the area on an official government investigation of the Batavia gold field. Most of the workings were systematically sampled by them. The samples were forwarded to Johannesburg for assaying (Wagner and Ross, 1925).

The resultant assay results of Wagner and Ross (1925) are summarised below:

- (1) Values of over 31 g (1 oz.)/ton Au were limited to a few small, isolated shoots or patches in the central part of Batavia no. 858.
- (2) The thickness of the gold - bearing conglomerates rarely exceeded 30 cm, except on Kameelboom no. 857 where values were poor.
- (3) The reef was impersistent over any distance along strike or dip and reverted to siltstones with scattered pebbles, micaceous shales or quartzites.
- (4) Where no conglomerates or pebbles were present, the footwall contact of the Black Reef mostly carries negligible gold.

A series of samples from the North and South shafts on Batavia, assayed by the Geological Survey, Pretoria, showed Ag/Au ratios of ~ 1:3.1. Two composite samples assayed for Platinum showed values of zero (Wagner and Ross, 1925).

Wagner and Ross (1925) concluded that the Black Reef is thin and impersistent with consistently low or very erratic gold values and that a liberal estimate of the total workable tonnages available was approximately 1400 tons assaying at ~ 10.3 g/t (6 dwt. per ton) and that this is too small to form "the basis of even the most modest gold - mining industry".

CHAPTER 4

4 BLACK REEF IN THE SOUTHWESTERN TRANSVAAL

In the southwestern Transvaal, the BRQF outcrop follows the southern boundary of the Transvaal basin westwards past Ventersdorp, turning abruptly northwards, 20 km west of Lichtenburg, to cross the border into Botswana in the vicinity of Lobatse (fig. 1.1 and Plate 1). The dip of the succession is northwards and then westwards respectively, towards the centre of the basin. Twenty five kilometres east of Ventersdorp, the outcrop diverges, a second exposure trending southwestwards and disappearing under younger Karoo cover, 15 km south of Klerksdorp (fig. 4.1).

In the southwestern Transvaal, the Black Reef Quartzite Formation outcrop has been extensively prospected for auriferous Black Reef. The only area to be successfully exploited, albeit in a relatively minor way, is the Klerksdorp - Ventersdorp - Potchefstroom area, most activity occurring along the southwestwards trending outcrop and near Klerksdorp (fig. 4.1).

4.1 Previous Work

Information on the previous work is mainly derived from van den Berg (1994).

Nel (1935) originally mapped the Klerksdorp - Ventersdorp area for the Geological Survey and concluded that the gold in the Black Reef originated from eroded Witwatersrand conglomerates. Swiegers (1938; 1939) investigated the mineralogy and geology of the BRQF and considered the gold and pyrite to be partly of hydrothermal origin and associated with faults. Frankel (1940) concluded from the mineralogy at Machavie Mine that the gold in the Black Reef originated from the Witwatersrand conglomerates and was deposited as a placer. Eriksson (1972) found that

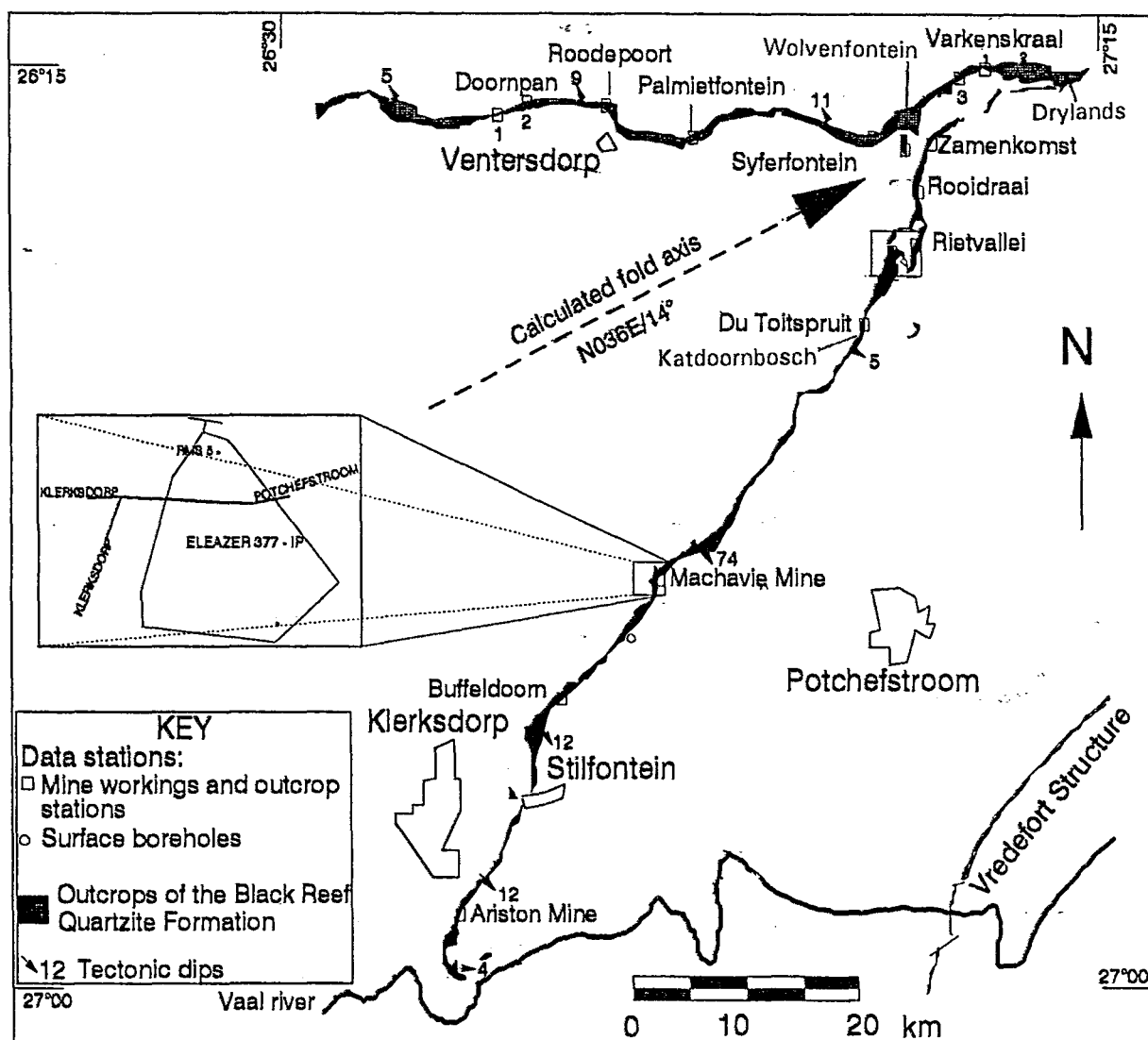


Fig. 4.1. Outcrop area of the Black Reef Quartzite Formation in the Klerksdorp - Ventersdorp - Potchefstroom area (After Els et al., 1995).

the thickest Black Reef coincided with longitudinal, southwest trending highs, east of Klerksdorp and Buffelsfontein, and that deposition occurred over growing anticlines. Tyler (1979b) interpreted the depositional environment of the BRQF in the west - central Transvaal, to have an early braided stream facies, followed by a marine transgression. Frey and Germs (1986) found that the clasts of the Black Reef originated from the

underlying rocks and/or small adjacent palaeohighs situated on antiforms or horst blocks. Deposition was into palaeovalleys. Els et al (1995) and van den Berg (1994) reached the same conclusions for the Klerksdorp - Ventersdorp area. Frey and Germs also found that authigenic opaque minerals in the Black Reef "represented remobilised constituents" resulting from a "metamorphic overprint of the sediments". Some minerals such as sphalerite and galena were found to be epigenetic.

4.2

Geology

Ventersdorp is located 60 km due north of Klerksdorp. Halfway between the two towns, a wide northeast - southwest trending anticline, of which the BRQF and overlying dolomites forms a part, plunges at 14 degrees to the northeast (fig. 4.1) (Els et al, 1995). Erosion of the spine of this anticline, has caused a divergence in strike of the shallowly dipping Black reef and exposed the older underlying basement granite, the Witwatersrand sediments and Ventersdorp lavas in the eroded core between the two Black Reef outcrops (fig. 4.2) (Swiegers, 1938; Els et al, 1995). The Black Reef exposure therefore splits into two ribbon - like outcrops, 25 km due east of Ventersdorp. The northern outcrop limb dips 2 to 14 degrees to the north and trends due east past Ventersdorp. The southern outcrop limb, dips at 3 to 20 degrees east - southeastwards and trends southwestwards past Klerksdorp (fig. 4.1).

The area, which encompasses the Klerksdorp Goldfield, overlies the northwestern margin of the Witwatersrand Basin. Numerous conglomerates, quartzites and shales of the West Rand Group outcrop nearby and north of Klerksdorp (Antrobus et al, 1986). In the western Transvaal the BRQF is usually separated from the auriferous Witwatersrand sediments by an interceding, thick, predominantly andesitic, Ventersdorp lava package (fig. 4.3). Metallogenically, the two auriferous successions therefore, have mutually exclusive epochs (Els et al, 1995). Roughly northeast - trending, angular unconformities exist between the

Witwatersrand, Ventersdorp and Transvaal successions (Antrobus et al, 1986).

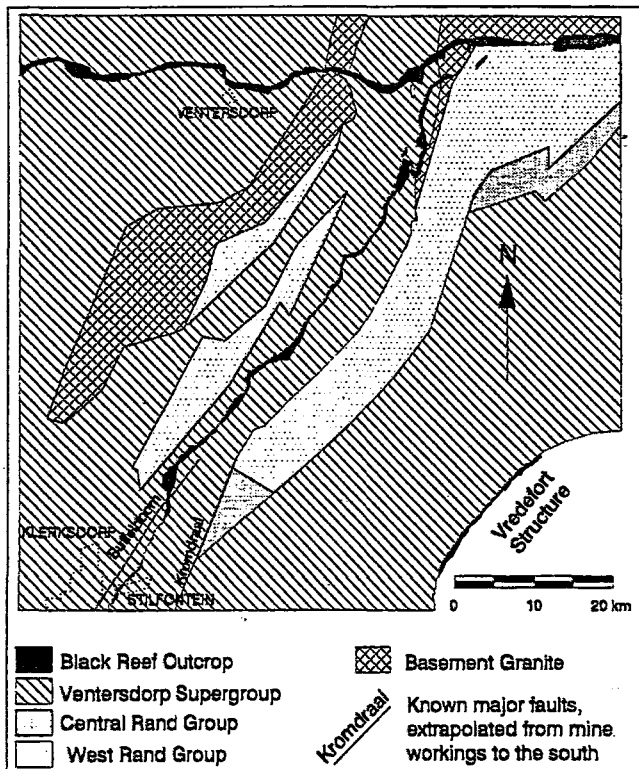


Fig. 4.2. Distribution of Archaean rocks underlying the Black Reef Quartzite Formation, and present outcrops of these rocks (Els et al., 1995).

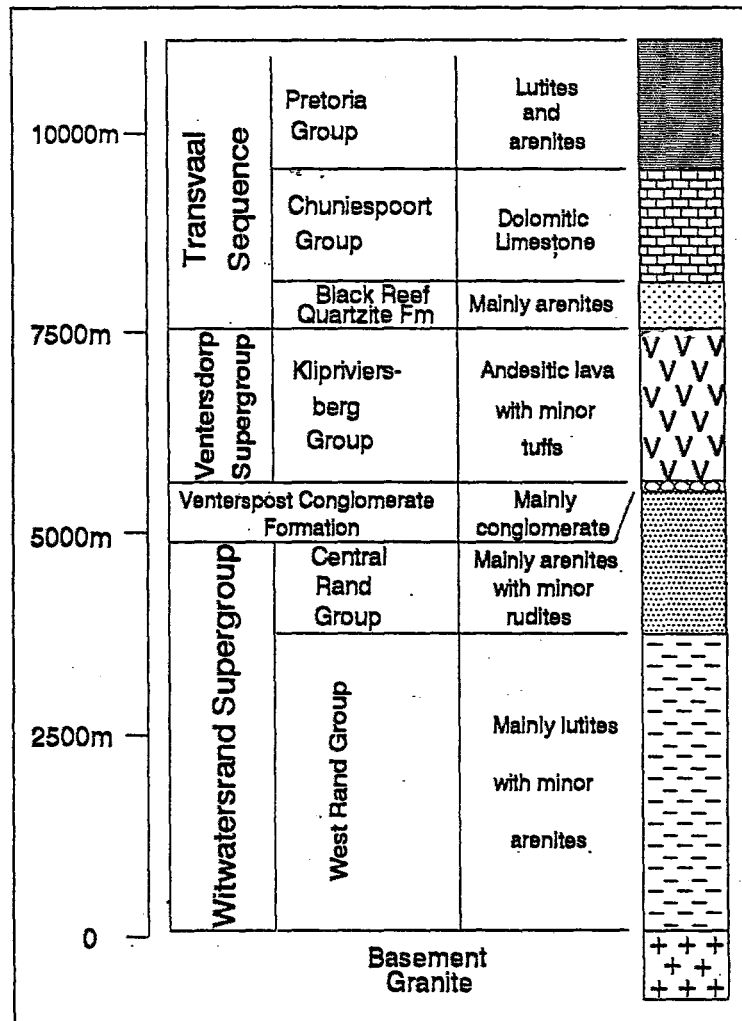


Fig. 4.3. Simplified lithostratigraphic column for the Klerksdorp area (Els et al., 1995).

4.3 Structure

The general strike of the successions (Witwatersrand, Ventersdorp and Transvaal), east and northeast of Klerksdorp, is generally northeast - southwest and dipping southeastwards. Structural boundaries are defined by a series of northeast trending grabens and horsts (fig 4.4), with a regional tendency to be downthrown to the southeast, resulting in a 5000 m thickness of Transvaal rocks to the southeast away from the area and towards the Vredefort Dome (Antrobus et al, 1986).

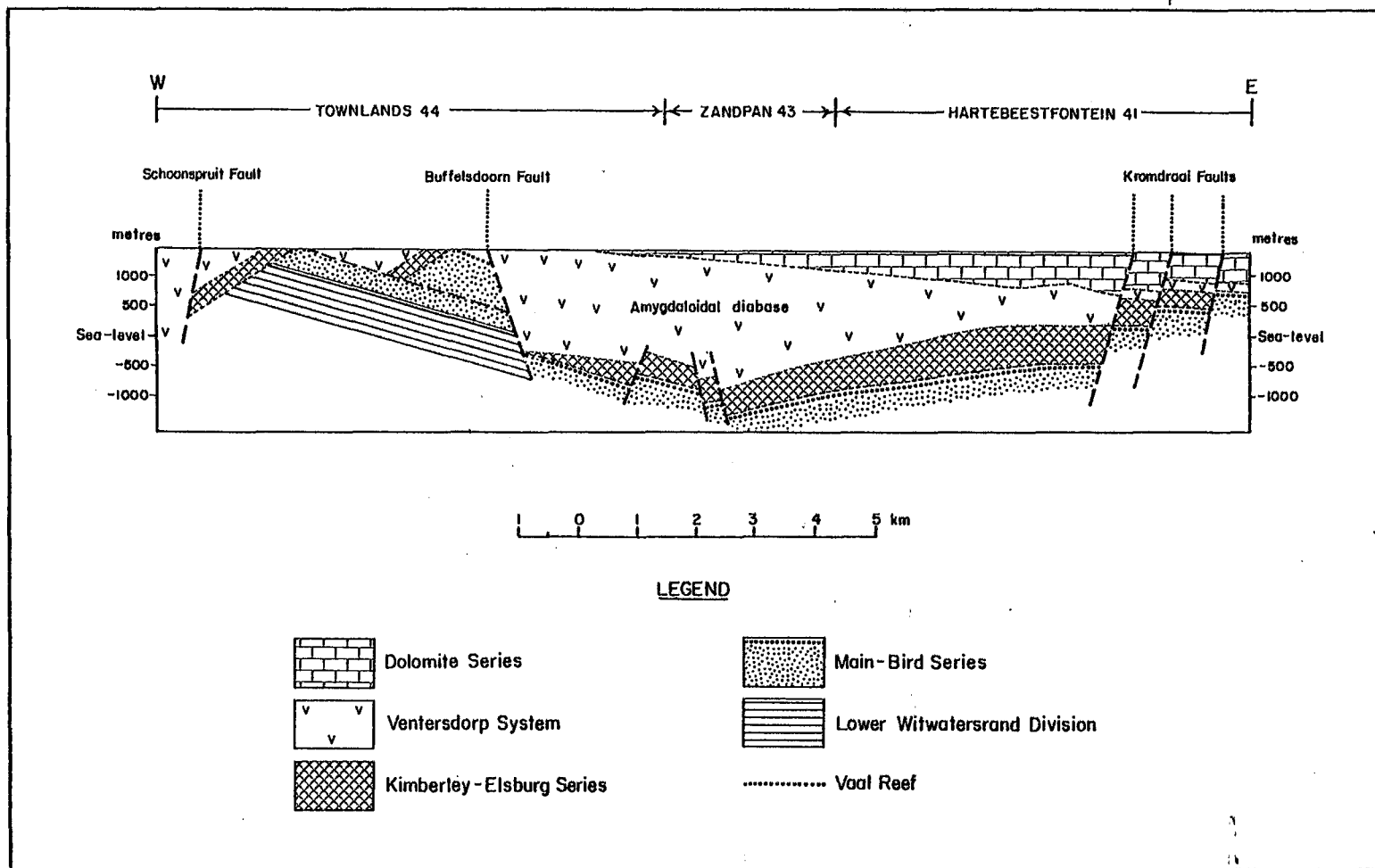


Fig. 4.4. Generalised section across the central part of the Klerksdorp gold field (Whiteside et al., 1976).

No faulting of Witwatersrand age is known with certainty. Most of the faulting is post - Klipriviersberg (early Ventersdorp) lavas and pre - Transvaal in age, the latter being much less folded and faulted than the underlying rocks (Antrobus, 1986) i.e. very little major faulting and folding occurs in the BRQF, even in areas of major underlying structural disturbance (Els et al, 1995).

4.4 Pre - Black Reef Palaeotopography

A compilation of available data was presented in Els et al., 1995; van den Berg, 1994) to compile figure 4.2. The pre - Transvaal palaeosurface is interpreted by the authors as elongate, northeast trending, partly eroded horst blocks of basement granite and West Rand Group (lower Witwatersrand) sediments and Ventersdorp lava grabens, overlying the anticline on either side of the southern arm of BRQF outcrop, which overlies a graben. The Buffelsdoorn and Kromdraai Fault trends, which define the boundaries of this graben (fig. 4.4) were extrapolated to surface from underlying gold mine structural data in Antrobus et al (1986). Notably the Black Reef basal conglomerate never overlies Witwatersrand rocks in the area (Els et al, 1986).

Van den Berg (1994) and Els et al (1995) produced computer processed trend surface maps showing thickness variations for the BRQF (fig. 4.5A) and its basal conglomerate (fig. 4.5B) in the area. Thicknesses varied between 4 and 29 m with large thickness changes over short distances in places for the BRQF. Two zero thickness contour zones (for the Black Reef conglomerate) (fig. 4.5B) trend parallel to the northern and southern Black Reef outcrops, occurring north of and southeast of these outcrops respectively. The latter zone coincides with a northeast trending belt of footwall (of Black Reef) West Rand Group rocks in figure 4.2, a probable horst block. Els et al (1995) noted that the Malmani dolomites, conformably overlying the Black Reef succession, must have been

deposited as horizontal beds and that the large thickness variations of the BRQF must therefore be "ascribed to an irregular pre - Transvaal footwall". Thickest parts of the formation would occur in palaeo - depressions.

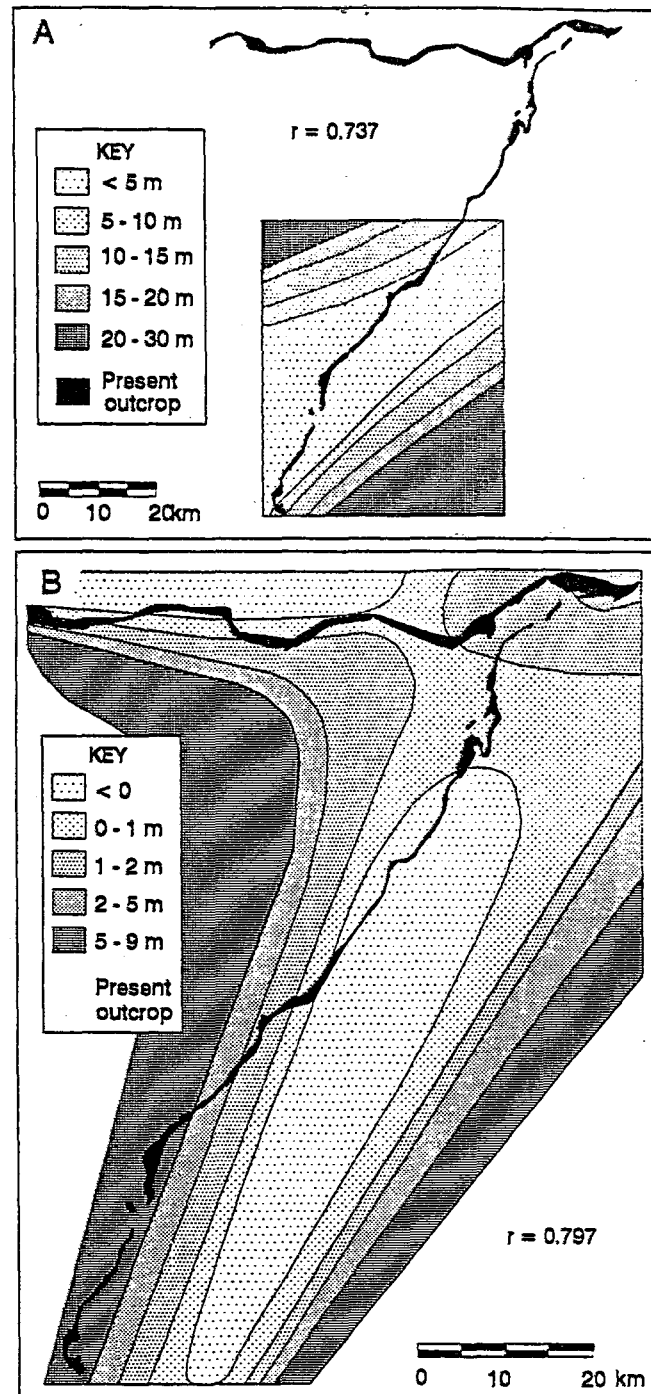


Fig 4.5 A. Second - order trend surface map showing thickness variations of the Black Reef Quartzite Formation in the southern parts of the area (Els et al., 1995), **B.** Third - order trend surface map showing thickness variations of the conglomerate unit in the area (Els et al., 1995).

4.5 Black Reef Quartzite Formation

In the Klerksdorp, Ventersdorp and Potchefstroom districts, the Black Reef Quartzite Formation comprises a thin succession of siliceous quartzites and carbonaceous shales with sporadically developed basal conglomerates (van den Berg, 1994). The package is usually informally divided into a lower Black Reef conglomerate unit and an overlying Black Reef quartzite unit.

4.5.1 The Black Reef

Where present, the basal unit consists of interbedded massive conglomerate and medium scale, planar cross - bedded quartzite (Els et al, 1995). Clasts consist of variable amounts of quartz, the dominant lithology and quartzite, chalcedony and chert. Quartzite is most common in the northern parts of the area, chalcedony in the south and chert in the central areas. Lateral clast compositions appear to be random. Clast sizes are largest in the northeastern parts of the area, where the Black Reef outcrop diverges into west - east and southwest trending branches, but no orderly lateral size variation is present. Pebble roundness is apparently random and highly variable. Els et al (1995) and Van den Berg (1994) interpret this to indicate a number of localised sources of sedimentary input along the course of a fluvial system.

4.5.2 The Black Reef Quartzite

Overlying the basal conglomerate, is a succession of usually trough cross - bedded, medium - grained, moderately mature quartz arenites. Textural maturity increases upwards to very mature quartzites near the top of the succession (van den Berg, 1994). Oscillation ripples are sometimes present at and near the upper contact of this unit. Interbedded in this siliceous unit are from one to five, variably positioned, laminated mudstones which make up about two - thirds of this unit's thickness (Els et al, 1995). Where the

lower conglomeratic unit is absent, the upper quartzitic package lies directly on footwall.

Note: A detailed description of the reef zone on Machavie Mine is given in section 4.8.1.2 to supplement the description above.

4.6 Palaeocurrent Directions

From the palaeocurrent data collected by Van den Berg (1994) separate rose diagrams were constructed for the Black Reef conglomerate and quartzite units (figs. 4.6A and 4.6B). Data was collected at only 3 stations for the Black reef conglomerate. Palaeocurrent directions were found to be unimodal.

Data collected along the northern limb of the anticline indicates a palaeocurrent direction towards the northwest. Along the southern limb of the anticline, the palaeocurrent direction is southwestwards (Els et al, 1995) and parallel to the Black Reef outcrop.

Palaeocurrent data for the Black Reef quartzite was found to be predominantly unimodal with a northerly palaeocurrent direction along the northern limb of the anticline and a southwesterly direction along the southern limb of the anticline. One bimodal distribution was found along the northern limb and two bimodal distributions along the southern limb. Dominant modes for the bimodal distributions coincide with the unimodal directions, with secondary modes in roughly the opposite directions (Els et al, 1995).

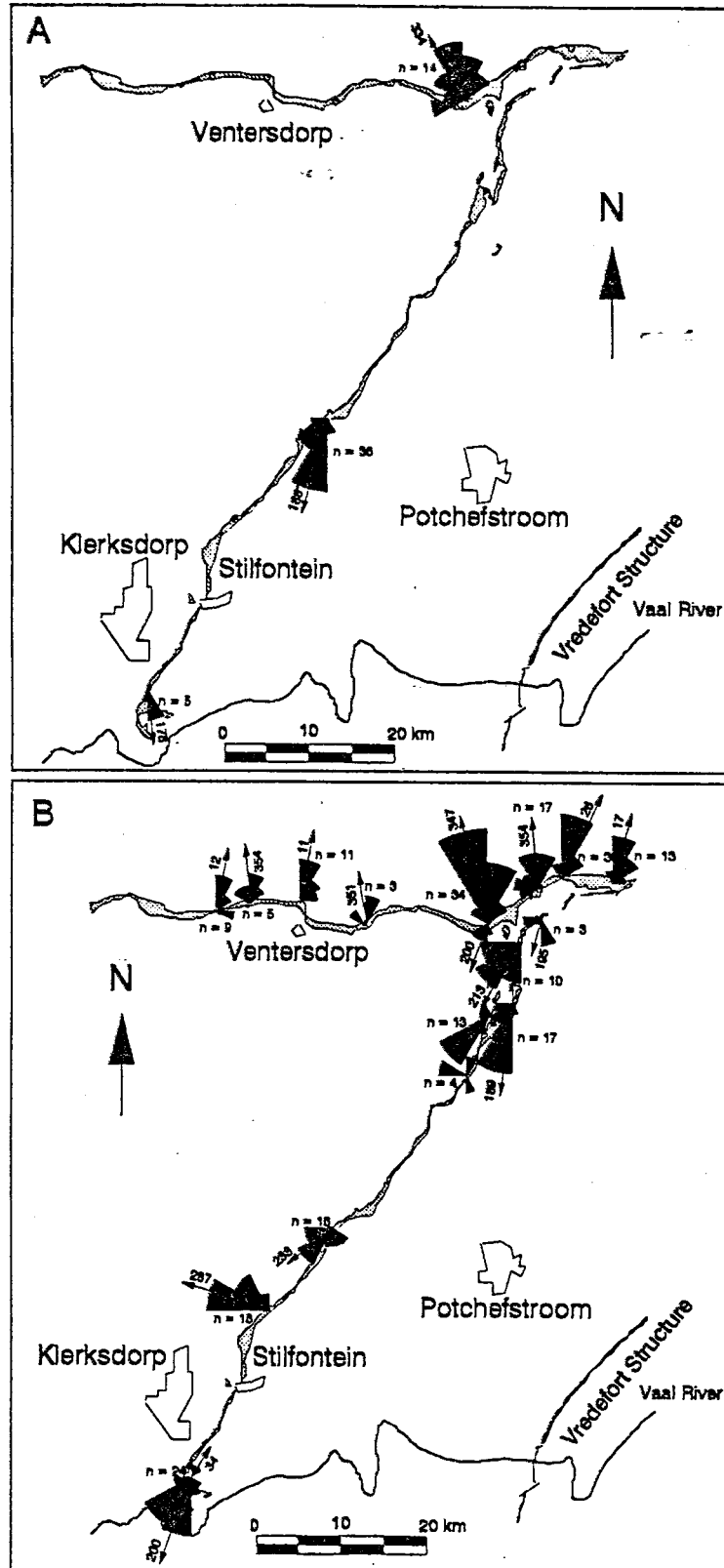


Fig. 4.6. Palaeocurrent distributions in the Ventersdorp - Klerksdorp area for A: the conglomerate unit, and B: the Quartzite Unit (Els et al., 1995).

4.7 Depositional Environment

The unimodal palaeocurrent directions found in the area for the Black reef conglomerate was interpreted by van den Berg (1994) and Els et al (1995) as indicative of a fluvial depositional environment for the unit (fig. 4.7). The differing palaeocurrent directions for the two limbs of the anticline implies a palaeodrainage divide in the northern parts of the area with a palaeo - drainage to the north on the northern limb of the anticline and a southwesterly directed palaeo - drainage along the southern limb of the anticline (Els et al, 1995).

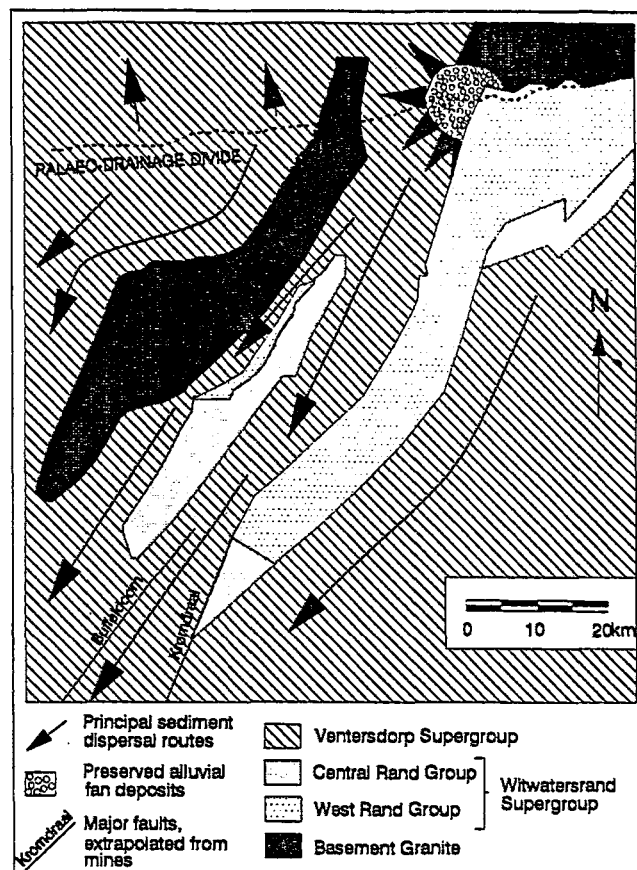


Fig. 4.7. Schematic representation of early Black Reef fluvial sedimentation in the Klerksdorp - Ventersdorp area (after Els et al., 1995).

The bimodal distributions acquired for the Black reef quartzites indicate tidally influenced ebb and flood currents, the differing directions for these along the northern and southern limbs of the anticline again implying a drainage divide between the two limbs (Els et al, 1995).

The palaeocurrent directions for the southern limb of the anticline coincide with the southwesterly trending palaeohorst and graben structures indicated on the pre - Transvaal palaeosurface (fig. 4.2). The conglomeratic unit of the BRQF was deposited by fluvial systems in southwesterly trending palaeo - grabens. Erosion of adjacent horst blocks, consisting of gold bearing Witwatersrand rocks, supplied the clastic sediments via alluvial fans to the main, southwesterly flowing drainage system (van den Berg, 1994). Palaeohydraulic reconstructions indicate maximum palaeoflows of 60 cm and flow velocities in the region of 1 m/s (van den Berg, 1994).

A marine transgression ended the fluvial conditions, indicated by the very mature (washed) upper Black Reef quartzites. The resultant base level rise, caused a diminished sediment supply to the now marine environment, resulting in the clear water conditions amenable to precipitation of the chemical sediments of the Malmani Subgroup (van den Berg, 1994).

4.8 Mining History

The Klerksdorp - Ventersdorp area was the scene of small scale mining activity from 1886, when gold was discovered at Klerksdorp, until approximately 1938. One of the reefs exploited during this time was the Black Reef. Because of its generally poor development in most of the western Transvaal, only two areas, one around Klerksdorp and the other at Machavie were actively mined (fig. 4.1) (Antrobus et al, 1986).

4.8.1 Klerksdorp -Ventersdorp Area

In the Klerksdorp area, the Black reef has been mined on Nooitgedacht 434 IP, 10 km south of Klerksdorp and on mines on the Klerksdorp Townlands. On Eleazar 377 IP, 30 km northeast of Klerksdorp, mining took place at the Machavie Mine (Hammerbeck, 1976) (Antrobus et al, 1986).

4.8.1.1 The Nooitgedacht Workings

Prospecting on Nooitgedacht 434 IP (or Nietgedacht) started in 1887. The area was mined intermittently until 1916 at a number of localities i.e. the Eastleigh, Niekerk, Ariston (Plate 1) and Southleigh mines (Body, 1988), as well as at the Quarry Hill, Warren Hill and Excelsior Mines (Antrobus et al, 1986) between 1908 and 1938. A number of small concerns operated these mines, along approximately 6 km of strike, "none of which lasted for any length of time or produced any significant quantities of gold (Table 4.1) (Antrobus et al, 1986).

Mine	Period	Production (t)	Gold (kg)	Uranium (t)	
(b) Black Reef					
Klerksdorp area	Nooitgedacht	1888-1891	20 927	267	—
	Ariston	1890-1899	45 722	719	—
	Eastleigh	1893-1898	196 859	2 922	—
	Quarry Hill	1908-1933	72 130	558	—
	Warren Hill	1909-1916	340 942	2 824	—
	Excelsior, etc	1933-1938	58 940	129	—
	Niekerk's	1895-1897	5 667	70	—
	Southleigh	1905-1911	10 400	80	—
	Southleigh	1909	4 380	28	—
Eleazar 377 IP	George Goch	1868	1 123	22	—
	Eleazar	1895	649	7	—
	Machavie	1909-1918	206 438	2 146	—
	New Machavie	1936-1943	744 377	3 001	—

Table 4.1. Tonnage mined and gold produced on the Black Reef in the Klerksdorp Goldfield (Antrobus et al, 1986).

The mines were situated along a well developed, 0.6 to 4.5 m thick, section of Black Reef conglomerate compared to the predominantly narrow quartzitic outcrop to the north and south (Papenfus, 1964). Conglomerates were medium pebble (12 - 19 mm) in size and large pebble conglomerates were sporadically found at the bases of channels, some of which were up to 4.5 m in depth (Body, 1988). The best gold values were found in the deepest channels. Pebbles are rounded, disc - shaped or ellipsoid and are predominantly quartz with minor chert and quartzite clasts. Fine, nodular and buckshot pyrite is a common constituent (Papenfus, 1964). Nel (1935) regarded the source of the pebbles to be from the Gold Estate Reefs (Kimberley Formation) which outcrop to the west.

The reef dips 10 - 15 degrees to the east and overlies soft, weathered Ventersdorp lavas. Stoping took place to a maximum 120 m downdip where values became unpay (Papenfus, 1964) (Hammerbeck, 1976). From a total of 756 000 tons of mined ore, 7600 kg of gold was produced at an average grade of 10.05 g/t (figures totalled from Antrobus et al, 1986).

4.8.1.2 The (New) Machavie Area

The area was mined intermittently between 1888 and 1943. The best reef development was on the farm Eleazar 377 IP, located 32 km northeast of Klerksdorp (fig. 4.1), where several companies operated the Machavie Mine over the years (fig. 4.8). Mining of the Black Reef by the New Machavie Mining Co. Ltd, commenced in 1904. The New Machavie Mine stoped the lode along strike for 1 km and mining reached a vertical depth of 150m. The highly pyritic ore reached values of 50 to 60 g/t Au. 55% of the gold occurred free (Frankel, 1939 in Hammerbeck, 1976). Although records are incomplete approximately 5200 kg of gold from ~1 Mt of ore was produced. Some of this ore was, however, probably mined from the Buffelsdoorn Mine (fig. 4.1), so total gold produced is probably somewhat less than stated (Antrobus et al, 1986).

The Black Reef in the area strikes northeast - southwest and dips 8 - 10° to the southeast. Two dykes cross the area as well as a number of oblique faults (fig. 4.8). The reef overlies Ventersdorp lavas and sediments (Antrobus et al, 1986).

Three northeast to southwest trending channels were mined in which basal conglomerates up to 6.5 m thick occur. High grades were found in these clast - supported conglomerates, especially where much buckshot pyrite is present (Body, 1988). Clasts are predominantly vein - quartz with minor amounts of chert, quartzite, quartz porphyry, shale, lava and agate. They are 15 - 20 mm in size and angular to subangular. Large, well rounded clasts often occur at the basal contact (Antrobus et al, 1986). Above the basal conglomerates, a zone of argillaceous quartzites and barren shales of variable thickness occurs, which is in turn overlain by a 50 cm wide, locally well mineralised conglomerate with high gold values. Overlying this conglomerate is an up to 20 m thick zone of dark grey quartzites and carbonaceous shales (Antrobus et al, 1986) (Body, 1988).

Gold recovery at the Machavie Mine was always poor, due to the presence of carbon, marcassite and pyrrhotite in the reef. The carbon tends to reabsorb gold whilst the pyrrhotite and marcassite oxidise rapidly into thiosulfate and sulphite, which are cyanicides (Body, 1988).

4.8.1.3 The New Ventersdorp Gold Mine

This mine is located 5 km to the east of Ventersdorp, on the farm Palmietfontein 189 IP (figs. 4.1 and 4.9). Mining activity took place between 1896 and 1899 (van den Berg, 1994). The Black Reef does not outcrop along the rim of the Witwatersrand basin but along the southern rim of the Transvaal "Bushveld" basin. Dip of the reef is therefore, generally to the north. Some of the areas stoped have a eastwards dip due to local faulting and folding (Papenfus, 1964).

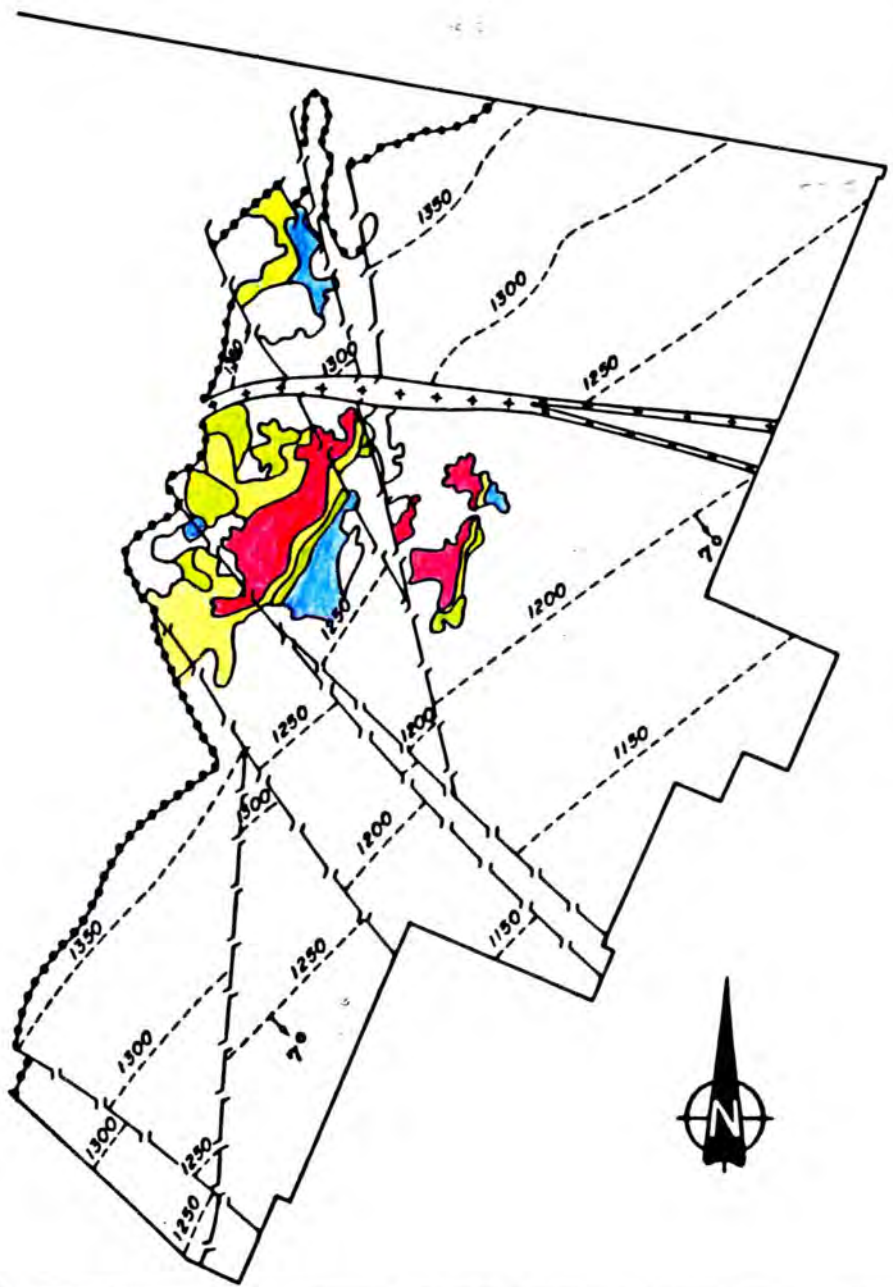
The Black Reef overlies Ventersdorp lavas in the area. Quartzites, tuffs and volcanic Rietgat conglomerates outcrop to the south (Papenfus, 1964). At least 0.7 kg of gold was produced (Body, 1988). Fair quantities of platinum group metals were reported by a Dr. Zermatten to occur in the tailings dumps of the mine (Papenfus, 1964).

4.8.2 Other Mining Operations

Approximately 35 km northeast of the Machavie Mine area, further north along the continuous Black Reef outcrop, mining activity has taken place on a number of farms. In this district, Black Reef conglomerates have been worked on Katdoornbosch 138 IQ where at least 0.5 kg of gold was produced (Body, 1988), Du Toit Spruit 137 IQ and Rietvallei 130 IQ (fig. 4.1) (Papenfus, 1964). Production figures at the two latter farms are unavailable (Body, 1988).

On the farm Drylands 132 (Drylands 64 IQ), located 40 km east of Ventersdorp, the Mooi River Prospecting and Development Syndicate, and then the Primus Gold Mine, produced a total of 9.7 kg gold (Body, 1988).

On Wolvenfontein 74 IQ, located 28 km east of Ventersdorp (fig. 4.1), 4.1 kg of gold was produced.



LEGEND	
REEF THICKNESS	
	No data
	< 50 cm
	50 - 100 cm
	100 - 150 cm
	> 150 cm
	Fault
	Dyke
	Black reef contour and 1
	Black reef outcrop

ISOPACH AND STRUCTURE PLAN OF THE BLACK REEF ON NEW MACHAVIE MINE

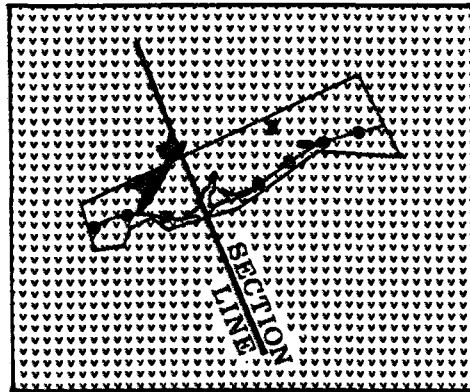


Metres
SCALE 1:20 000




AFTER: Mineral Deposits of Southern Africa, p 596; J BODY 1988

THE NEW VENTERSDORP MINE

SCALE 1:50 000



LEGEND

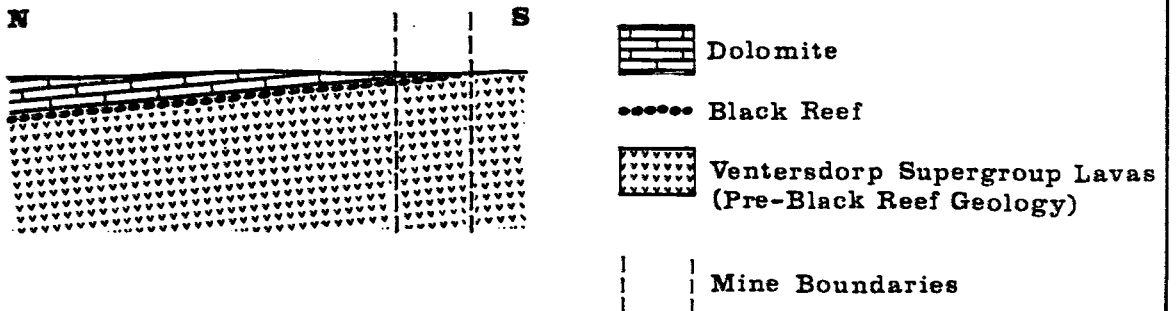
-  Stopped out on Black Reef
-  Black Reef Outcrop
-  Venterdorp Supergroup Lavas (Pre-Black Reef Geology)

After Papenfus, 1964 & Body, 1988

**SCHMATIC SECTION
ACROSS THE NEW VENTERSDORP MINE
LOOKING EAST**



LEGEND



CHAPTER 5

5 BLACK REEF ON THE WEST WITS LINE

There is no real history of Black Reef mining on the West Wits line. The area will therefore not be discussed in detail. A few points, pertinent to the Black Reef, are discussed.

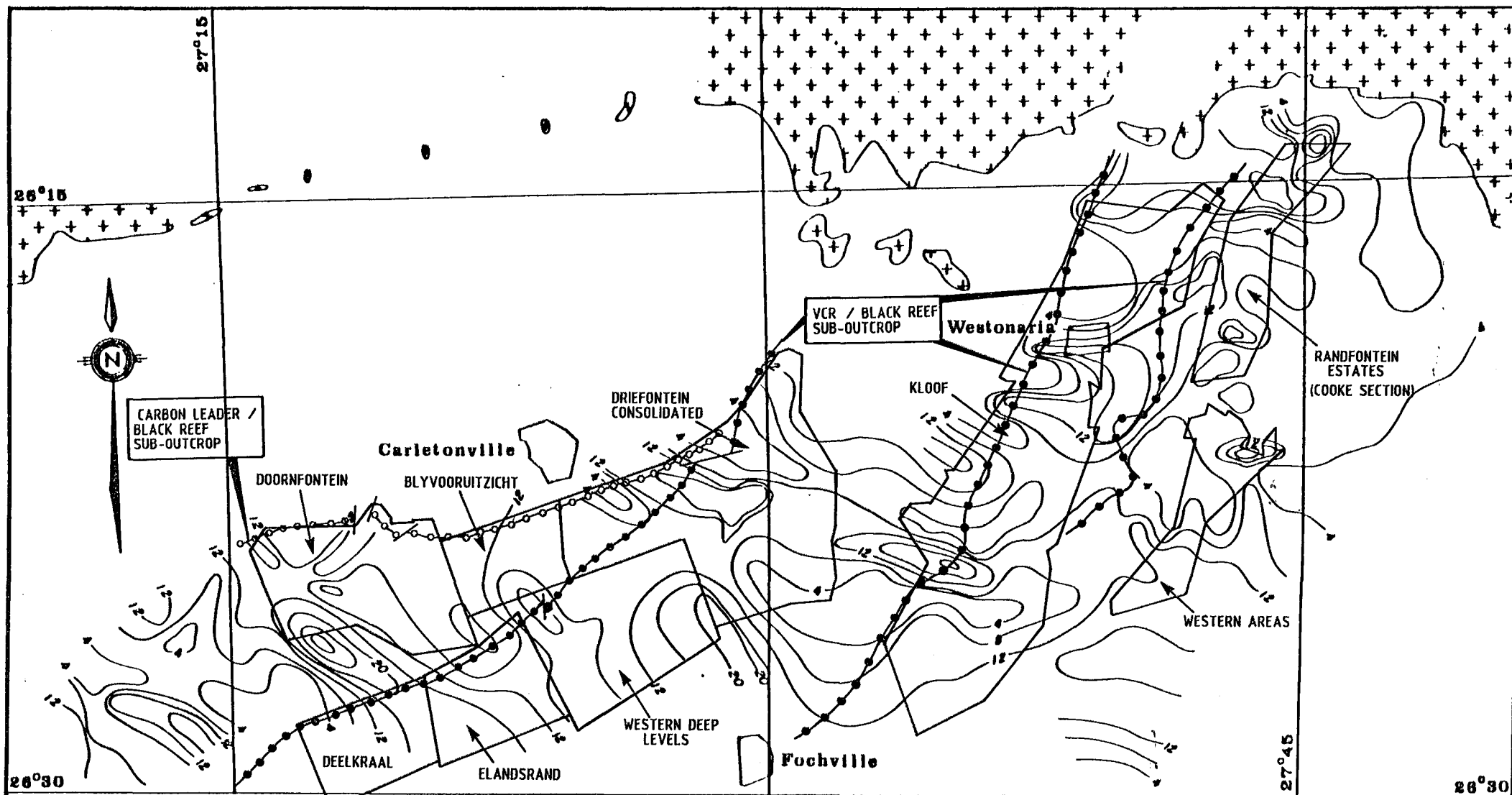
For a comprehensive review of the geology and previous work of the area, the reader is referred to De Kock (1964) with updated information in Engelbrecht (1986).

5.1 Geology

The area lies on the southern slope of the Rand Anticline, south of a line between the Klerksdorp Goldfield in the west and the West Rand Goldfield to the east (Engelbrecht et al., 1986). It overlies the northern boundary of the Potchefstroom Synclinorium with the general succession dipping south and southeastwards (Plate I).

The BRQF is exposed in two areas. It outcrops along the southern fringe of the west - east trending Rand Anticline, and it has been exposed underground on the West Wits gold mines to the south and southeast of this area.

Along the Rand Anticline, the BRQF dips southwards, overlies basement granite, and underlies progressively thicker Chunniespoort Group dolomites to the south. On the mines of the West Wits Line, due to pre - Transvaal tectonics, peneplanation and post - Transvaal, southward tilting of the area, the BRQF overlies suboutcropping Central Rand Group sediments which include the richly auriferous Carbon Leader Reef (fig. 5.1). South of this suboutcrop, the BRQF overlies the suboutcrop of the auriferous Ventersdorp Contact Reef (VCR) and the Ventersdorp Supergroup lavas.



LEGEND

- Contour Interval - 4 metres
- + + Pre-Black Reef Rock Types

POTCHEFSTROOM SYNCLINORIUM - SUB AREA B

Black Reef Member Isopach Map

(After Eriksson, 1972; Body, 1988)



Figure 5.1

East of this area on Kloof, Randfontein and Western Areas Mines, the BRQF similarly intersects the VCR. The BRQF has an angular unconformity with the underlying successions of 15° to 20° in the western sector of the area and 30° to 40° in the eastern sector (De Kock, 1964).

In the area, the BRQF consists of a lower quartzite, a sporadically developed basal conglomerate and an overlying zone of interbedded quartzite and shale bands (fig. 6.4) (Engelbrecht, 1986) which form a transitional contact with the overlying Malmani dolomites.

5.2 Morphology and depositional environment

Using available borehole data, Eriksson (1972) compiled a isopach map of the BRQF thickness on the mine properties and surrounds. This indicated a 'lensoid geometry' and thickness of 4 to greater than 28 m for the BRQF (fig. 5.1). The thickest zones coincided with elongate, southeast trending depressions in the footwall of the BRQF. Eriksson (1972) concluded that these are incised channels. Away from these depressions, clastic sediments were mostly absent, with a thin seam at the base of the Malmani dolomites "probably" representing the BRQF succession. The depositional environment was considered by the author, to be a braided fluvial environment, which was followed by transgressive conditions resulting in deposition of the shales and later carbonate sediments.

5.3 Mining and exploration

Since the incised Black Reef channels intersect the high grade, auriferous Carbon Leader and VCR, potential for economic Black Reef channel deposits should be high. The point is of academic interest only at present, since the Black Reef is considered to be a hindrance to mining on the deep Witwatersrand gold mines. The unoxidised state of the ore, interferes with the metallurgical processing of the Witwatersrand ore. Its high carbon

content, resorbs the gold, resulting poor extraction results. Black reef is therefore avoided at all costs, as it cannot be mixed with Witwatersrand reef ores and is uneconomic to process independently at present.

The Black Reef has been extensively prospected along its outcrop on the Rand Anticline. Numerous boreholes, drilled to intersect Witwatersrand reefs, have intersected the BRQF as well. The Black Reef, although frequently well mineralised, has low or trace gold values (De Kock, 1964).

CHAPTER 6

6 BLACK REEF ON THE WEST RAND

6.1 West Rand

This area is located approximately 40 km west of Johannesburg in the Randfontein area, on the western boundary of the Johannesburg Dome (fig. 6.1). It overlies the southern limb of the anticlinal warp (Rand Anticline) (fig. 6.1) separating the main "Bushveld" basin from the subsidiary basin overlying the Witwatersrand basin (Plate 1). The present day watershed, separating major northwards and southwards drainage overlies this area. A similar drainage divide, separating the two basins may have existed in pre - Transvaal times in the same area. Large areas of horizontal, outcropping Black reef with outcropping tongues and inliers of steeply dipping, underlying Lower and Upper Witwatersrand rocks occur in the area (fig. 6.3) (Papenfus, 1964) (Mellor, 1917). Truncation of the pre - Black Reef succession to the southeast by the Witpoortjie and Panvlakte/Roodepoort faults (fig. 6.2) has resulted in a triangular shaped block of Witwatersrand sediments that is detached from the Central Rand to the southeast and the West Wits Line to the southwest (Whiteside et al. 1976). Preservation of the Black Reef is largely due to the flat dip and hardness of the Black Reef quartzite which acted as a protective cap (Mellor, 1917).

6.2 Previous work

Mellor (1913) mapped the geology of the West Rand. Toens and Griffiths (1964), incorporating information from previous authors, described the geology and structure of the West Rand, and briefly described the Black Reef. Swiegers (1938) concluded from his studies on the New Machavie and Randfontein Estates Mines, that where the Black Reef is economic, hydrothermal enrichment of the gold has taken place. Papenfus (1964) briefly described the Black Reef geology at Randfontein Estates. Shaw

(1994) discusses the geology, opencast mining and evaluation of the Black Reef at Lindum Reefs on the Randfontein Estates property. The latter two authors conclusions are discussed in the text below.

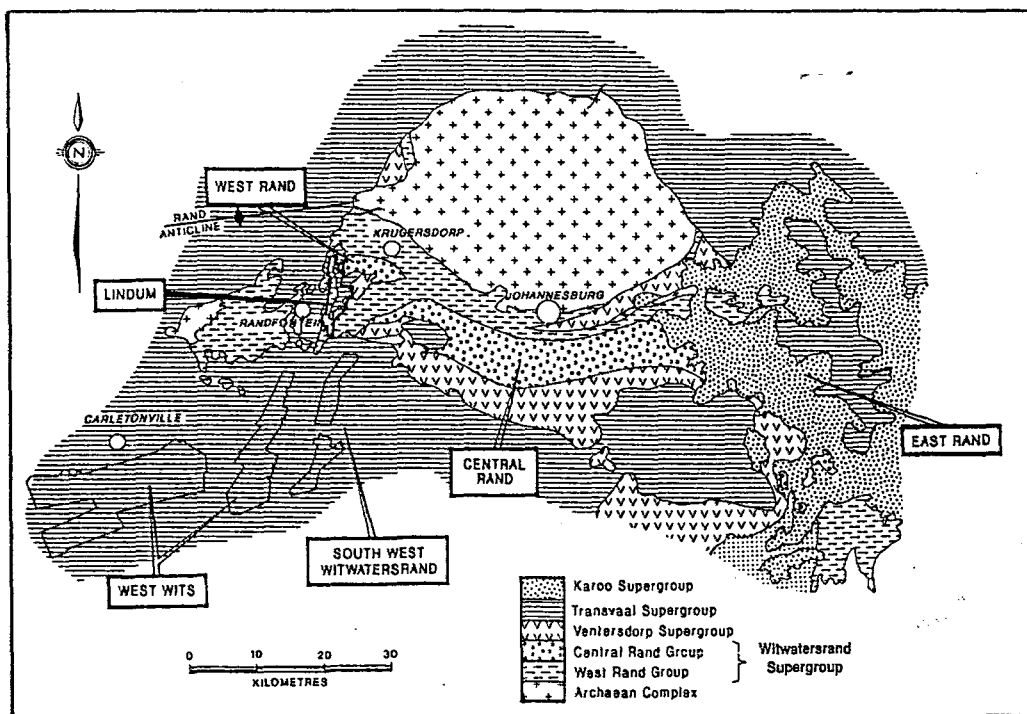


Fig. 6.1. Regional geology and the location of Lindum Reefs Gold Mine (Shaw, 1994).

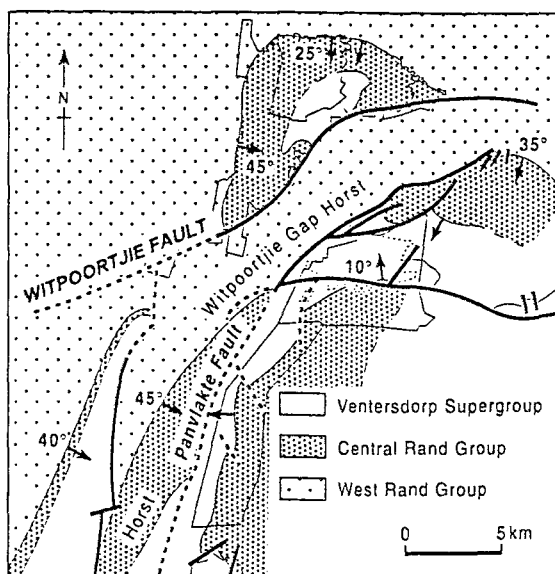


Fig. 6.2. Sub - Transvaal geology of the West Rand (adapted from Lednor, 1986).

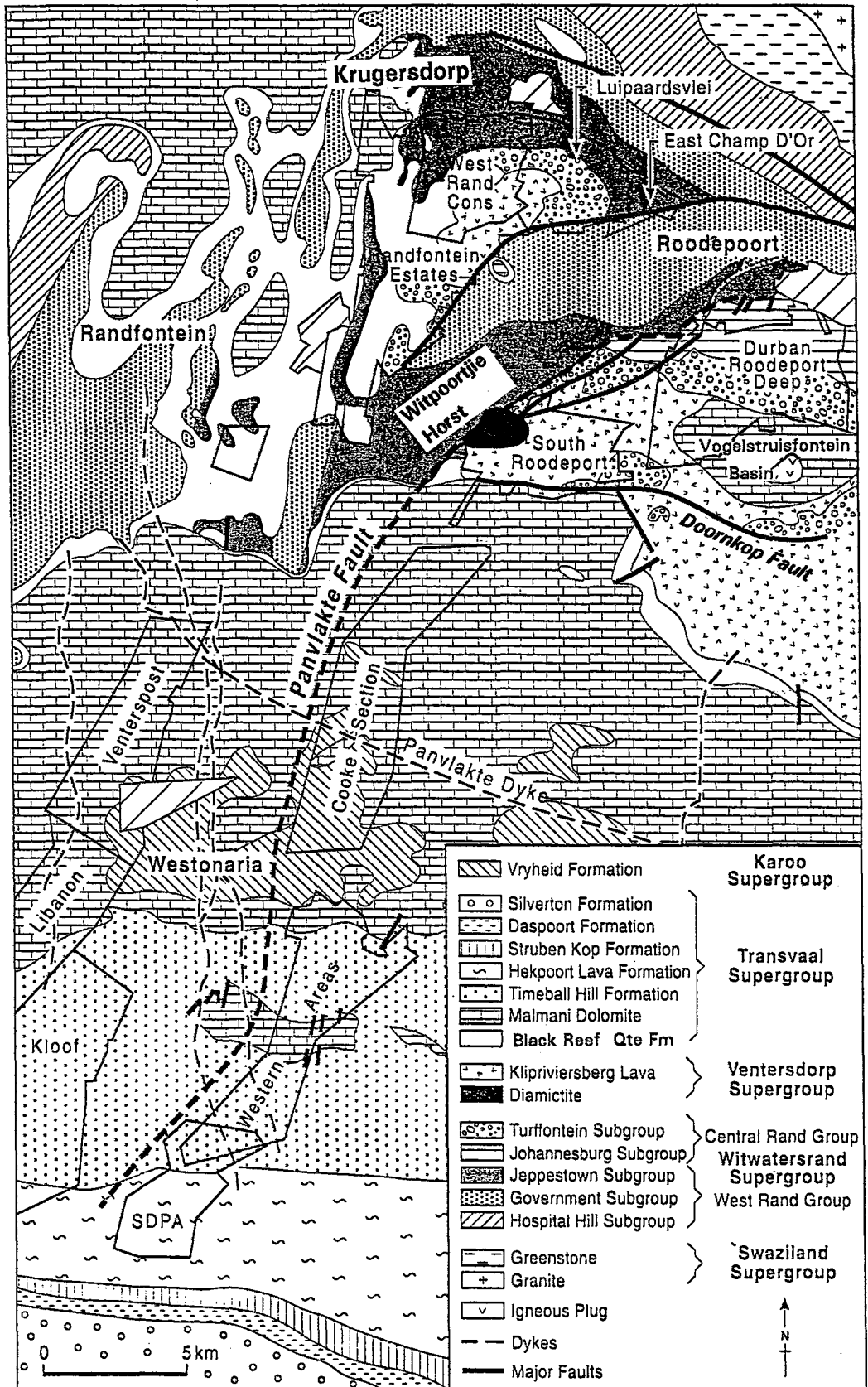


Fig. 6.3. Surface geology of the West Rand (adapted from Stewart, 1981).

6.3 West Rand Geological Setting

On the West Rand, the "entire area was peneplaned in post - Ventersdorp time". Deposition of the BRQF took place on this surface (Tucker and Viljoen, 1986). The BRQF forms a major unconformity with the Ventersdorp Supergroup and older successions (fig. 6.4) (Shaw, 1994). Between Krugersdorp in the north and Randfontein, to the south - southwest, a distance of 10 km, a major southeast plunging, near symmetrical syncline of Witwatersrand sediments with some overlying Ventersdorp rocks occurs (fig. 6.2) (Whiteside et al, 1976). The conglomerates of the Central Rand Group therefore form a "crescentic" - shaped suboutcrop pattern with the overlying BRQF. The western limb dips approximately 65 degrees east and the northern limb dips 25 degrees south (Toens and Griffiths, 1964). On the southeast side, this syncline is truncated by the major, northeast trending, steeply northwest dipping, Witpoortjie Fault (fig. 6.2) (Whiteside et al, 1976). This pre - Black Reef, post - Ventersdorp fault has a variable downthrow to the northwest of between 300 m south of Randfontein, a maximum of 3050 m on the southern boundary of REGM (Whiteside et al, 1976) and approximately 1800 m on the eastern boundary of the Luipaardsvlei Estate property. From northwest of Krugersdorp, southeastwards across the area, the BRQF transgresses basement granite, followed by the West Rand Group, the Central Rand Group and inliers of Ventersdorp rocks (Papenfus, 1964) up to the Witpoortjie Fault. All Black Reef mining of any importance in the West Rand has occurred in areas overlying this syncline, termed the West Rand Triangle by Whiteside et al (1976). The Witwatersrand strata thickens towards the fold axis of the syncline and also down - plunge to the southeast, indicating a transport direction predominantly from the north. This thickening resulted from the tendency to fill up the basin during deposition (Toens and Griffiths, 1964).

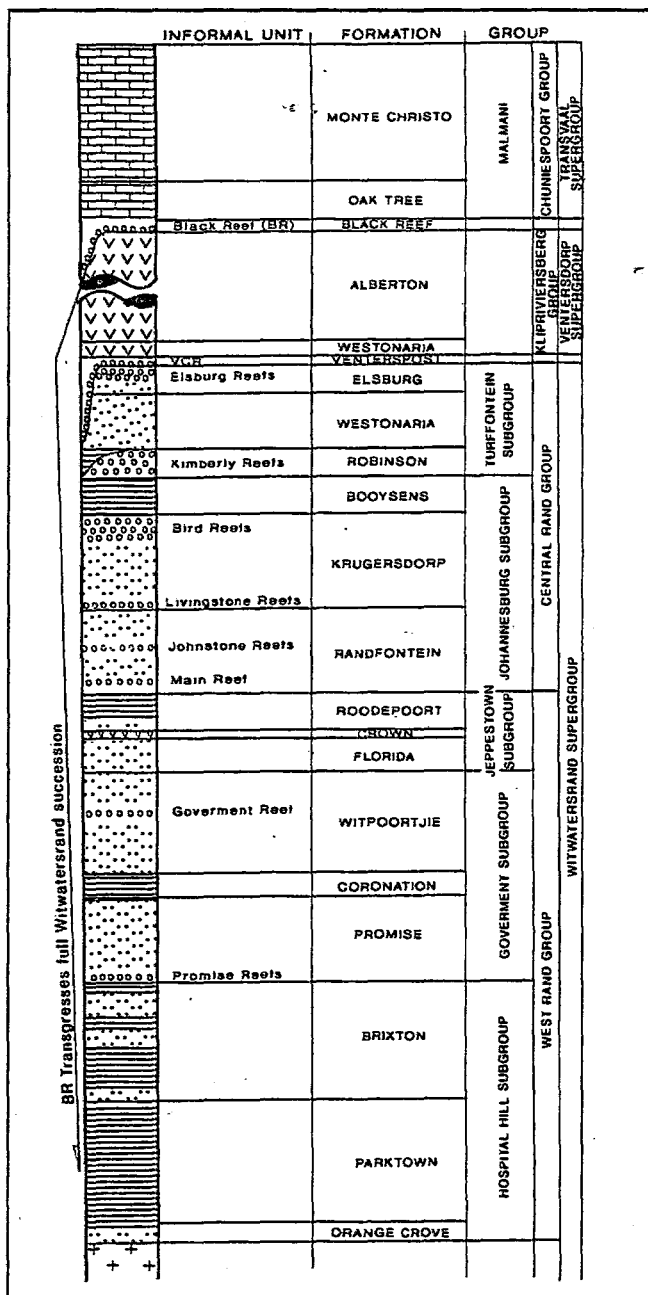


Fig. 6.4. Type stratigraphic column of the West Rand (Shaw, 1994).

The Randfontein Estates Gold Mine (fig. 6.5) is situated along the north - south trending, east dipping, western limb of the aforementioned syncline. This limb has been duplicated to the west by movement on the north - south trending, pre - Black Reef West Rand Fault (Mellor, 1917).

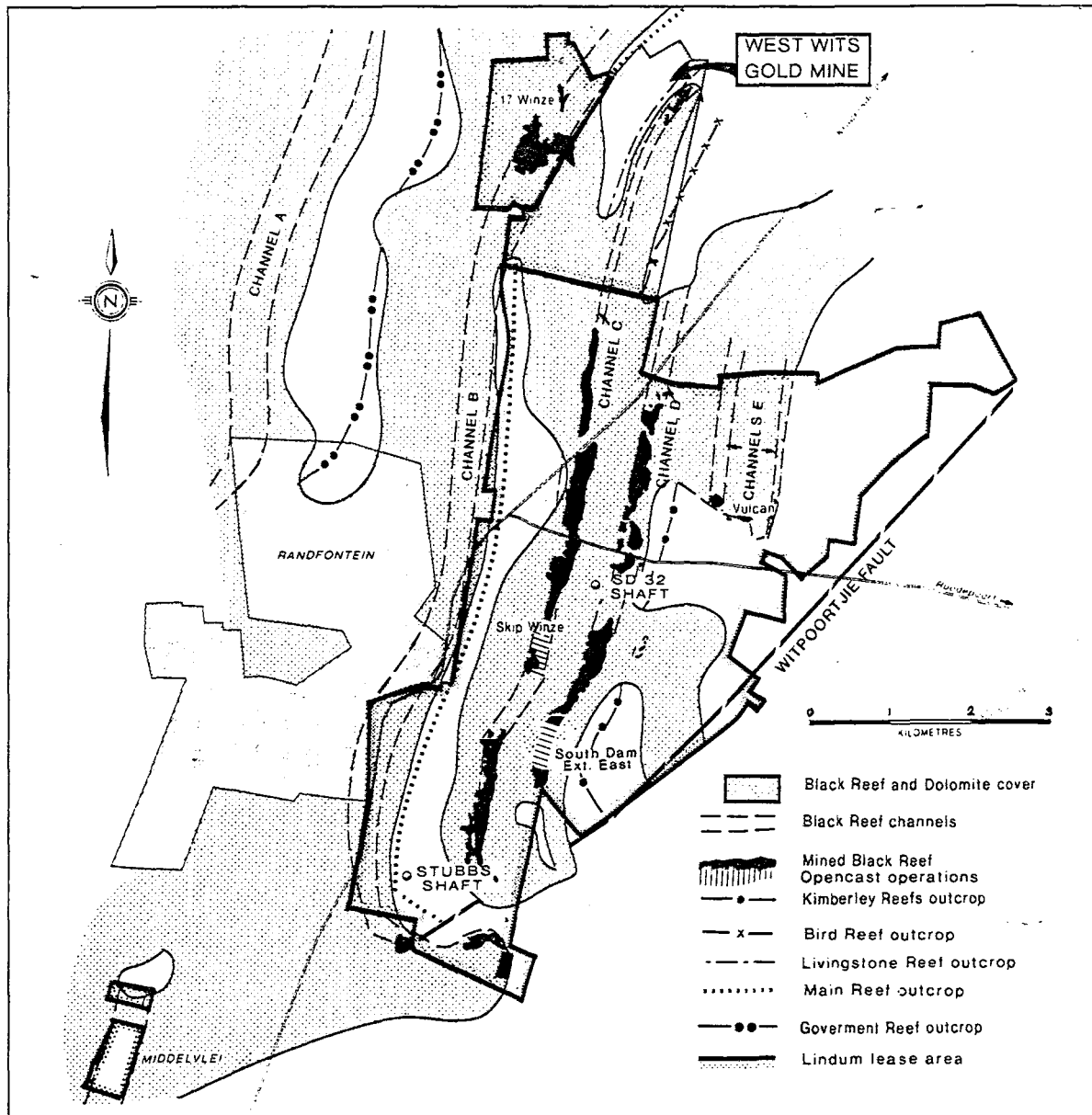


Fig. 6.5. Randfontein Estates/Lindum Reefs Gold Mine and the localities of the Black Reef channels (Shaw, 1994).

Southeast of the Witpoortjie Fault, the area is underlain across a 4 km wide zone, by upthrown, shallowly southwards dipping West Rand Group sediments which are truncated by the northeast trending Roodepoort Fault with its 750 m downthrow to the north (Whiteside et al, 1976). This zone is known as the "Witpoortjie Break" (Mellor, 1917) (Toens and Griffiths,

1964) or Witpoortjie Horst. The Durban Roodepoort Deep and South Roodepoort Gold Mines are located southeast of this horst on Central Rand Group sediments and the overlying Ventersdorp Supergroup. This block of ground terminates against the west - east trending Doornkop Fault on the southern boundary of the South Roodepoort property (fig. 6.3). South of this fault, the thin strip of outcropping BRQF, unconformably overlying Ventersdorp lavas, dips gently southwards under a progressively increasing thickness of Transvaal dolomites overlying the Witwatersrand basin proper.

The west - east trending, 6 km by 3 km, Vogelstruisfontein basin (Papenfus, 1964) forms an outlier of Transvaal dolomites in Central Rand Group rocks (Mellor, 1917), a few kilometres east of the South Roodepoort property (fig. 6.3). The Black Reef outcrops around the rim of this basin, dipping moderately to steeply inwards, and reaching a depth of possibly 700 m or so in the centre. Bushveld Complex rocks have intruded the basin. Prospecting activities around the rim have located no economic Black Reef (Papenfus, 1964).

6.4 Black Reef Structure

On the West Rand, major faulting of syn- or post- Ventersdorp age has had no major influence on the BRQF. There is however evidence of minor movement. A displacement of 4 m on the Black Reef has been observed across the major Witpoortjie Fault at REGM (Mellor, 1917) (Papenfus, 1964). Outcrop mapping on the West Rand and drilling in the southern dolomite covered areas, has indicated little effect on the Black Reef by the major faults in the area, such as the Witpoortjie and Roodepoort faults (Papenfus, 1964). Although virtually no faulting occurs on the Black reef, thrusting occurs in the upper quartz arenite units, some of which may have been duplicated (Shaw, 1994).

Post - Transvaal, northeasterly directed compression caused mild folding in the BRQF (Toens and Griffiths, 1964) resulting in "minor flexures and

basins" (Papenfus, 1964). Shaw (1994) found intensely deformed areas of Black reef on the Randfontein Estates property, consisting of closed and overturned, northeast - southwest aligned, northwest verging folding at the base of the formation. This second phase is ascribed to gravity sliding on the "Black Reef Decollement Zone" associated with late uplift of the Rand Anticline by Fletcher and Reimold (1989). The earlier, northeasterly directed (northwest trending) compressional folding is ascribed to the Vredefort event by McCarthy et al. (1990).

Evidence of faulting on the Black reef channel margins, which is confined to and overlying the Booyensens shale (fig. 6.6) in the South Dam Extension East area on the Randfontein Estates property, implies uplift and erosion of the BRQF outside the main channel, caused by a post - Transvaal compressional event. This resulted in the preservation of the Black reef main channel over the Booyensens shale (Shaw, 1994).

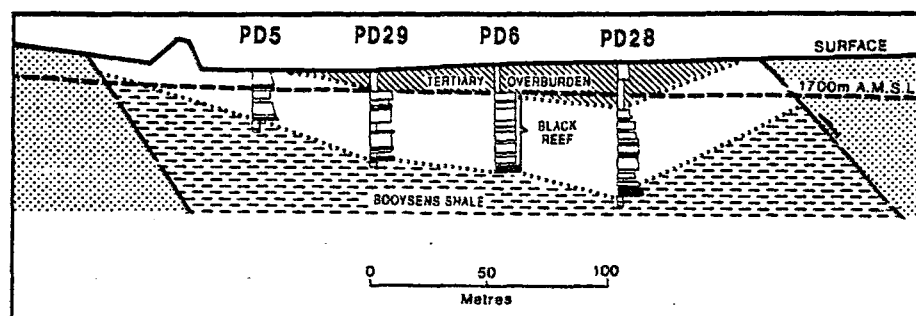


Fig. 6.6. Section through the South Dam Extension East channel (Shaw, 1994).

6.5 Pre - Black Reef Palaeotopography

The Black Reef is best developed in depressions which strike parallel to the footwall Witwatersrand succession (Toens and Griffiths, 1964) (Papenfus, 1964). According to Germs (1982) in Shaw (1994), the steeply dipping, Witwatersrand succession underlying the Black Reef on the Randfontein Estates property, resulted in a palaeotrellis drainage system with the Black

reef conglomerates confined to narrow, north - south aligned channels (fig. 6.5) between the competent, topographically positive conglomeratic horizons. At the South Dam Extension East site, the Black Reef channel was found to have a gently eastwards dipping footwall with the deepest part of the channel near the eastern flank (fig. 6.6) (Shaw, 1994).

6.6 Stratigraphy

6.6.1 Black Reef Footwall Succession on REGM

The regional footwalls succession is discussed in section 6.3 above. The relevant footwall succession pertaining to economic Black Reef on REGM consists of the eastwards dipping auriferous Central Rand Group sediments. Dips vary from 80° on the Main Reef on the west side to 45° in the east on the Kimberley Reefs (Shaw, 1994). According to Whiteside et al (1976), twenty different Central Rand Group reefs have been mined for gold and/or uranium in the West Rand Triangle. These make up 5 main major reef zones or groups (fig. 6.7) with the Ventersdorp Contact Reef (VCR) as a sixth. This, according to Sharpe (1949) in Toens and Griffiths (1964) and Papenfus (1964) is the source of the Black reef gold on the West Rand which has not been transported far from its source of supply.

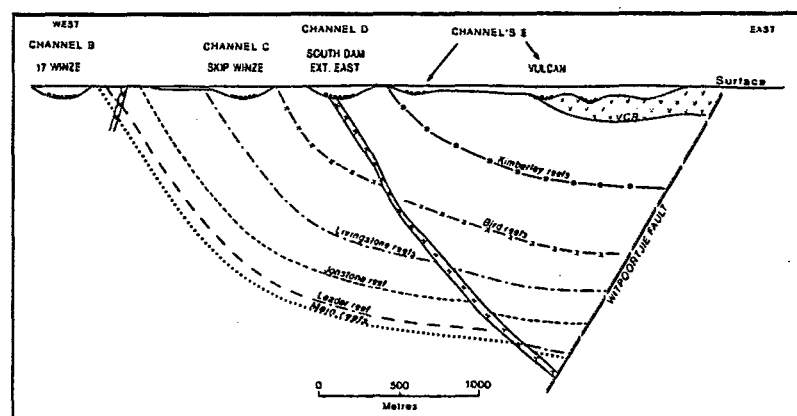


Fig. 6.7. Idealised section through Lindum Reefs Gold Mine (Shaw, 1994).

The Black Reef channels occur in the topographically negative, comparatively soft, successions between these reef zones (fig. 6.7) (Shaw, 1994).

6.6.2 Black Reef Quartzite Formation

In the Randfontein area, the BRQF consists of a typically 20 m thick, fining upwards, increasingly argillaceous upwards package of alternating quartz arenite and shales (fig. 6.8) (Mellor, 1917) (Shaw, 1994) with the amount of shale frequently predominating (Mellor, 1917). A conglomerate is sometimes present at its base. It has a gradational contact with the overlying Oaktree Formation dolomites of the Malmani Subgroup of the Transvaal Sequence (Shaw, 1994). A similar description for the succession is given by Toens and Griffiths (1964) for the South Roodepoort area with the shales being described as "black and highly fissile".

6.6.2.1 Black Reef

In the Randfontein area, the Black Reef is a channel facies. In the South Dam Extension site on the Randfontein property, the "typical, normal Black Reef" is described by Shaw (1994) as consisting of a bottom, 5 cm to 75 cm thick, small to medium pebble conglomerate. The conglomerate contains a series of upward fining cycles. Because of oxidation of the pyritic matrix, the conglomerate is often friable near its base. Sometimes there is some difficulty in distinguishing between the Black Reef and the underlying Witwatersrand conglomerates (Mellor, 1917).

On the South Roodepoort property, the Black Reef is a small pebble, lenticular conglomerate with sporadic, generally low tenor gold values. Occasionally high gold values occur (Toens and Griffiths, 1964) and is probably a channel facies (Authors opinion).

6.6.2.2 Black Reef Quartzite

In the Randfontein area, an up to 1 m thick, coarse - grained quartz arenite "hardcap" (fig. 6.8) overlies the basal conglomerate. Overlying this quartzite, the individual alternating arenaceous and argillaceous units are up to 0.5 m thick near the bottom of the package and thin progressively upwards towards the top (Shaw, 1994). The Black Reef quartzite of the South Roodepoort area is dark, highly siliceous and indurated, has a variable thickness and contains shales (Toens and Griffiths, 1964). The Black Reef quartzite is laterally continuous between channels.

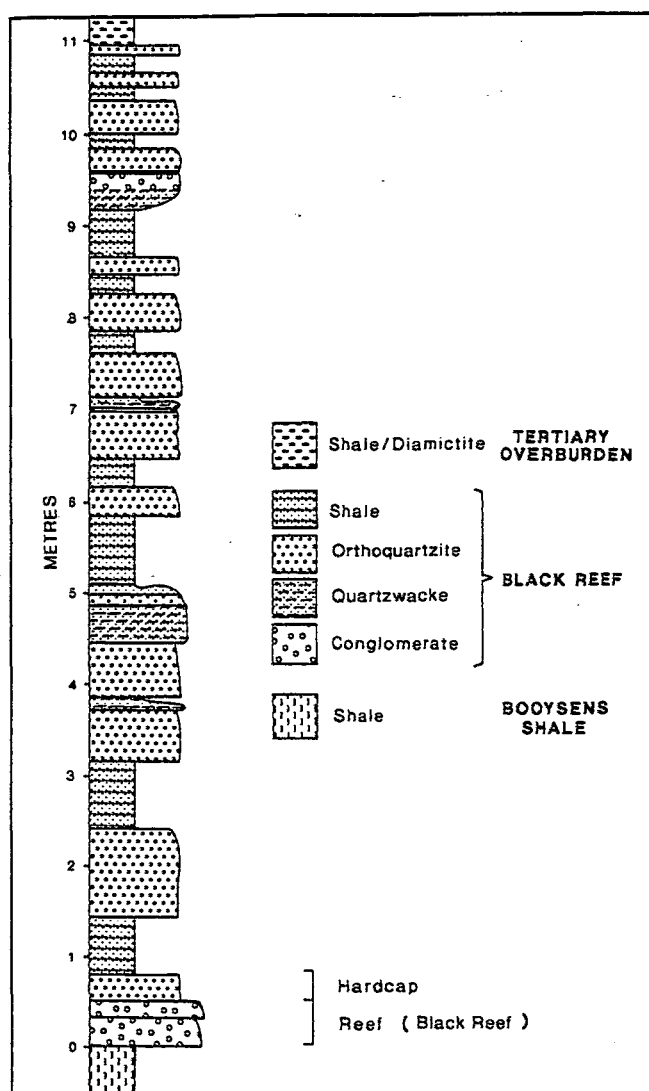


Fig. 6.8. Black Reef Quartzite Formation stratigraphy at the South Dam Extension East site (Shaw, 1994)

6.7 Black Reef Channels

According to Shaw (1994), five main channels (fig. 6.7), associated with the underlying Witwatersrand succession, have been recognised on the Randfontein Estates property. From west to east across the property, these are:

- (1) West of the Government Reefs on the West Rand shales.
- (2) West of the Main Reef on the Jeppestown shales.
- (3) Between the Livingstone and Bird Reefs.
- (4) Between the Bird and Kimberley Reefs on the Booyens shales.
- (5) East of the Kimberley Reefs.

Papenfus (1964) found the best gold values to be present in the channel over the Booyens shale "with a parallel zone" over the footwall of the Bird Reefs. A "less persistent trend" was found over the Jeppestown Shales.

According to Shaw (1994), most of the mining at Lindum Reefs is taking place on the Livingstone - Bird reefs channel in the Skip Winze area (fig. 6.5) and the Booyens Shales channel (between the Bird and Kimberley Reefs) in the South Dam Extension area (fig. 6.5). A probable extension of this channel, displaced by faulting, occurs south of the property on Middelvlei 255 IQ (fig. 6.5). Assessment of this extension by Lindum reefs was taking place in 1994.

The Black Reef channel east of the Kimberley Reefs, was mined on a small scale in the past, next to and on the Vulcan claims (fig. 6.5 and 6.7) (Shaw, 1994). The Vulcan claims are associated with the VCR suboutcrop.

Records do not indicate any exploitation of the Black Reef channel west of the Government Reefs (Shaw, 1994).

6.8 Mineralization

According to Shaw (1994) the proximity of payable Black reef channels to auriferous Witwatersrand reefs on Randfontein Estates indicates that they are the source of the Black Reef gold. The channel on the Booyens shale has high grades on its western margin which decrease eastwards (fig. 6.9). Grades are laterally very erratic and high grades are concentrated in narrow payshoots of not more than a few metres width.

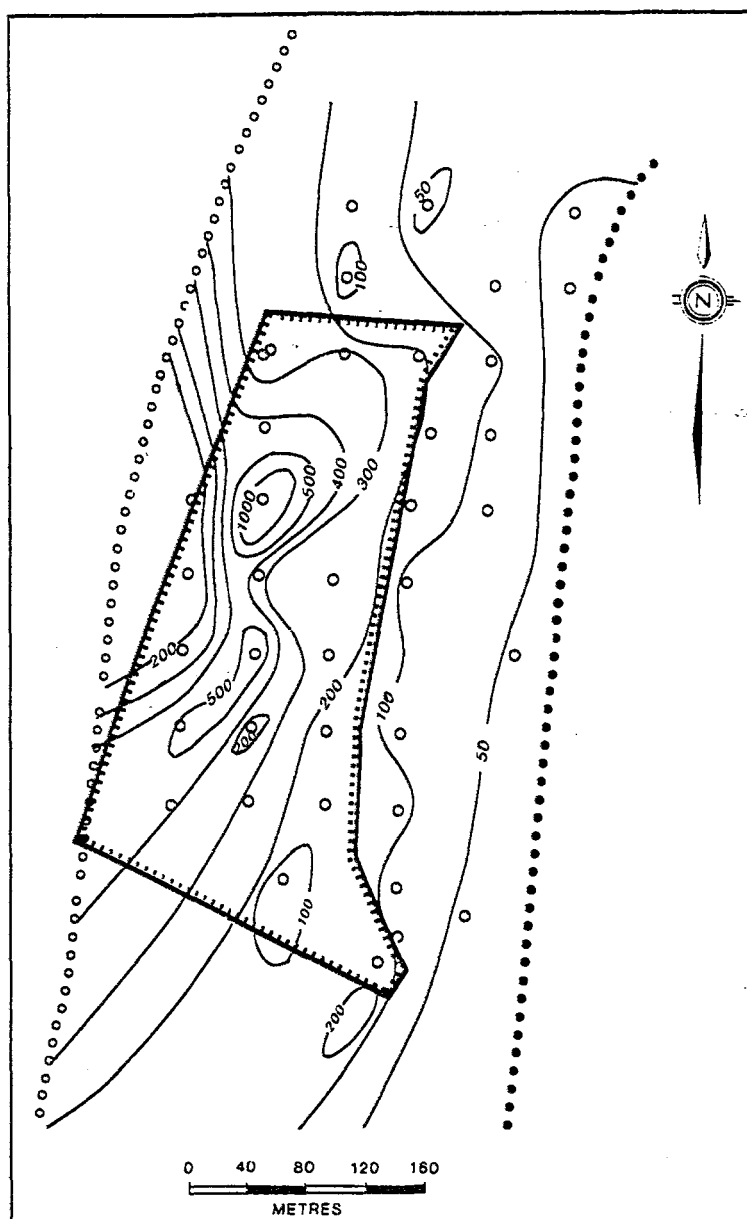


Fig. 6.9. Gold distribution based on percussion holes in the South Dam Extension East site (Shaw, 1994).

Grades are evenly distributed through the vertical reef profile, specifically in thicker reef. On the western, higher grade parts of the channel, the gold is concentrated at the base of the reef (Shaw, 1994).

The lowermost hardcap quartzite overlying the Black Reef carries an average grade of ~1.0 g/t Au. Uranium grades are low and assay between 0.1 and 1.5 g/t (Shaw, 1994).

6.9 Depositional Environment / Model

Deposition of the Black Reef in the West Rand area took place in a degradational system of actively incising braided streams flowing southwards off the Rand Anticline. The basal conglomerate was confined to north - south trending channels, cut into the less resistant inter - reef successions of the footwall Witwatersrand such as the Booysens Shale Formation. A major transgression of the epeiric Transvaal sea followed, resulting in deposition of the overlying Black Reef quartzites and then dolomites (Shaw, 1994).

Episodic minor transgressions and regressions, associated with a fluctuating shoreline, resulted in the deposition of the laterally continuous, alternating quartz arenite and shale units. The upper contacts of the shale units contain desiccation cracks indicating fluvial or upper tidal deposits (Shaw, 1994).

The transition to overlying dolomites and the general upward fining of the higher parts of the succession, reflects a transition from fluvial or upper tidal muds to subtidal muds (Shaw, 1994).

6.10 Mining History

Gold was first discovered on the West Rand in 1887. From then until 1905, only small scale outcrop mining took place in the area. After this, amalgamation of these small operations resulted in the creation of four major and one minor mine (fig. 6.3). At present, only Randfontein Estates and West Rand Consolidated are still actively mined (Whiteside et al, 1976).

Low grade, flat lying Black Reef has been extensively mined at shallow depths at Randfontein Estates Gold Mining Co. Ltd. (REGM) (Body, 1988). Payshoots were mined underground "in conjunction with the underlying Witwatersrand conglomerates" (Hammerbeck, 1976). Underground mining took place from the early 1900's until the 1960's (Shaw, 1994). No production statistics are available but from figure-- , Body (1988) estimated that 2 000 000 centares of Black Reef had been mined at Randfontein Estates. Using a density of 2.7 T/m³ and an average stope width of 105 cm, a total tonnage of 5.6 million tons of ore was calculated. North of REGM on West Rand Consolidated Mines Ltd., minor tonnages of Black Reef is mined as well (Chapman and Briggs, 1989). A few small mines exploited the Black reef, many years ago, in the area-north and west of West Rands Consolidated Mines (Toens and Griffiths, 1964) about the farm Waterval No. 74 (Mellor, 1917).

Some economic Black Reef outcrops further to the south on Middelvlei 255 IQ (Middelvlei Inlier) (fig. 6.5) and Luipaardsvlei 234 IQ (Papenfus, 1964). Near the eastern boundary of Middelvlei 255 IQ, low tonnages of high grade Black reef were mined by Johannesburg Consolidated Industries Ltd (JCI). The ore was processed initially over a mercury table but was later sent to Randfontein Estates for processing. Grades of 2.4 g/t are reported for the remaining slimes dump. Production statistics are unavailable. Source of the gold is probably the underlying Government Reef conglomerates (Body, 1988).

Ten kilometres southeast of Randfontein, at the South Roodepoort Mine property (fig. 6.3), limited tonnages of payable Black reef ore were mined underground in the vicinity of the Ventersdorp Contact Reef suboutcrop. This reef was probably the source of the gold in the Black Reef (Papenfus, 1964).

6.11 Present Mining

Successful opencast mining of the Black Reef is at present being undertaken by Lindum Reefs Gold Mining Company Limited (Lindum) adjacent to the town of Randfontein. This company was started in 1988 to mine the remaining underground ore reserves of the Randfontein Section of REGM. Small scale open - cast operations on the Black reef commenced in 1990 in the South Dam Extension East area (fig. 6.5). This was stopped without proper evaluation in 1991, along with the unsuccessful underground activities. Mining activities for the next year relied wholly on processing of surface sand and slimes dam reserves. The present open - cast mining operations recommenced in August 1992 (Shaw, 1994).

A percussion drilling programme in early 1992, successfully delineated a preliminary reserve of 161 000 t at an in situ grade of 4.1 g/t in the South Dam Extension East site. An actual tonnage of 126 218 t was mined (Table 6.1). This area overlies the Booyens Shale Formation and had been mined extensively underground both north and south of the reserve area (Shaw, 1994), and was considered be the best prospect with reference to reserves, shallowness and little infrastructural interference (Stewart and Johnson, 1991 in Shaw, 1994). A successful trial pit operation was followed by mining of the main reserve and surrounding areas. By June 1993, 230 000 t had been excavated (Shaw, 1994).

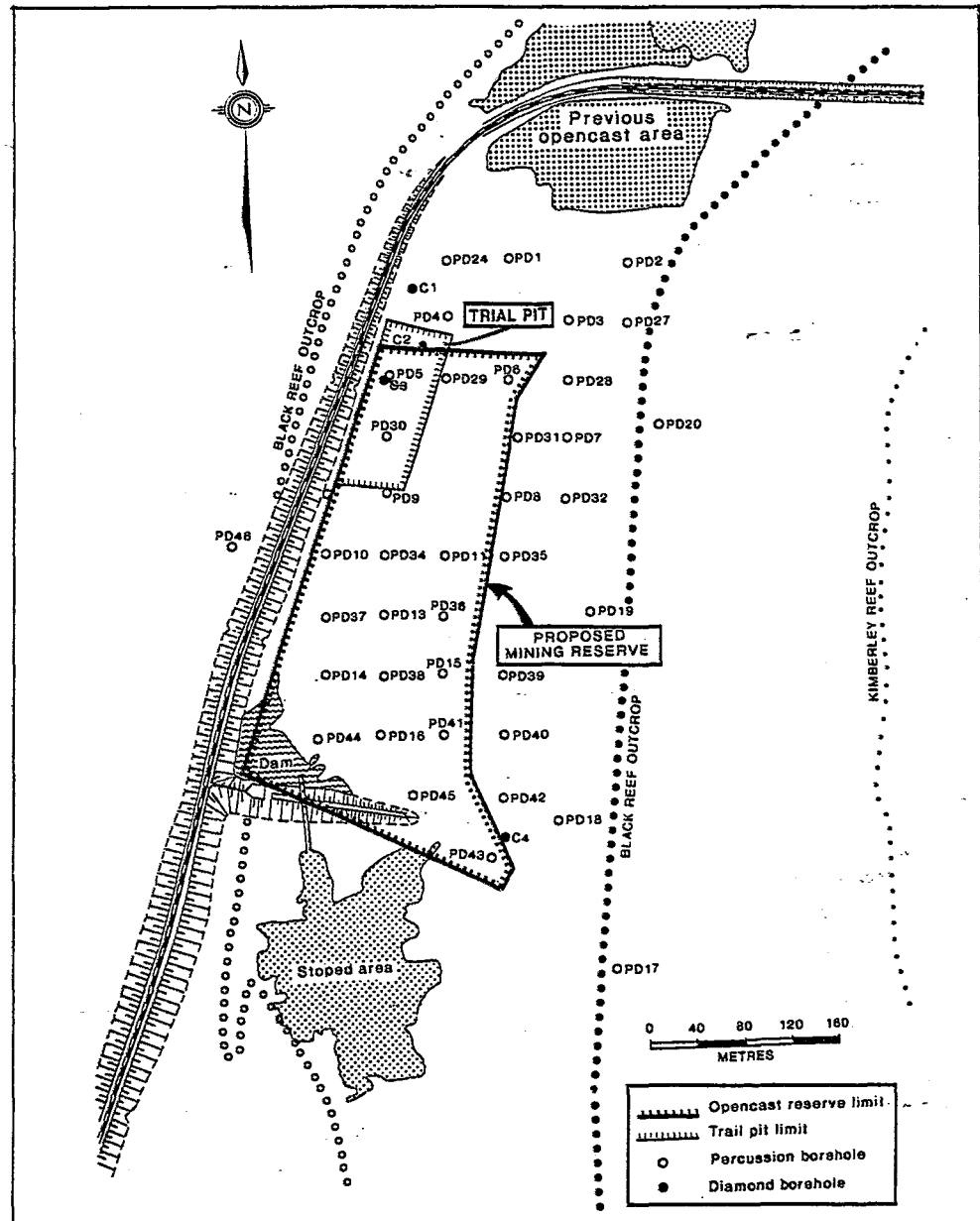


Fig. 6.10. The South Dam Extension East site in relation to infrastructure and previously mined areas (Shaw, 1994).

Evaluation of other Black Reef areas in the vicinity was so promising, that a second open - cast operation was started in the Skip Winze area (fig. 6.5 and 6.10) in February 1993. Mining of the channel between the Livingstone and Bird reefs is done in this area with better grades obtained than in the South Dam Extension area (Shaw, 1994). Evaluation and mining of new areas has continued successfully up to the present day. Part

of this success is due to the use of outside contractors for virtually all the stages of mining , thereby limiting overhead costs and risk factors.

Table 6.1. Breakdown of ore within the original reserve area (Shaw, 1994).

	Area (m ²)	Thickness (cm)	Tonnes (S.G. 2.75)	Grade (g/t)	Au Content (Kg)
Hardcap	-	40.58	59 539	0.94	- 56.22
Reef	-	36.41	53 415	7.63	407.76
Footwall	-	9.04	13 264	1.81	24.06
	53 354	86.03	126 218	3.87	488.04

CHAPTER 7

7 THE BLACK REEF ON THE EAST RAND

This region is located approximately 40 km east of Johannesburg, between Springs and Benoni (fig. 7.1), along the northeastern extension of the trough of Transvaal Sequence rocks which overlie the Witwatersrand basin (Plate 1). Two outlier basins of Transvaal Sequence rocks are preserved. The outer of these two basins overlies much of the East Rand Goldfields in the area between Boksburg and Springs due east of Johannesburg. The inner Mapleton basin is separated from the main basin by the northwest trending Palmietfontein anticline to the west (Plate 1) and from the East Rand basin by the van Dyk (Marievale) anticline (Papenfus, 1964).

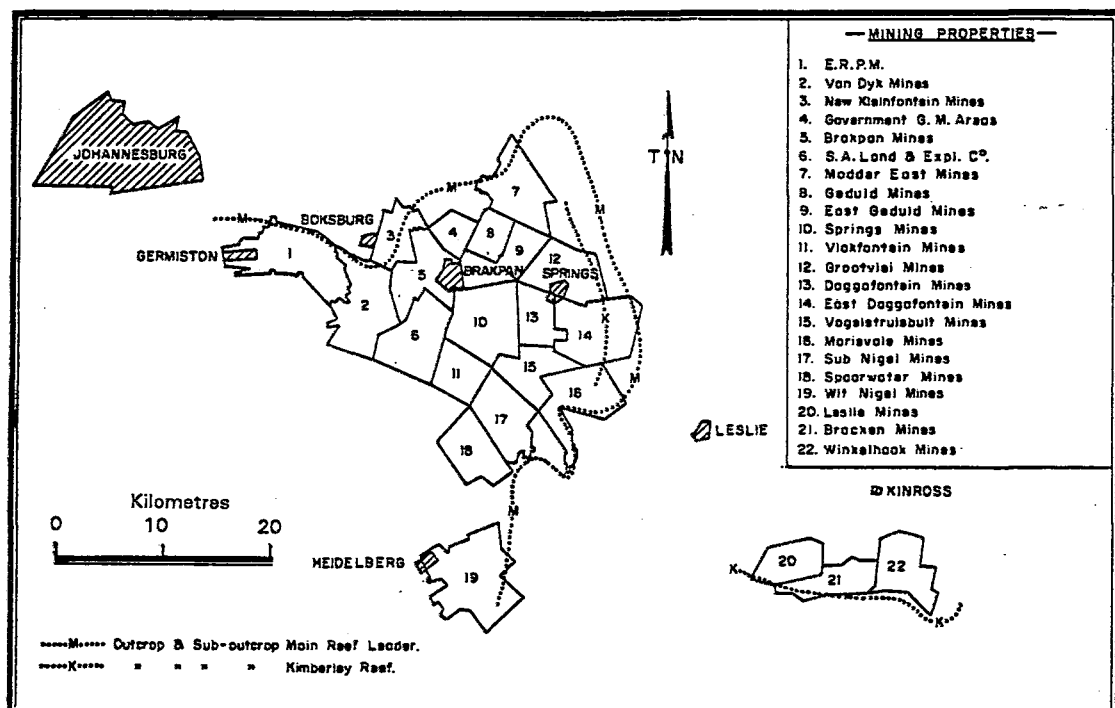


Fig. 7.1. Locality map of the East Rand goldfield (Whiteside, 1964).

7.1 Previous work

Swiegers (1939) concluded from his studies of the Black Reef mineralogy, that "at least some of the gold" on Government Gold Mining Areas (GGMA) is hydrothermal in origin and that the mineralogy and petrology was very similar to that on the Randfontein Estates and Machavie Mines. Sharpe (1949) interpreted a similar geological history for the Black Reef at GGMA as Papenfus (1957; 1964). The latter author studied the sedimentology, structure and mineralogy of the Black Reef. Spellman (1986) and Pouroulis (1988) studied the sedimentology of, and established facies types for, the BRQF. Results of their work is discussed below.

7.2 East Rand Geology

More than 90% of the East Rand basin is covered by highly weathered lower Karoo sediments up to 80 m thick (De Jager, 1964). This consists of shale, sandstones and coal beds of the Ecca Group with Dwyka Formation at its base (Pouroulis, 1988). Pre - Transvaal erosion produced an irregular palaeosurface, with successively older stratigraphic units being eroded northwards across the basin. The BRQF was deposited on Ventersdorp lava over the southwesterly parts of the basin, followed progressively northwards and eastwards by upper and then lower Witwatersrand rocks so that footwall rocks of the Main Reef Leader were peneplained along the northern and northeastern rim of the East Rand basin (Papenfus, 1964). The angular unconformity between the Witwatersrand and Ventersdorp Supergroups is slight and often indistinct (Swiegers, 1940).

About two - thirds of the East Rand basin is covered by the Malmani dolomites and BRQF of the Transvaal Supergroup (fig. 7.2), reaching a depth of 400 m on the Daggafontein/Grootvlei boundary (fig. 7.3) (Whiteside, 1964).

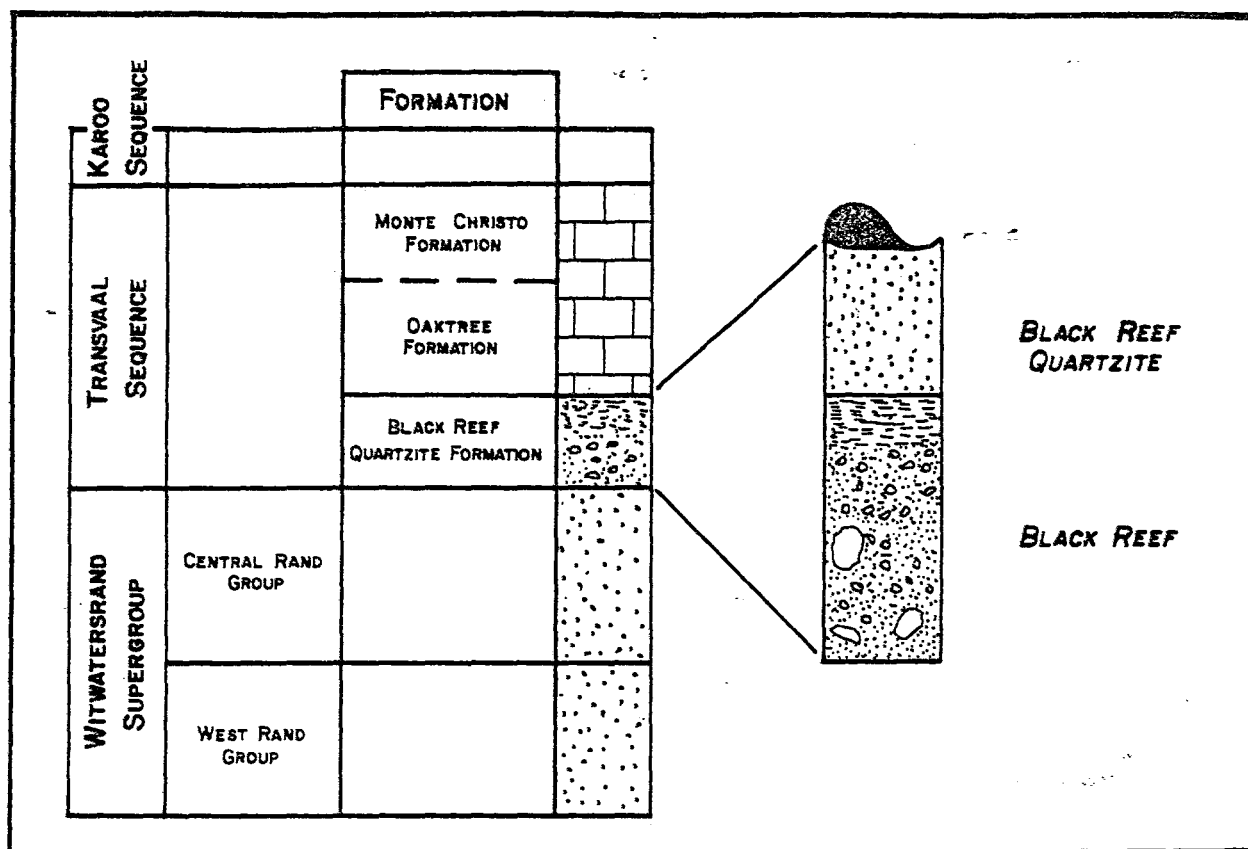


Fig. 7.2. Simplified stratigraphic column at NEP Shaft, Consolidated Modderfontein Mines Ltd (Pouroulis and Austin, 1989).

The Ventersdorp lavas, which were eroded away over the northeastern parts of the basin by pre - Transvaal erosion, consist of amygdaloidal and coarsely porphyritic lavas up to 500m thick. The basal blackish - grey, fine - grained amygdaloidal lava has the probable equivalent of the conglomeratic Ventersdorp Contact reef at its base (Whiteside, 1964). These lavas should therefore be the equivalent of the Alberton Porphyry Formation and basal komatiitic Westonaria Formation of the West Wits Line (Authors opinion).

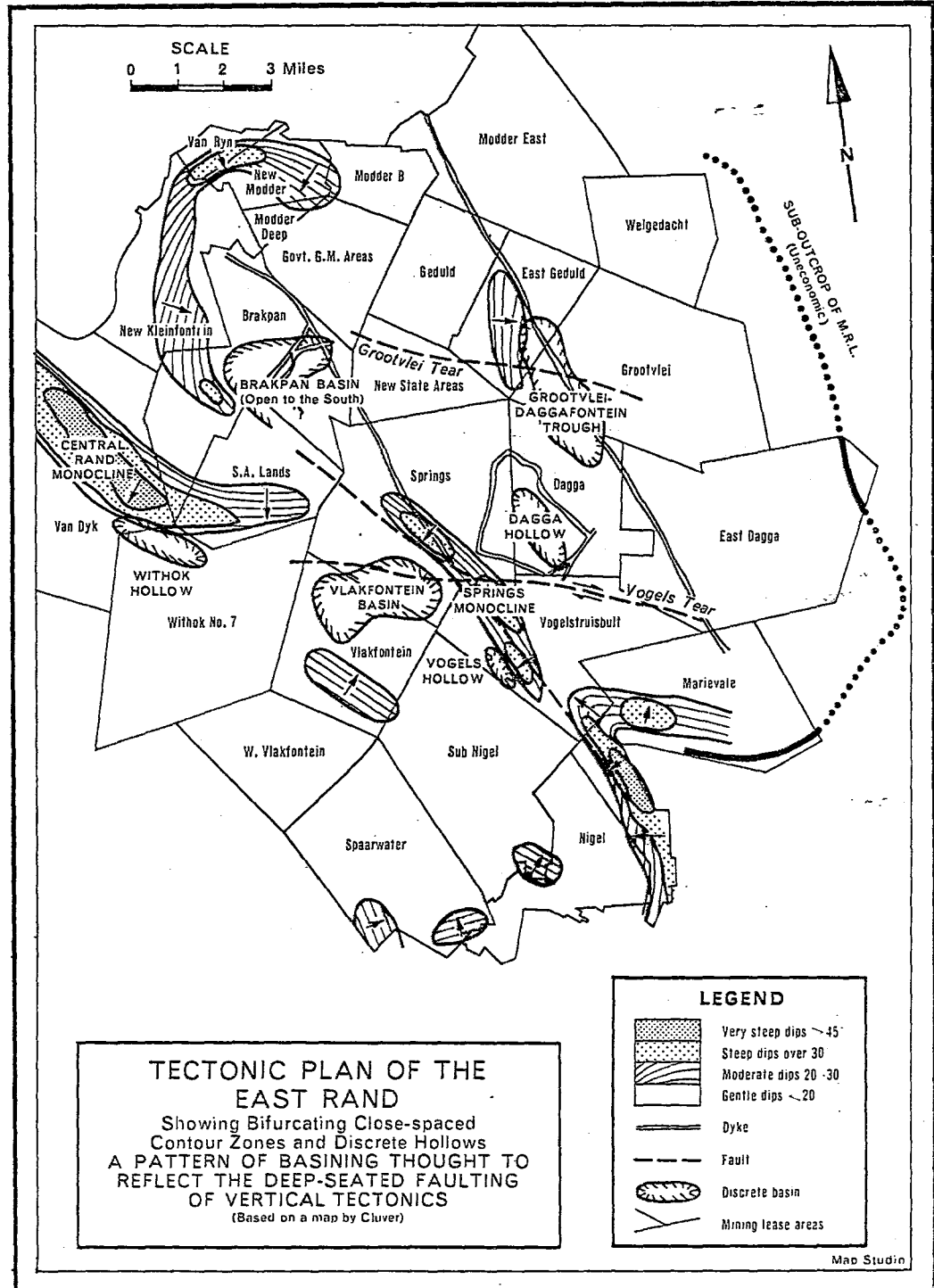


Fig. 7.3. Map showing main structural features and basins of the East Rand goldfield (Brock and Pretorius, 1964).

7.3 East Rand Structure

The East Rand basin occurs on the south side of a gentle anticline or warp, separating it from the northwards dipping Transvaal "Bushveld" basin proper (Plate 1). The macro - structure is that of a syncline plunging to the southwest, with the northern limb striking due east and the southerly limb striking south - southwestwards (Whiteside, 1964). A dominant structural overprint of synclines and anticlines trends northwest - southeast across the basin (fig. 7.3).

The Black Reef basin of the East Rand is divided into "a number of depositional lows or sub - basin's (Spellman, 1986). The folding which produced these subsidiary basins, involved the BRQF as well. Comparisons of the Black Reef and Main Reef Leader contour maps indicates a distinct similarity in the distribution of their subsidiary basins. The best examples of this occur in the Grootvlei and Daggafontein Mines, and the southern parts of the Springs Mine (fig. 7.3). In the Government Areas basin, the basin structure of the Kimberley and Black reefs is similar (Papenfus, 1964).

A dominant syncline extends from Modderfontein in the northwest to Marievale in the southeast (fig. 7.3) (Papenfus, 1964) with the major, northwest trending Springs Monocline (Brock and Pretorius, 1964) on its southwestern boundary. The Government areas, New State Areas, Daggafontein and Marievale Mines form 4 subsidiary basins on its uneven floor, from north to south, along this syncline, with the Grootvlei and Springs Mines basins situated on its east and west sides respectively. Minor anticlinal warps separate the basins (Papenfus, 1964).

Information from mining operations shows minor flexures in the folding, but only small scale faulting is present in the Black Reef (Papenfus, 1964). A series of west - east trending, pre - Transvaal wrench - faulting caused by a late compressional event is present in the area (Brock and Pretorius, 1964).

The southwestern boundary of the East Rand basin is demarcated by the northwest trending Marievale - van Dyk anticline which separates it from the Mapleton basin (Plate 1). The area was peneplaned before being covered by the Karoo Sequence.

The Mapleton subsidiary basin is separated from the main Transvaal synclinal trough to the southwest, by the northwesterly trending Palmietfontein anticline (Plate 1). This 30 km wide, subsidiary basin outcrops in a roughly circular pattern. Variability of strike along the northern rim of this basin indicates that secondary folding probably influenced this basin as well. A bed - parallel sill, which occurs a short distance above the Black Reef, outcrops extensively in the basin, indicating that the Black Reef does not reach depths of more than a 100 m or so (Papenfus, 1964).

7.4 Pre - Black Reef Palaeotopography

Deposition of the Black Reef on the East Rand took place on an irregular eroded surface of shallowly dipping Witwatersrand quartzites and conglomerates (Papenfus, 1964). The present, undulating nature of the Black Reef is partly due to post - Transvaal folding but is mostly due to the highly irregular surface of the pre - depositional topography. Palaeo - troughs up to 13 m deep are present (Swiegers, 1940) and can be described as erosion channels (Spellman, 1986). The presence of palaeo - highs is indicated by non - deposition of BRQF in certain areas (Papenfus, 1964).

Deposition of the BRQF and more specifically the basal conglomeratic facies was largely controlled by the palaeotopography. Sculpturing of this topography was dictated by the nature and morphology of the then outcropping Witwatersrand strata (Spellman, 1986). Competency contrasts between the harder quartzites, enclosing shale units, resulted in scarp - type

palaeohighs and palaeolows respectively. Channels were deflected towards these palaeolows (Spellman, 1986).

On Geduld Proprietary Mines, negatively weathered, pre - Transvaal dykes appear to have acted as traps for the rich payshoots in the Black Reef which overlie them (Papenfus, 1964) whilst northwest trending faults control the orientation of the Black Reef channels in the area (fig. 7.11) (Pouroulis, 1988; Pouroulis and Austin, 1989).

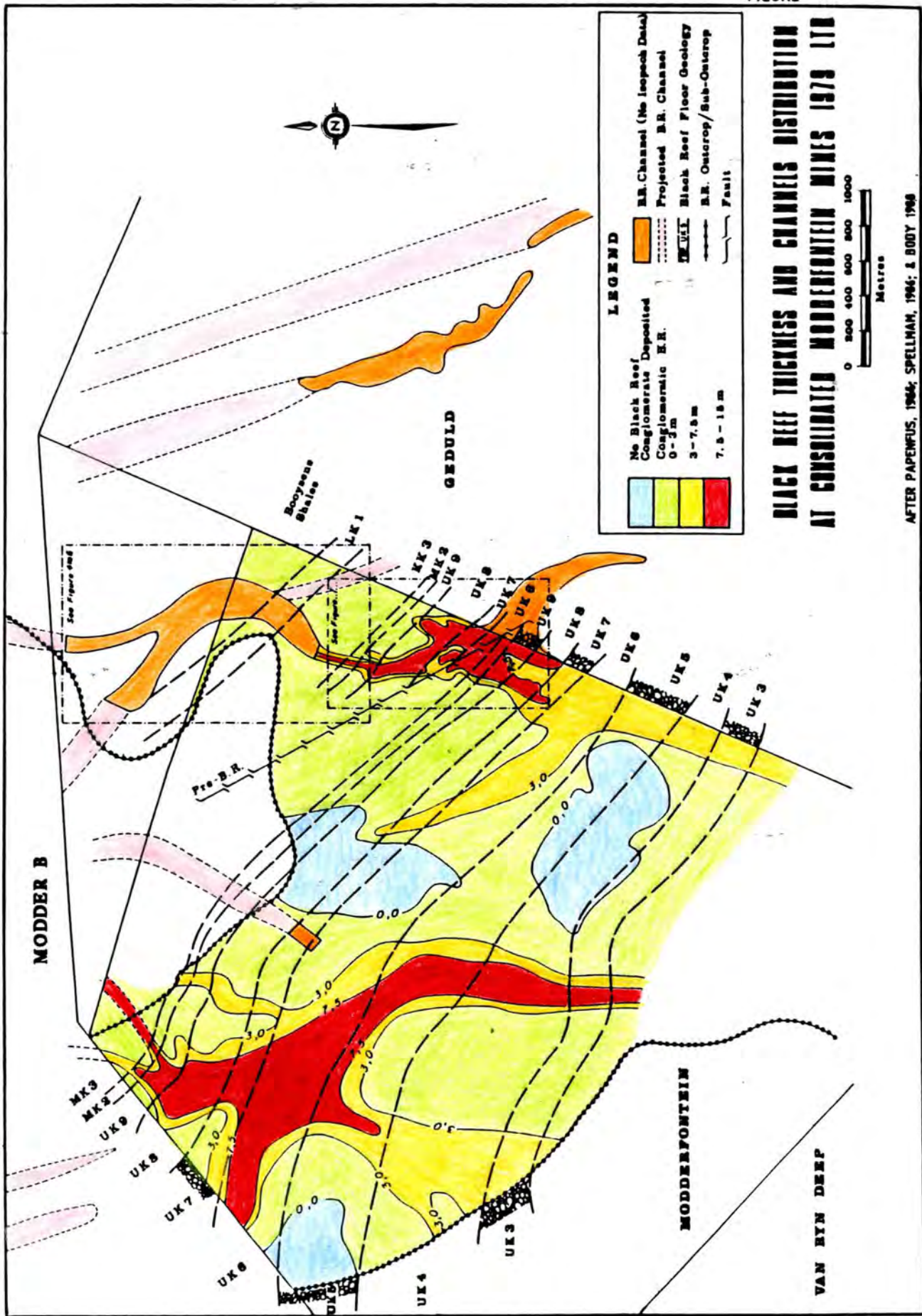
Footwall lithologies appear to dictate channel geometries. Channels are wide (up to 40 m) with shallow boundaries over softer strata such as the Booyens shales and deep and narrow (less than 5 m) over harder formations such as the Doornkop Quartzites (fig. 7.4) (Pouroulis and Austin, 1989).

The low dips of the strata on the pre - Black Reef footwall exposed larger Au - rich conglomeratic surfaces to erosion. Dip directions of the footwall, parallel downstream flow directions, exposing more Au - rich surface area downstream as footwall incision progressed (Papenfus, 1964).

7.5 Stratigraphy

The Witwatersrand succession which underlies the BRQF on CMM was a major influence on most facets of the package at the time of deposition and before.

FIGURE 7.4



7.5.1 Footwall Succession on Consolidated Modderfontein Mines (CMM)

The footwall Witwatersrand succession on CMM strikes southeast and dips at a low angle to the southwest. On the northeastern side of the mine properties, the quartzitic Krugersdorp Formation underlies the Transvaal rocks (Pouroulis, 1988). Overlying this is the argillitic Booyens Shale Formation (Kimberley shales), which is the uppermost formation of the West Rand Group (Lower Wits) and suboutcrops in the northeastern corner of GGMA (fig. 7.4). Overlying this conformably to the southwest is the competent quartzitic Doornkop Quartzite Formation, followed by the auriferous Kimberley Conglomerate Formation of the Central Rand Group (Papenfus, 1964) in which the economically important MK1, MK2 and UK9A reefs occur (Pouroulis, 1964).

7.5.2 Black Reef Quartzite Formation

The palaeotopography of the pre - Transvaal surface is reflected in the "distribution, lithological features and thickness variations" of the Black reef succession (Papenfus, 1964) (Pouroulis, 1988).

The BRQF on the East Rand consists of two major facies or sequences (Papenfus, 1964) (Pouroulis, 1988). These are the Lower Black Reef or Channel Facies (Spellman, 1986) or Lower Massive Boulder Sequence (Pouroulis and Austin, 1989), and the Upper Black Reef or Blanket Facies (Spellman, 1986) or Stratified Blanket Sequence (Pouroulis and Austin, 1989) (Table 7.1).

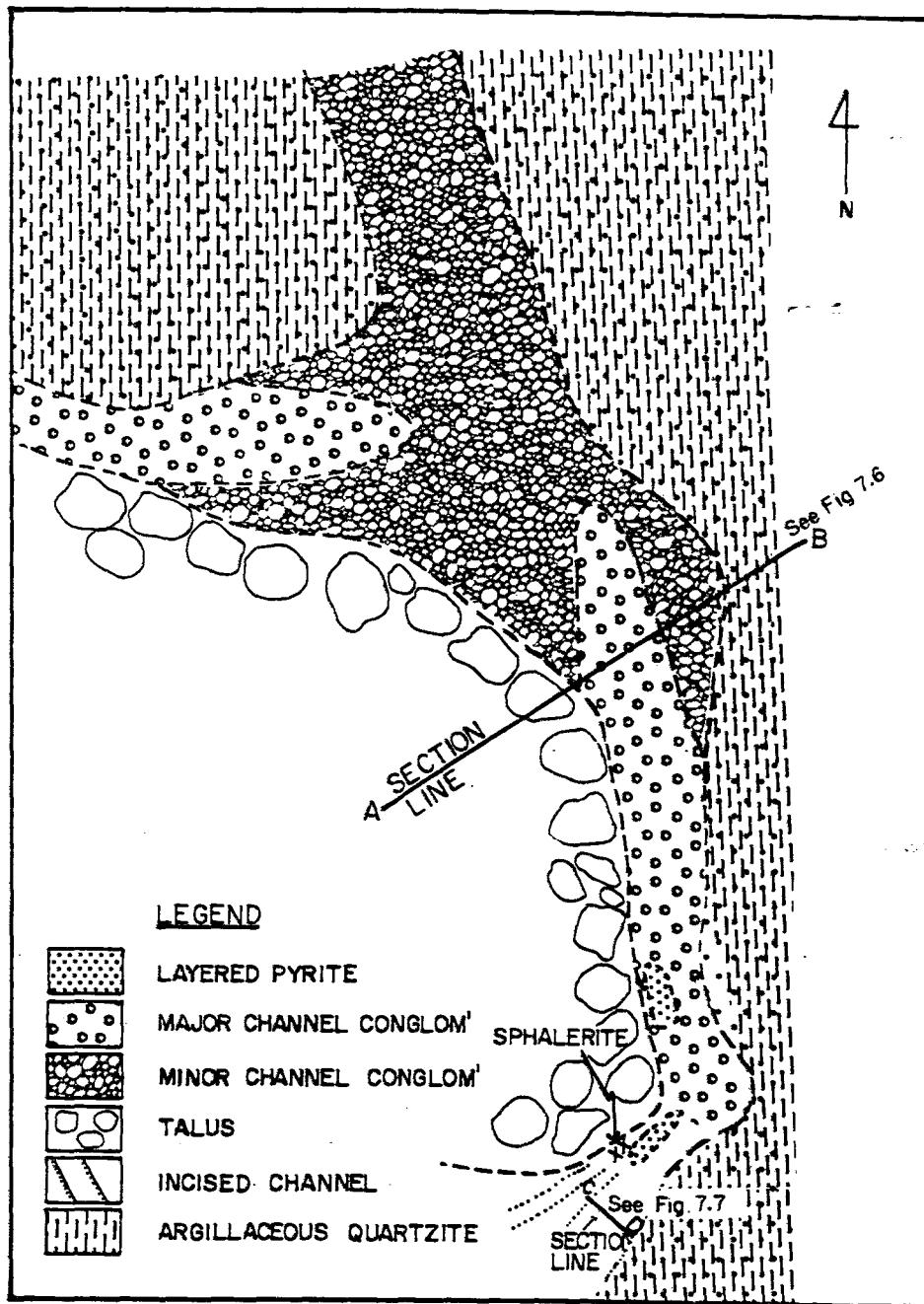
7.5.2.1 Lower Black Reef or Channel Facies

This is the channel deposits of Papenfus (1964) and is the basal conglomeratic unit that contains all the known, economic, auriferous, Black Reef placer deposits found elsewhere in the Transvaal Supergroup. The facies consists of massive conglomerate bands with thinner bands of grits,

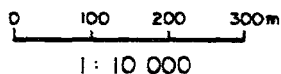
quartzites and carbonaceous shales. Some conglomerate bands are up to 8 m thick (Papenfus, 1964). Spellman (1986) describes this erosional channel fill deposit, as up to 15 m thick with up to 7 identifiable, economic horizons (figs. 7.5 - 7.8). Pouroulis (1988) and Pouroulis and Austin (1989) recognise 5 facies in this "structureless" "sequence". These are: the protoquartzite, conglomerate, graphitic mudstone, calcareous siltstone and boulders facies (Table 7.1A) Distribution of these facies is controlled by their location in the channels. The sequence is mineralogically and texturally less mature than the overlying Blanket facies (Pouroulis, 1988). Pyrite is evenly distributed throughout the matrix of the conglomerates.

Spellman (1986) identifies 6 minor facies in the eastern (NEP) channel. These are: the layered pyrite, major channel conglomerate, minor channel conglomerate, talus, incised channel and overbank argillaceous quartzite facies. A description of these facies is given in Table 7.1B below.

According to Swiegers (1940), the expected sharp, basal erosional contact between this channel facies and the underlying Witwatersrand succession is often indistinct and frequently gradational, indicating a "rapid change in conditions of sedimentation" at the time of deposition. Deposition of the basal unit followed erosion fairly quickly. The author also describes the characteristics of the Black Reef and Kimberley conglomerates as similar. Where the former overlies the latter, the contact is often difficult to pinpoint, especially underground. Swiegers (1940) described the general features of the Black Reef Series in comparison to similar rocks in the Witwatersrand Supergroup (Table 7.2).

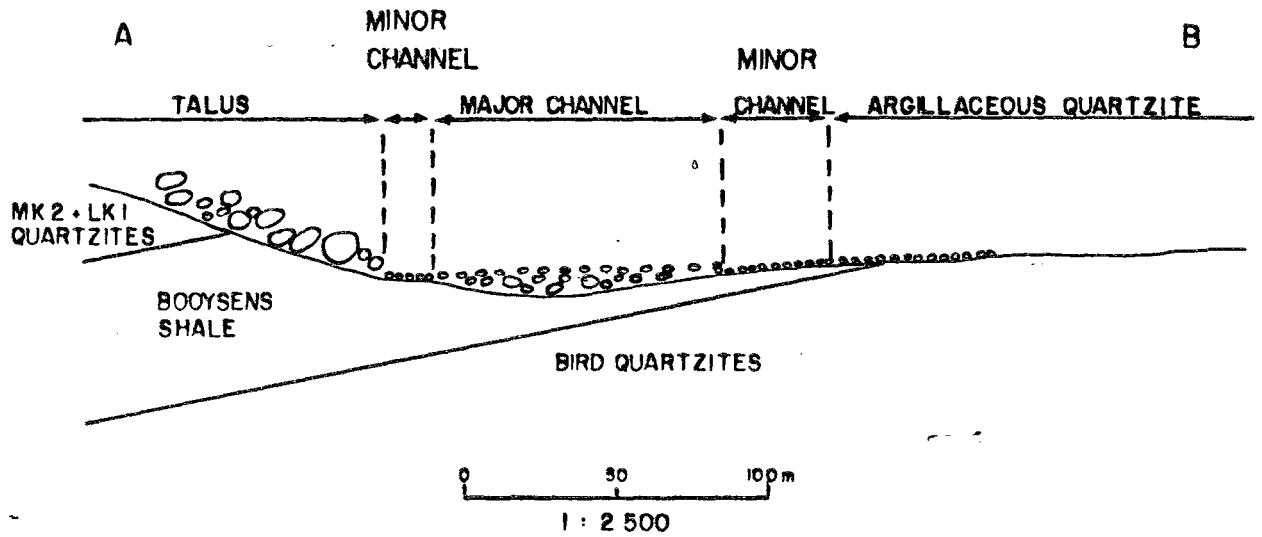


Facies distribution within the NEP shaft Black Reef channel,
 CONSOLIDATED MODDERFONTEIN GOLD MINE



AFTER SPELLMAM, 1986 & BODY 1988

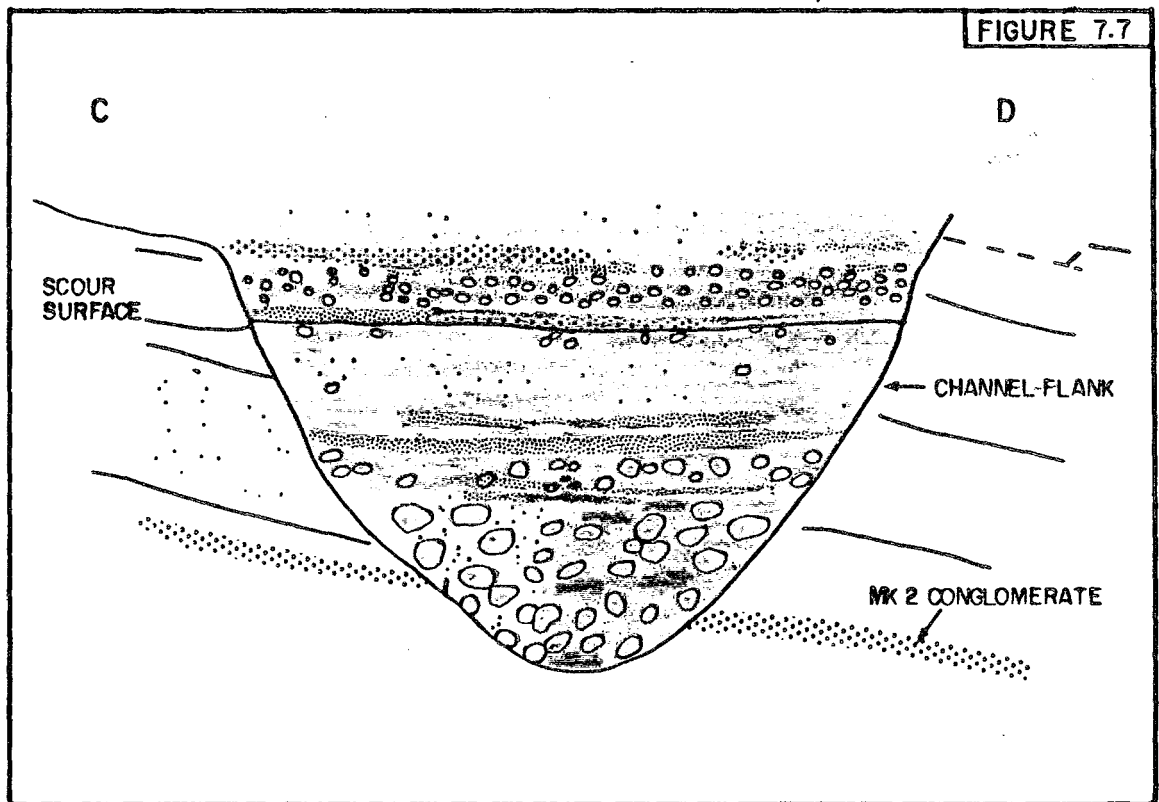
FIGURE 7.6



SECTION THROUGH NEP SHAFT CHANNEL SHOWING SUB-OUTCROPPING GEOLOGY AND FACIES DISTRIBUTION (SECTION LINE : SEE FIG. 7.5)

AFTER SPELLMAM, 1986 & BODY 1988

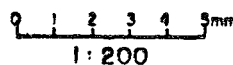
FIGURE 7.7



LEGEND

- KIMBERLEY BOULDERS
- CONGLOMERATE
- BUCKSHOT PYRITE
- ARGILLACEOUS QUARTZITE
- QUARTZITE
- SHALE

SECTION THROUGH AN INCISED CHANNEL (SECTION LINE: SEE FIG. 7.5)



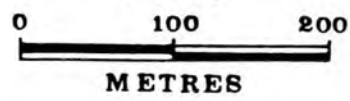
AFTER SPELLMAM 1986 & BODY 1988

Figure 7.8

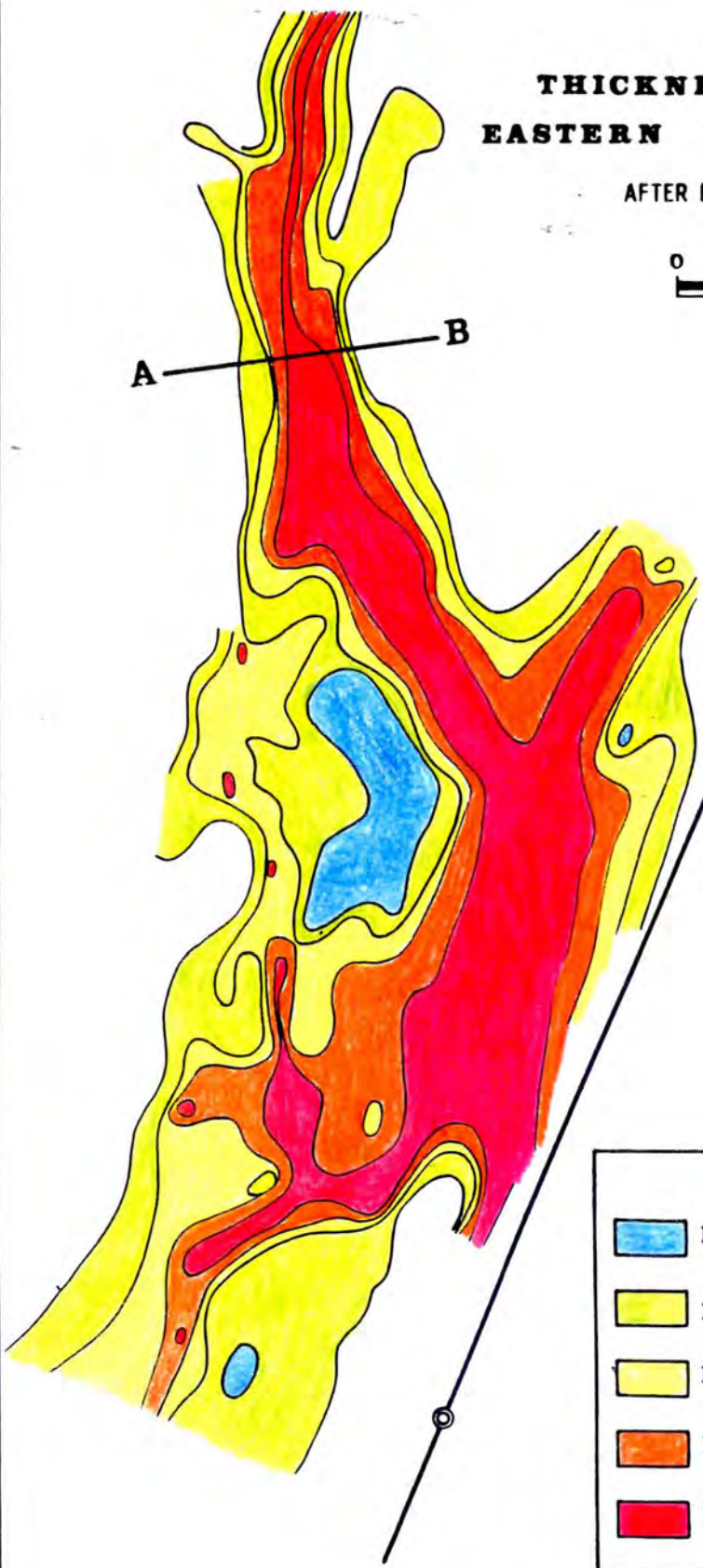
THICKNESS CONTOURS OF EASTERN CHANNEL FILLINGS

AFTER PAPENFUS 1964 & BODY 1988

1:5000

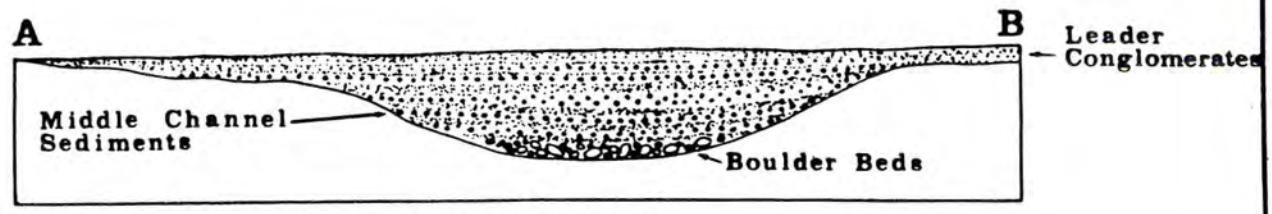


A ————— B



LEGEND

-  BR Beds less than 3m thick
-  BR Beds 3m - 6m thick
-  BR Beds 6m - 9m thick
-  BR Beds 9m - 12m thick
-  BR Beds over 12m thick



SECTION A-B
Scale 1:1000

7.5.2.2 Upper Black Reef or Blanket Facies

This is the generally clean, mature Black Reef Quartzite which usually overlies the Black Reef where present and is developed almost everywhere around the Transvaal basin. This consists of fine - grained, up to 8 m thick, glassy, layered quartzites which grade upwards through carbonaceous and dolomitic shales into the overlying dolomites (Papenfus, 1964). Spellman (1986) and Pouroulis and Austin, (1989) describe this facies on CMM as a widespread, more uniform facies (due to a more uniform depositional environment) which covers the channel facies where present and the Witwatersrand succession where not. Pouroulis (1988) and Pouroulis and Austin (1989) consider the blanket "sequence" in the eastern (NEP) channel to consist of 5 facies. These are: the quartzarenite, bedded conglomerate, graphitic mudstone, pisolithic pyrite (buckshot pyrite and a very fine pyritic mud) and boulders facies (Table 7.1C).

7.6 Channel Morphologies

The largest portion of the two main, south - southeast trending Black Reef channels transect the GGMA property (fig. 7.4). Each has minor tributaries. The western channel extends somewhat northwards onto the Modder Deep property whilst the eastern channel, extends onto the Modder B property at its north end and onto the Geduld property at its southern extension. A third, smaller, south - southeast trending channel occurs on the Geduld Property (fig. 7.4) (Papenfus, 1964). The Northeast Prospect (NEP) Shaft is located near the eastern channel.

The western channel at CMM properties is up to 700 m wide and 16 m deep. Channel cross - sections are usually fairly gentle. Channels become wider and more dispersed towards the southeastern side of the property. Clasts in the western channel consists predominantly of white and smokey quartz.

The eastern channel has much steeper, near vertical flanks (fig. 7.7), than the western channel. In the northern sections of the mine, large boulders of Witwatersrand rocks have been deposited downstream from their outcrops (Spellman, 1986) (Papenfus, 1964). Boulders range from 15 cm to 95 cm in size with some up to 2.5 m in size and decrease in size but increase in roundness to the south or downstream direction. Booyens shale fragments are ubiquitous downstream from outcrop in the eastern channel (Papenfus, 1964). The major feeder channel follows the Booyens shale suboutcrop whilst the competent, younger Kimberley quartzites forms a scarp which controls the western flank of the channel. (Spellman, 1986).

7.7 Palaeocurrents directions

A palaeocurrent exercise undertaken on the eastern channel in the NEP shaft area by Pouroulis (1988) was only partially successful. No palaeocurrent features were seen in the upper sheetlike facies. They are also absent in the channel facies where exposed on stope faces. Palaeocurrent readings were however taken on the overlying trough - crossbedded orthoquartzite facies where exposed. An example of readings taken in 14 West Stope is shown in figure 7.9. Readings were taken on trough - crossbedding, ripple marks and scours.

Results of the exercise indicate a bimodal northwest - southeast oriented current direction with the southeast trend dominant. Channel flow was therefore southwards.

A small number of trough - crossbedding readings were taken on the trough - crossbedded orthoquartzite facies in the 11 West Cross - cut and 11 North Stope (fig. 7.10). They have an east - west trend.

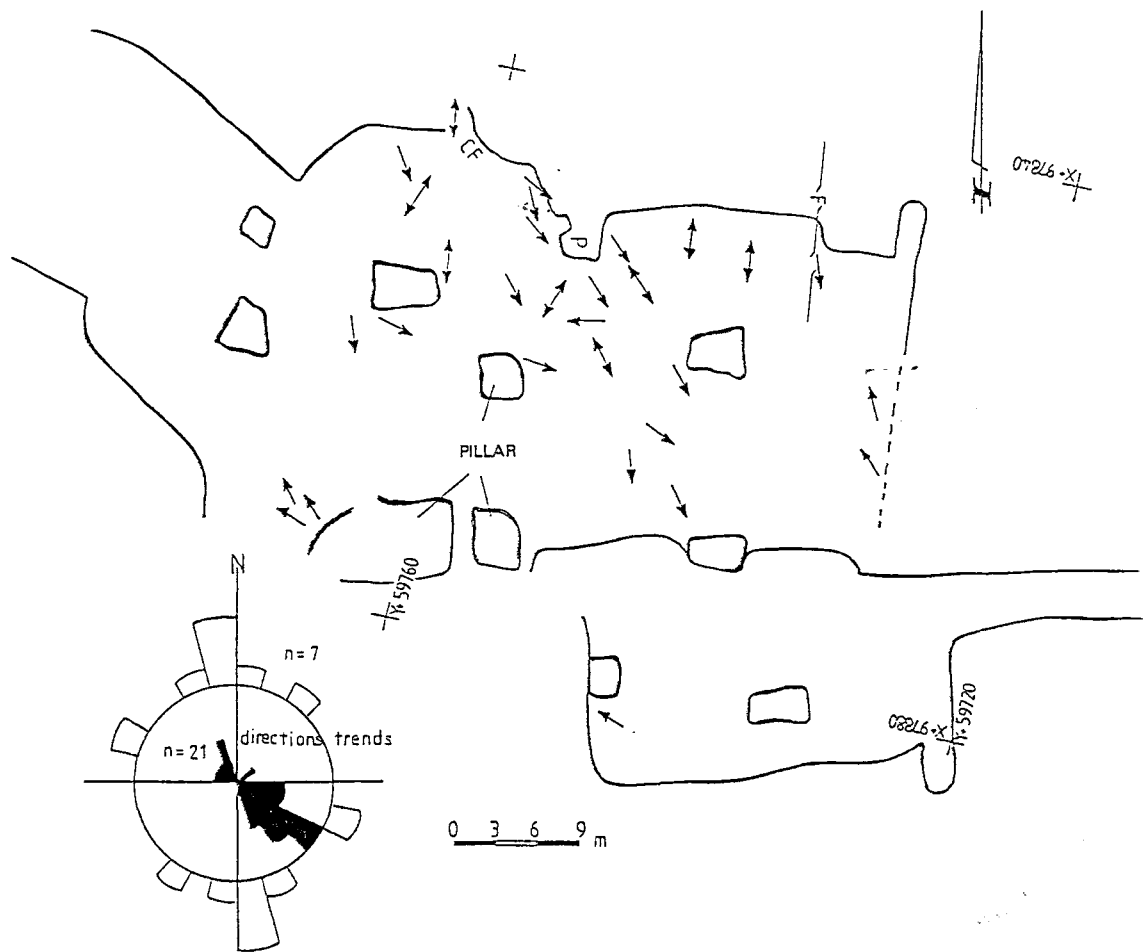


Fig. 7.9. Palaeocurrent readings from the trough cross - bedded hangingwall quartzite in the 14 West Stope in NEP Shaft, GGMA (Pouroulis, 1988).

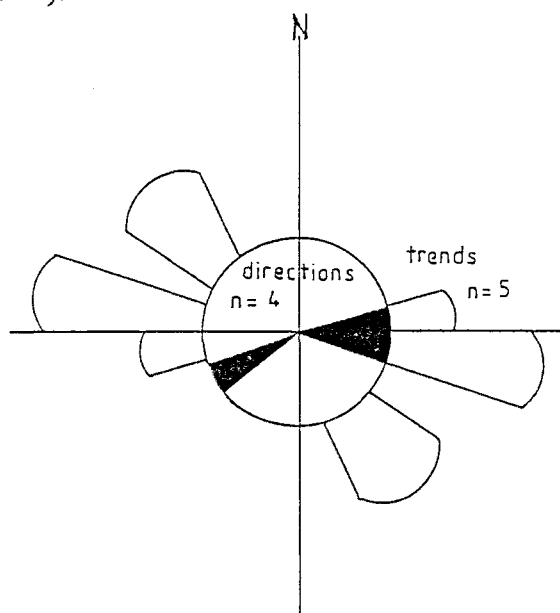
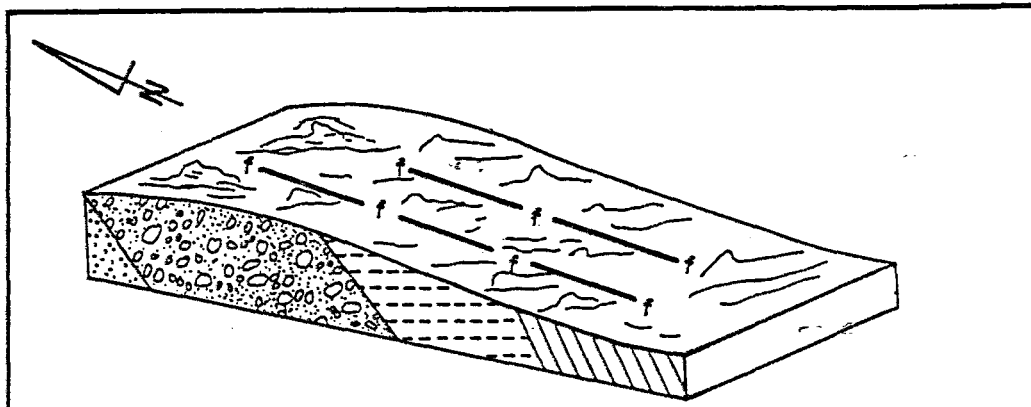


Fig. 7.10. Palaeocurrent readings for the trough cross - bedded quartzite hangingwall (Pouroulis, 1988).

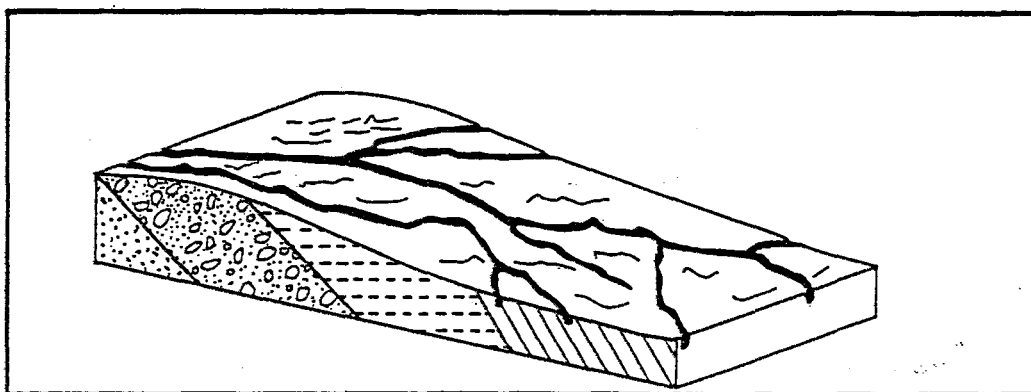
A number of other indicators show that the palaeorivers flowed southwards. Papenfus (1964) noted that the source of the shale fragments, which are a major constituent of the eastern channel, were probably derived from the Booyens shales outcropping to the north. In the eastern channel, boulders of Kimberley Quartzite Formation rocks decrease in size and increase in roundness southwards. Characteristic square and angular chert pebbles in some of the boulders originate from the MK3 zone which suboutcrops to the north of the boulders present location. Gold values are increased over or south of the high grade UK9 and MK2 beds. High gold grades persist for a 1000 m or more downstream. Gold values also diminish downstream.

7.8 Depositional Environment / Model

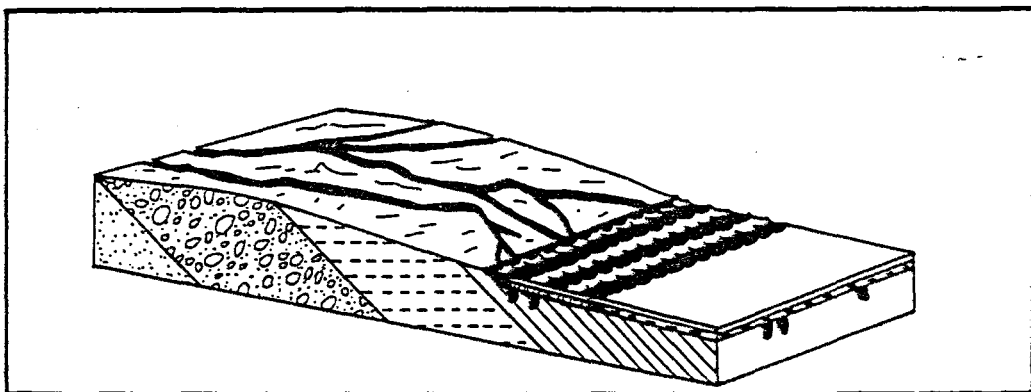
Pouroulis (1988) compared the 10 identified facies of the BRQF to modern day analogues and concluded that the Black Reef channels on the CMM properties consisted of a juvenile, northwest trending system of "actively incising, anastomosing braided rivers", with transportation and deposition of Witwatersrand succession derived clastic sediments, down a regionally southwards dipping slope (fig. 7.11). Expansion of the Transvaal basin, with a resultant marine transgression, submerged the fluvial system. Destruction of primary sedimentary features initially occurred, followed by active reworking of the channelised sequence (Pouroulis and Austin, 1989). The dominant basal conglomerates and quartzites are interpreted as reworked fluvial deposits. The upper, attenuated sequence of conglomerates and protoquartzites alternating with graphitic muds and calcareous silts, is interpreted as upper shoreface and offshore facies respectively. A series of minor transgressions and regressions formed these upper successions (Pouroulis, 1988) (Pouroulis and Austin, 1989).



SOUTHWARD SLOPING BLACK REEF UNCONFORMITY SURFACE ; NW - SE ORIENTATED FAULTS AND FRACTURES.



INITIAL PHASE OF BLACK REEF SEDIMENTATION CHARACTERISED BY DEGRADING NETWORK OF ANASTOMOSING CHANNELS OF A BRAIDED FLUVIAL SYSTEM PREDOMINANTLY ALONG NW - SE ORIENTATED PLANES OF WEAKNESS. DEPOSITION OF MASSIVE BOULDER SEQUENCE.



BASIN EXPANSION RESULTS IN MARINE TRANSGRESSION THAT DROWNS CHANNELS, REWORKS CHANNEL SEDIMENTS AND DISRUPTS SEDIMENTARY STRUCTURES. AN E - W COASTLINE IS PROPOSED LOCALLY. INITIAL FLUCTUATING SHORELINE RESULTS IN DEPOSITION OF INTERCALATED ARENITES, CONGLOMERATES AND ARGILLITES (IN TOP PORTIONS OF SOME CHANNELS) ON UPPER SHOREFACE AND OFFSHORE ENVIRONMENTS RESPECTIVELY. SUBSEQUENT STABILIZATION OF SHORELINE AND DEPOSITION OF STRATIFIED BLANKET SEQUENCE ON A RELATIVELY HIGH ENERGY SHOREFACE.

Fig. 7.11. Hypothetical model for the formation of the Black Reef at NEP Shaft (Pouroulis and Austin, 1989)

The quartzarenites, conglomerates and most of the pisolithic buckshot facies of the upper sheet - like facies is interpreted to have formed "under stable shoreline conditions" in a wave and tide dominated upper shoreface environment. The graphitic and pyritic muds were deposited during minor periods of sediment starvation (Pouroulis, (1988).

An east - west oriented coastline is indicated, by the regionally southwards inclined slope, as well as by the north - south elongated megadomal stromatolites in the overlying Transvaal dolomites (Pouroulis and Austin, 1989). These views are in accord with those of Papenfus (1964) and Spellman (1986).

7.9

Mining History

The East Rand basin has been a major gold producer since the early nineteenth hundreds (Antrobus and Whiteside, 1964) (Sohnge, 1986) with mining operations at Nigel Gold Mine having started in 1888 (Whiteside, 1964). The GGMA of the East Rand basin, is the largest producer of Black Reef to date. On the adjoining Geduld Proprietary Mines Ltd. and Modderfontein Deep Levels the Black reef was also actively mined. All three mines are presently part of CCM Ltd. (fig. 7.12). Other, relatively minor mining activities occurred along the northern rim of the Mapleton basin near Natalspruit Station (Papenfus, 1964).

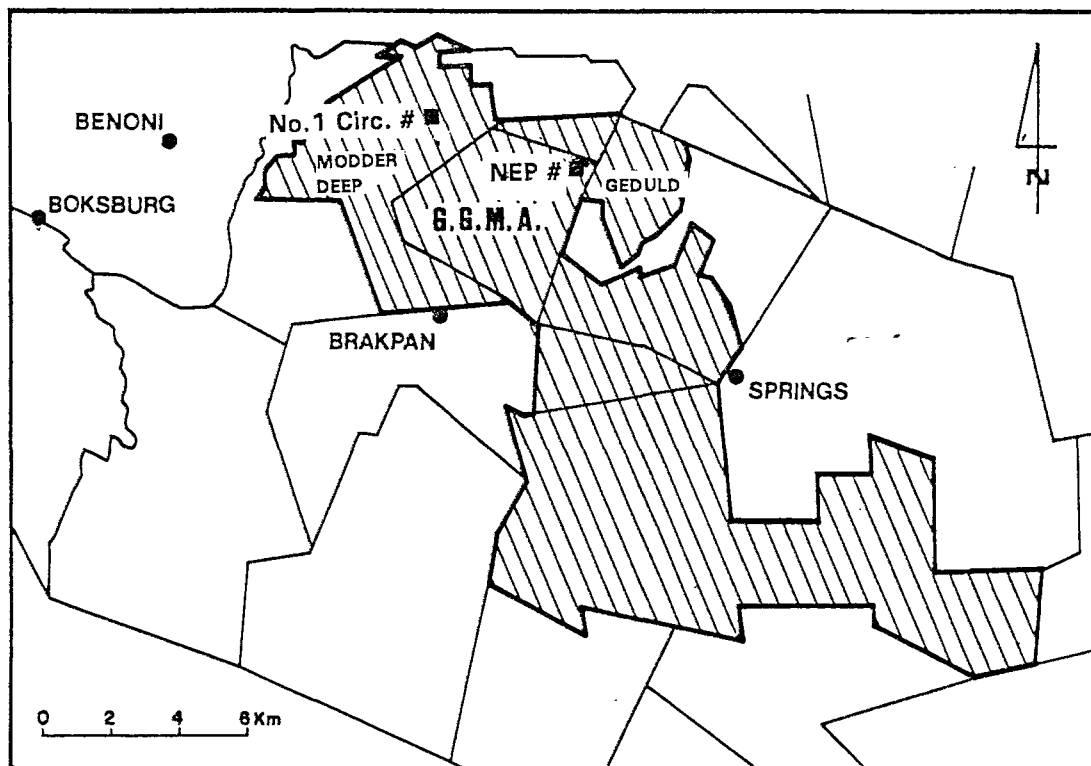


FIGURE 1 LOCATION OF NORTH EAST PROSPECT (NEP) SHAFT AT CONSOLIDATED MODDERFONTEIN MINES LTD.

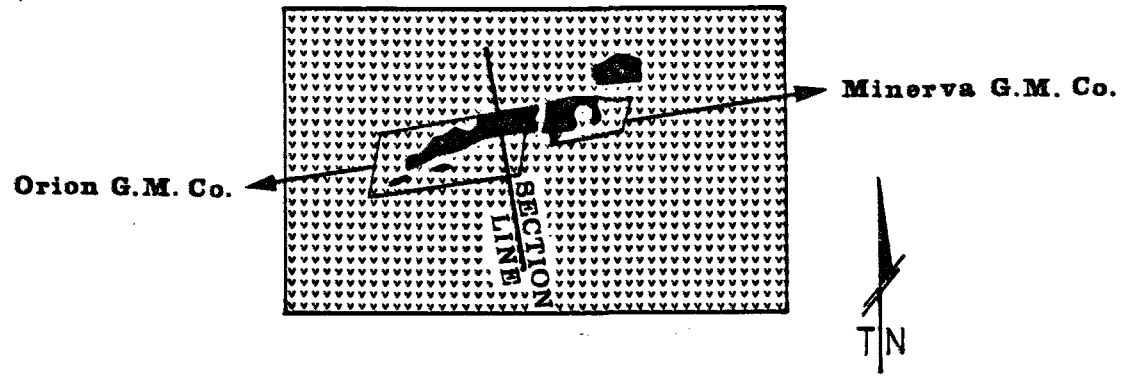
Fig. 7.12. Location of NEP Shaft and No. 1 Circular Shaft at Consolidated Modderfontein Mines 1979 Ltd (Pouroulis and Austin, 1989).

7.9.1 Mapleton Basin



Along the southwards dipping, northwesterly rim of this basin, in the vicinity of Natalspruit Station (Plate 1), south of Germiston, intermittent outcrops of Black Reef were mined at the Orion, Minerva (fig. 7.13), Meyer, Leeb, Black Reef and Cornucopia Mines on Roodekop 139 IR and Rooikop 140 IR farms (Pretorius, 1964). Down dip stoping extended for 160 m in places, with numerous prospecting pits occurring along strike for over 1 km (Papenfus, 1964). Production figures for the area are unavailable but Body (1988), using figure 7.13, estimated that 175 000 centares of Black Reef were mined out on the Minerva and Orion mines. Using a stope width of 105 cm and a density of 2.7 T/m³, this equals 496 000 tons of ore.

THE ORION AND MINERVA MINE

SCALE 1:50000

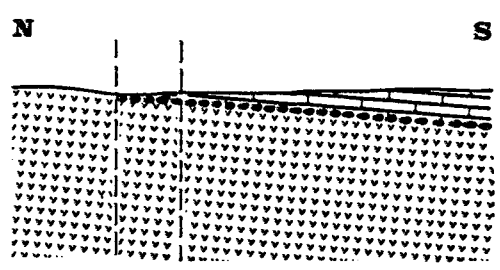


LEGEND





-  Stoped out on Black Reef
-  Ventersdorp Supergroup Lavas (Pre-Black Reef Geology)

AFTER PAFENFUS, 1964;
BODY, 1988.

**SCHEMATIC SECTION
ACROSS THE ORION MINE LOOKING EAST**



LEGEND

-  Dolomite
-  Black Reef
-  Ventersdorp Supergroup Lavas (Pre-Black Reef Geology)
-  Mine Boundaries

The Black reef, which is less than 120 cm wide, consists of "small, rounded quartz and chert pebbles set in a siliceous matrix" (Papenfus, 1964). As at GGMA, the ore carries high osmiridium values (Papenfus, 1964) and gold and pyrite mineralization tends to be concentrated in the bottom 15 cm of the basal conglomerate and occasionally in the ferruginous footwall (Pretorius, 1964). The closest outcropping Witwatersrand "Elsburg" conglomerates are 4.5 km away (Papenfus, 1964).

Stonestreet (1897) in Pouroulis (1988) described the Ventersdorp lava footwall topography in the area as highly undulating, 100 m to 130 m amplitude rolls, which affected the reef thickness (4 m to zero), and gold values which varied from trace to hundreds of ounces per ton (~3100 g/t).

Overlying the Black Reef is a 10 - 22 m zone of alternating quartzite and shales which are in turn overlain by 3 - 30 m of quartzite followed by dolomite. Pyrite also occurs in the quartzites and occasionally in the dolomites (Stonestreet, 1897 in Pretorius, 1964).

7.9.2 East Rand Basin

The principal producer of gold from the Black Reef was the Government Gold Mining Area (GGMA) which started mining operations in 1914, principally on the Main Reef Leader of the Witwatersrand Supergroup (Papenfus, 1957). Some Black Reef was probably mined sporadically where it overlay the latter reef. Diminishing ore reserves focused attention on the Black Reef. Production therefore commenced on the Black Reef in 1938 and 30 m tons of Black reef ore had been milled by 1962 when operations were halted. Production often exceeded 2 m tons per annum over long periods (Papenfus, 1964).

When production recommenced in 1979, GGMA and the surrounding mine areas were amalgamated to form Consolidated Modderfontein Mines 1979 Ltd. (CMM) (Pouroulis, 1988). Since then, the Black Reef has been

selectively mined as a high grade, low tonnage ore body, with two shafts presently in operation (Pouroulis and Austin, 1989). These are the NEP (North East Prospect) Shaft on GGMA and the no. 1 Circular Shaft on New Modder (fig. 7.12).

At present (January 1997), the mine is running at a profit and is engaged in a programme of upgrading and expansion (Citizen Newspaper, 1997).

CHAPTER 8

8 BLACK REEF IN THE EASTERN TRANSVAAL

In the eastern Transvaal the BRQF occurs along the eastern and northeastern boundary of the main Transvaal 'Bushveld' basin (fig. 1.1). The BRQF is developed as a continuous, roughly north-south trending, arcuate outcrop over a distance of more than 450 km between Badplaas in the south to northwest of Potgietersrus in the north (fig. 8.1). It occurs as a prominent but narrow outcrop along the rim of the Drakensberg escarpment (Henry et al, 1990).

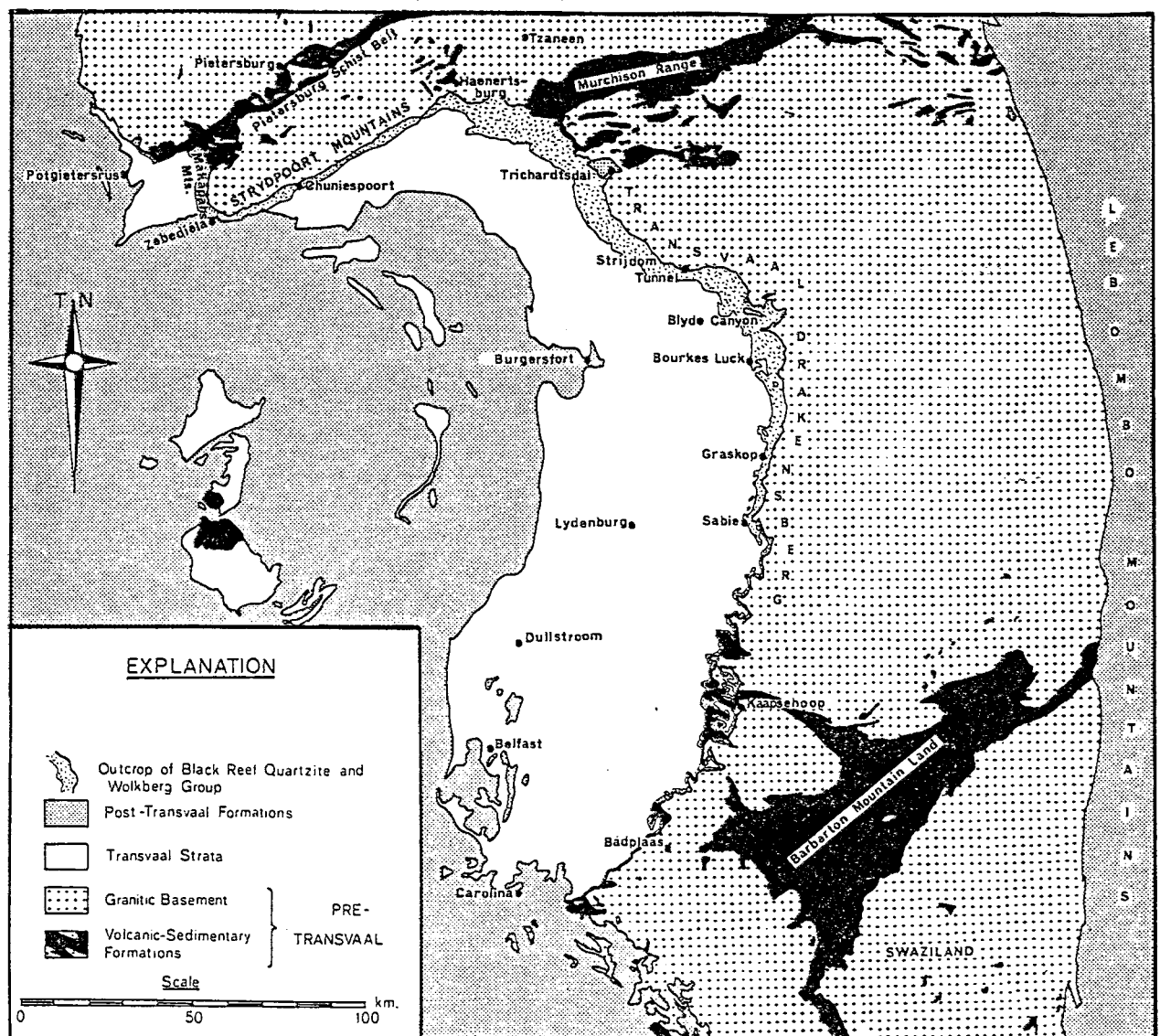


Fig. 8.1. Map showing locality and regional geology of the eastern Transvaal (Button et al., 1973a).

8.1 Previous Work

For a detailed discussion of the previous work on the Black Reef in the area, the reader is referred to Button (1973 a and c) from which much of this section is summarised. Localities are shown on figure 8.1.

In the Pilgrims Rest area, Brown (1896) described the "Berg Sandstone" (synonymous with the Black Reef Quartzite) as 33.5 m thick with 25 cm of conglomerate at its base. In the Sabie area, Wilson - Moore (1896) referred to the BRQF as the "lower sandstones and conglomerates" or "lower Lydenburg series". Molengraaff (1898) referred to the BRQF as the "Duiwelskantoor or Kantoor sandstone" and noted the presence of sporadic gold in the Kaapsehoop area. Thord - Grey (1905) partially mapped the Sabie - Pilgrims Rest area and intersected 57 m of Black Reef Series quartzite (Drakensberg Sandstone) with a 15 cm conglomerate band included, in a borehole on the farm Lisbon. In 1910, Hall mapped the geology of the Pilgrims Rest mining area.

Hall mapped the Murchison Range District in 1912 and the Haenertsburg goldfields (Olifants River area) in 1914, where he described the Mhlapitsi Fold Belt. Kynaston *et al.* (1911), documented the presence of the Serala Volcanic Member (Serala lava) in the Black Reef Series, in the Potgietersrus area. Wybergh (1925) noted the variable thickness of the BRQF on the irregular basement footwall south of Sabie. Reinecke and Stein (1929) incorrectly concluded that the basement granites were intruded into the Black Reef Series. Willemsse (1938) described the conglomeratic BRQF around Potgietersrus as well as Brandt and le Roex (1944) for the Olifants River Poort area.

Truter (1949) noted a 213 m thickness for his "upper quartzite zone", which is actually the BRQF below the Serala lava, along the northern section of the Drakensberg. In the Kaapsehoop and Badplaas areas, Visser *et al* (1956) described the locally auriferous Black Reef in detail, noted the

anomalous thickness of the unit, the pinching out of the Black Reef quartzite against, and local development of conglomerates around, topographic highs. The Godwan Formation was also mapped in detail. Visser and Verwoerd (1960) did similar work on the Black Reef in the Sabie area, described the transition zone to the overlying dolomites and noted the presence of an unconformity between the BRQF and the footwall Godwan Formation. Along the Drakensberg, Schweltnus et al. (1962) included the Serala lava as well as the underlying "main quartzite zone" in the Wolkberg Group. They described the Godwan and Wolkberg successions in detail. Zietsman (1964) dealt primarily with the distribution, geomorphic expression and heavy mineral composition of the BRQF. De Waal (1968 - 1969) undertook a detailed mineralogical study of a uraniferous conglomerate, as well as an included quartzite pebble, from near Kaapsehoop.

Button (1973a and c) identified the Wolkberg Group as the proto - basin to the Transvaal Supergroup and conformable with the overlying BRQF, which was calculated to be more than 500 m thick in the northerly Selati trough. This consisted of an upper and lower quartzite zone with the Serala Member basalt intercalated between them.

Clendenin et al (1989) interpreted the less than 50 m thick upper quartzite, overlying the Serala Member basalt, as BRQF, whilst the lower quartzite was reinterpreted to be a new "The Downs" unit at the top of the Wolkberg Group which was correlated with the Ventersdorp Supergroup. An unconformity was identified at the base of this BRQF across the Serala Member basalt, where present, and Wolkberg where not.

Henry et al (1990) described the sedimentary facies and depositional environment of the BRQF.

8.2 Geological Overview of the Eastern Transvaal

The Archaean granites and greenstone basement are exposed as a broad belt in the Transvaal Lowveld which borders the base of the escarpment on the eastern side (fig. 8.1). The greenstone belts occur as southwestwards trending remnants in the granitic basement (Anhaeusser and Viljoen, 1986). Overlying these are the youngest known rocks of the Transvaal Supergroup. These are the Wolkberg Group which occurs between Sabie and Potgietersrus in the north (fig. 8.1) and the Godwan Formation (fig. 8.2) which is restricted to the Kaapsehoop area in the south (fig. 8.1). They are overlain by the younger BRQF, which is in turn overlain by the carbonates and lesser banded iron formation of the Chunniespoort Group, followed by the sediments and volcanics of the Pretoria Group (fig. 8.3) (Button, 1973a).

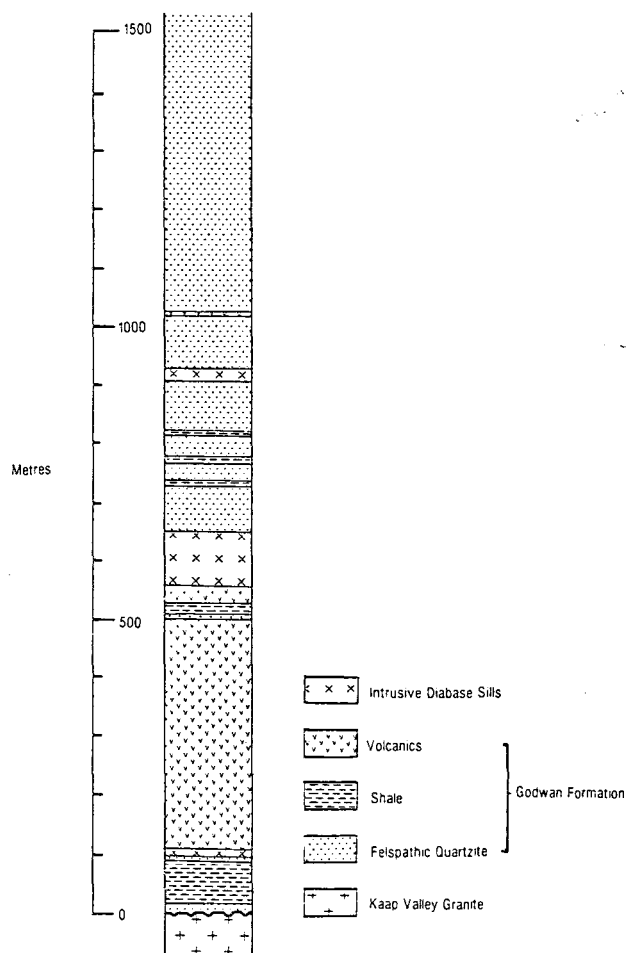


Fig. 8.2. Stratigraphy of the Godwan Formation (modified after Visser, 1956) (from Button, 1978).

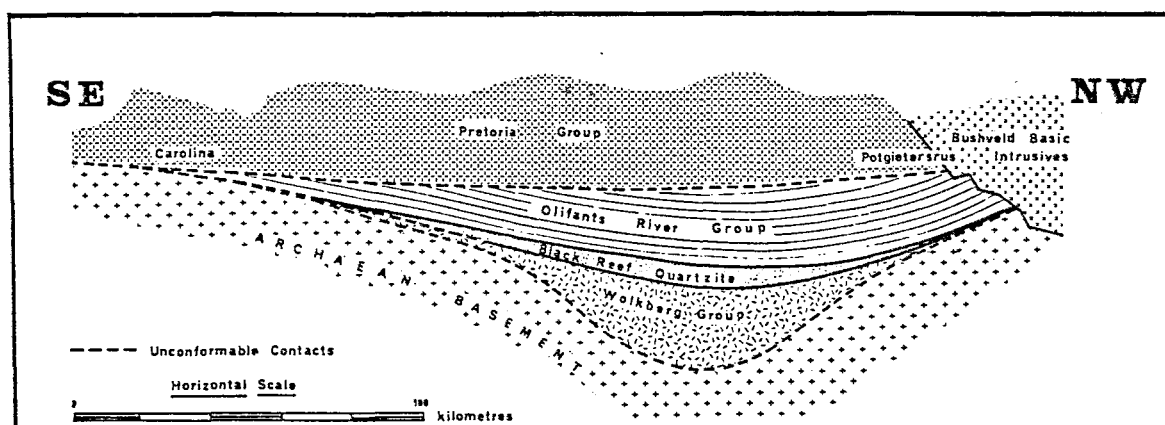


Fig. 8.3. The gross stratigraphic subdivision of the Transvaal Supergroup in the eastern and northeastern Transvaal (Button, 1973a).

The Wolkberg Group is considered to be the protobasin to the Transvaal sequence with the BRQF conformably overlying it (Button, 1973b; SACS, 1980) except for a slight basin - edge unconformity in the Sabie area (fig. 8.4) (Button, 1978). Clendenin et al (1989) however, consider the BRQF to lie unconformably on the Wolkberg Group (see section 8.7.2 below). The Godwan Formation, which has been variously correlated, is unconformably overlain by the BRQF. The BRQF unconformably overlies Archaean basement granite and greenstone belts over much of the southern parts of the area where these two successions are not present (fig. 8.4) (Button, 1973a).

The basic phase of the Bushveld Complex has intruded and covers much of the western and southern parts of the Transvaal Sequence in the eastern Transvaal, which in turn are covered by Phanerozoic Karoo sediments over its southern parts (Button, 1973a).

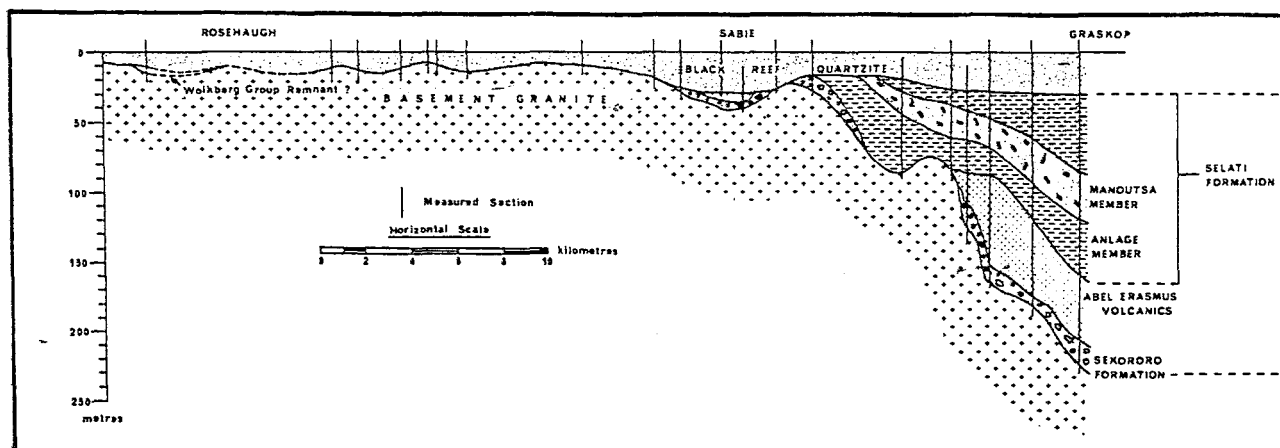


Fig. 8.4. The relationship of the Black Reef Quartzite to the Wolkberg Group in the Sabie - Graskop area (Button, 1973a).

8.3 Black Reef Structure

The dip of the Transvaal Sequence strata is homoclinally disposed. From north to south around the basin rim, it progressively dips southwards, southwestwards and westwards (Button, 1973c).

In the northern parts of the eastern Transvaal, the Transvaal succession has been affected by east - west or east - northeast trending folding (Brandt and le Roex, 1944). North - northwest directed compression produced the regional, east - northeast fold trend and thrust faults. Several phases of deformation, with roughly similar trends, occurred over widely different periods (Roering, 1965). All formations older than, and including, the Transvaal dolomites were affected by this folding (Brandt and le Roex, 1944). In the area of Potgietersrus (fig. 8.1), the northernmost extent of the BRQF, a major, east - northeast trending, left - lateral fault (Button, 1973c; Du Plessis and Walraven, 1990), with a throw of at least 60 m, has displaced the Transvaal succession by 15 km, thereby juxtaposing the BRQF against older Wolkberg Group rocks on its north side (Button, 1973c). South of this, in the north - northeast trending Mhlapitsi Fold Belt (Potgieter, 1991), which coincides with the southwesterly extension of the

Murchison greenstone belt, a distinctive, steeply north or south dipping, east - northeast trending planar fabric is present in the BRQF. Bed - parallel quartz veins and slickensides occur (Button, 1973c). In the Sudwala area, 20 km north of Kaapsehoop, the predominant trend of post - Black Reef dykes, as well as many small faults with less than 10 m throws, is north - northeast (Maske et al, 1986).

8.4

Depositional History and Thickness of the Wolkberg Group

The Wolkberg Group is the footwall succession to the BRQF over the deepest parts of the Transvaal 'Bushveld' basin and occurs as a 190 km wide, east - northeast trending zone of preserved sediments, lying between the Uitloop and Sabie platforms over the northern half of the area (fig. 8.5). Its thickest zone of accumulation overlies the Selati trough (fig. 8.5), which overlies a southwesterly extension of the Murchison range. The Wolkberg Group pinches out against the Uitloop Platform to the north and pinches out partially over the Sabie Platform to the south. A number of second order features, consisting of a series of basins and arches (fig. 8.5.), causes respective thickening and thinning of the group (Button, 1973a).

According to Button (1973b), the Murchison greenstone belt was a zone of rapid and continuous subsidence, between rigid and tectonically positive granitic areas which accumulated thinner sediments than the Selati trough. Early Wolkberg deposition was limited to restricted areas of probable, channelised stream sediments, which were controlled by the irregular palaeotopography (fig. 8.4) generated by the tectonic subsidence. Continued deposition of sediments and later volcanism, slowly covered the pre - Wolkberg footwall so that the upper parts of the group were deposited on a fairly even surface. Gross sedimentation patterns of the Wolkberg Group are transgressive (onlapping) (fig. 8.3) and generally fining upwards (Button, 1973a).

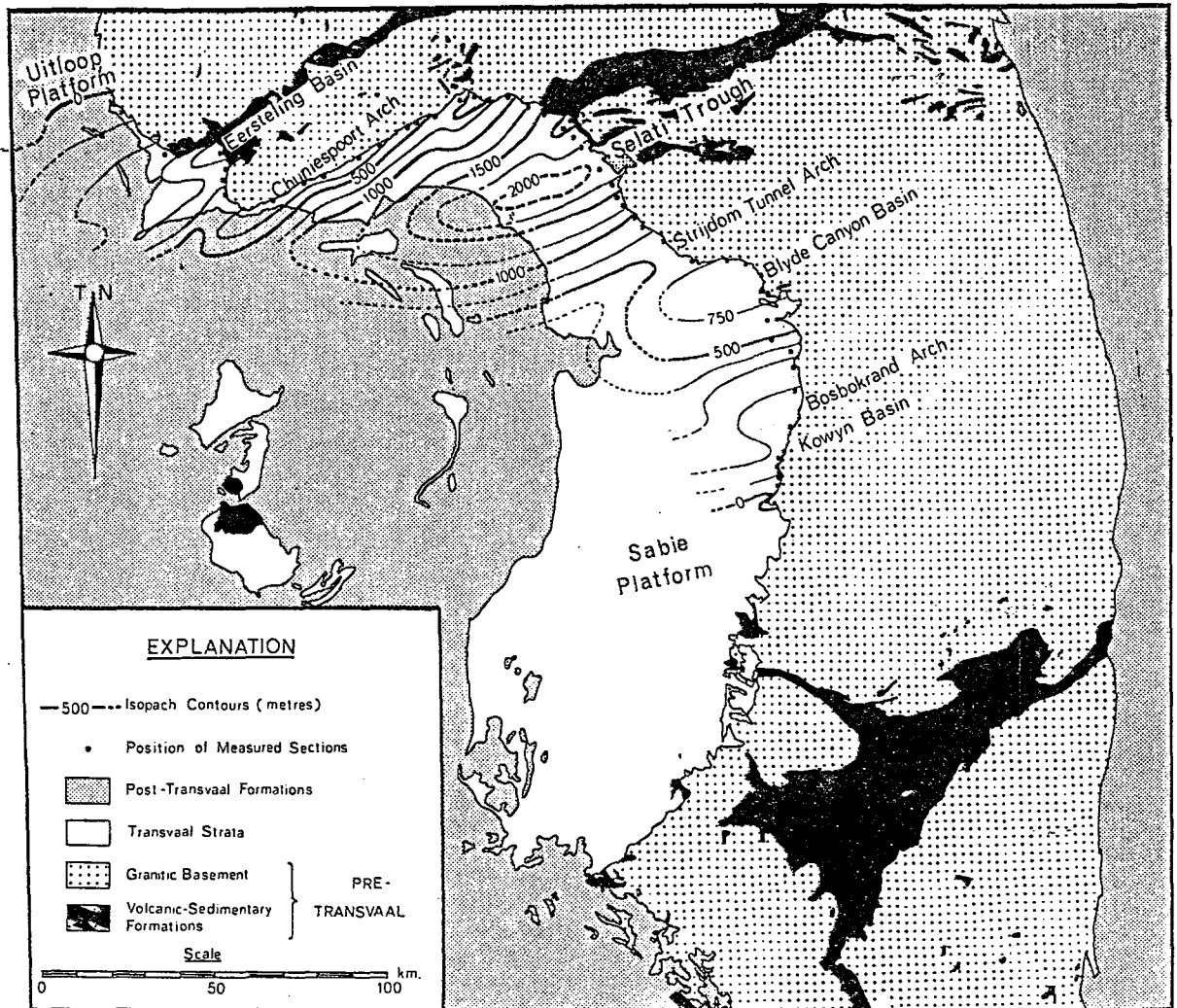


Fig. 8.5. Wolkberg Group isopach map (Button, 1973a).

Deposition of the lower Wolkberg Group (Sekororo, Abel Erasmus and Schelem Formations) took place under tectonically unstable conditions. Relatively stable tectonic conditions existed, during deposition of the overlying, upper Wolkberg Group Selati, Mabin and Sadowa formations. Uplift in the southeast ended Wolkberg sedimentation (Clendenin et al, 1989).

8.5 Deposition and Thickness of the Black Reef Quartzite Formation

In the Transvaal basin, the BRQF is usually a relatively thin attenuated formation. Only in the Eastern Transvaal, where it reaches its maximum thickness, does it consistently attain thicknesses of more than 50 m (Button, 1973a).

Button (1973a and c) constructed an isopach map of the Black Reef along the Eastern Transvaal escarpment from Potgietersrus in the north to near Carolina in the south (fig. 8.6). Variable contour intervals were used, in draughting the roughly east - west trending contour intervals, due to uneven thickness changes, specifically towards the north. Towards the south, thickness variations are more gradual. Towards the north, the formation is greater than 500 m thick over the Selati Trough. Northwards of this trough, the formation thins out rapidly and "pinches out completely near Potgietersrus". South of the Selati Trough, the formation thins more gradually as far as Sabie, southwards of which the thickness rarely exceeds 20 m as far as Carolina. In the Kaapsehoop area, the isopachs thicken slightly (fig. 8.6), indicating channelisation of the Black Reef. Further to the south around Badplaas, the BRQF is always less than 10 m thick (Button, 1973a and c) and often less than a metre of arenite is present overlying the Archaean basement (Button, 1973a and c; Clendenin et al, 1989).

The anomalous thickness of both the Wolkberg and BRQF over the Selati trough is considered by Button (1973a and c) to indicate that subsidence under the Selati trough continued into Black Reef times and dominated Black Reef sedimentation. Thus over 500 m of sediments, including approximately 100 m of Serala Member basalts were deposited in the trough. Against the topographically positive Uitloop platform to the north, the BRQF pinched out rapidly. South of the Serala trough, subsidence occurred further southwards than in Wolkberg times. Relatively slight subsidence over the southern Sabie - Carolina platform resulted in a thin, less than 20 m thick, sandy succession over the area similar to that

commonly found over large parts of the rest of the Transvaal basin (Button, 1973a).

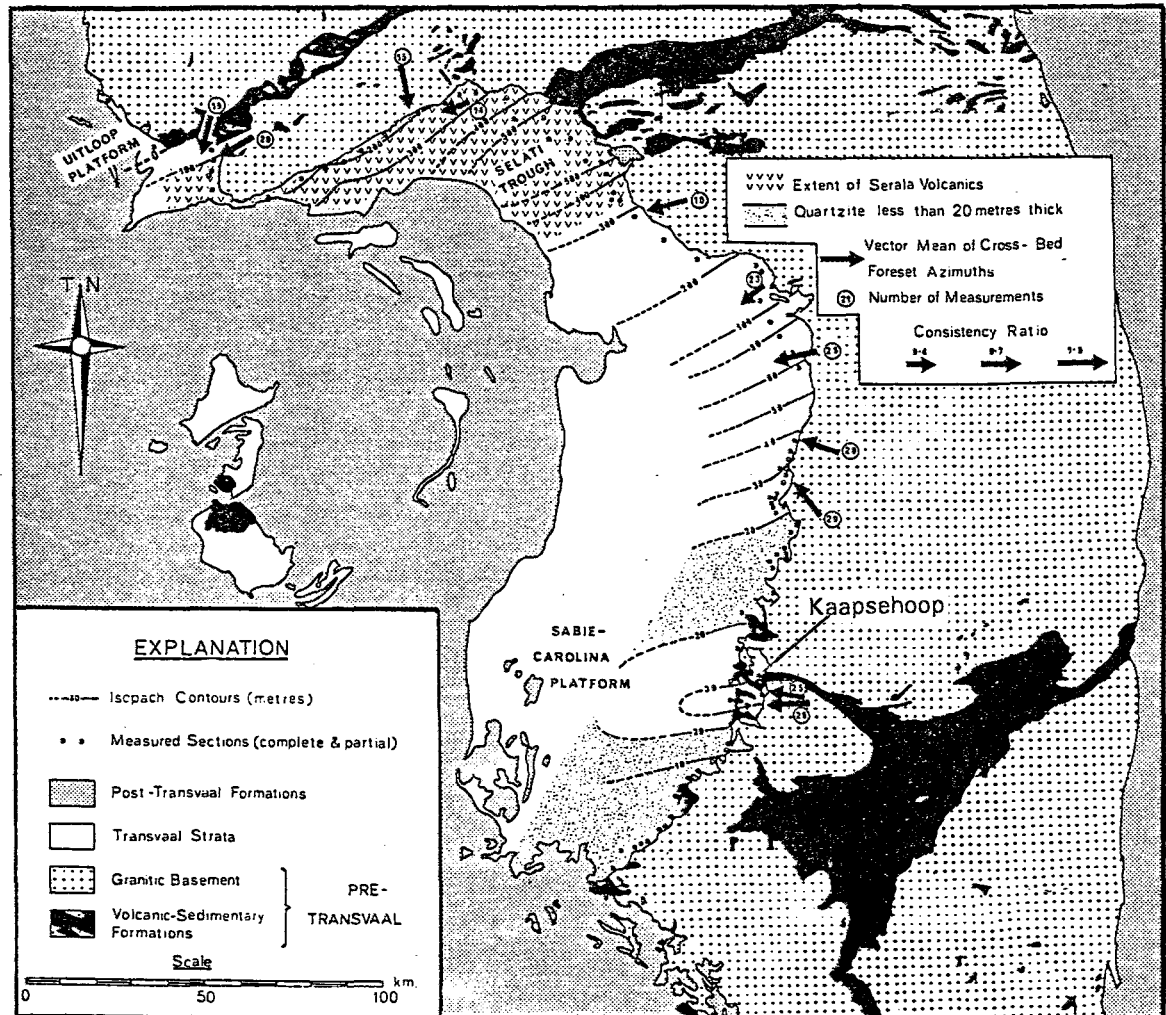


Fig. 8.6. Isopach map of the Black Reef Quartzite Formation with palaeocurrent determinations superimposed (Button, 1973a).

Although Clendenin et al (1989) agree with the generally thin nature of the BRQF in the southern parts of the area, the formation is considered to be much thinner than the +500 m measured by Button (1973a and c) northwards of the Blyde River Canyon overlying the Selati Trough, due to their different interpretations of the stratigraphy (fig. 8.7 and 8.8). It has a maximum thickness of 35 m (Henry et al, 1990) (fig. 8.9).

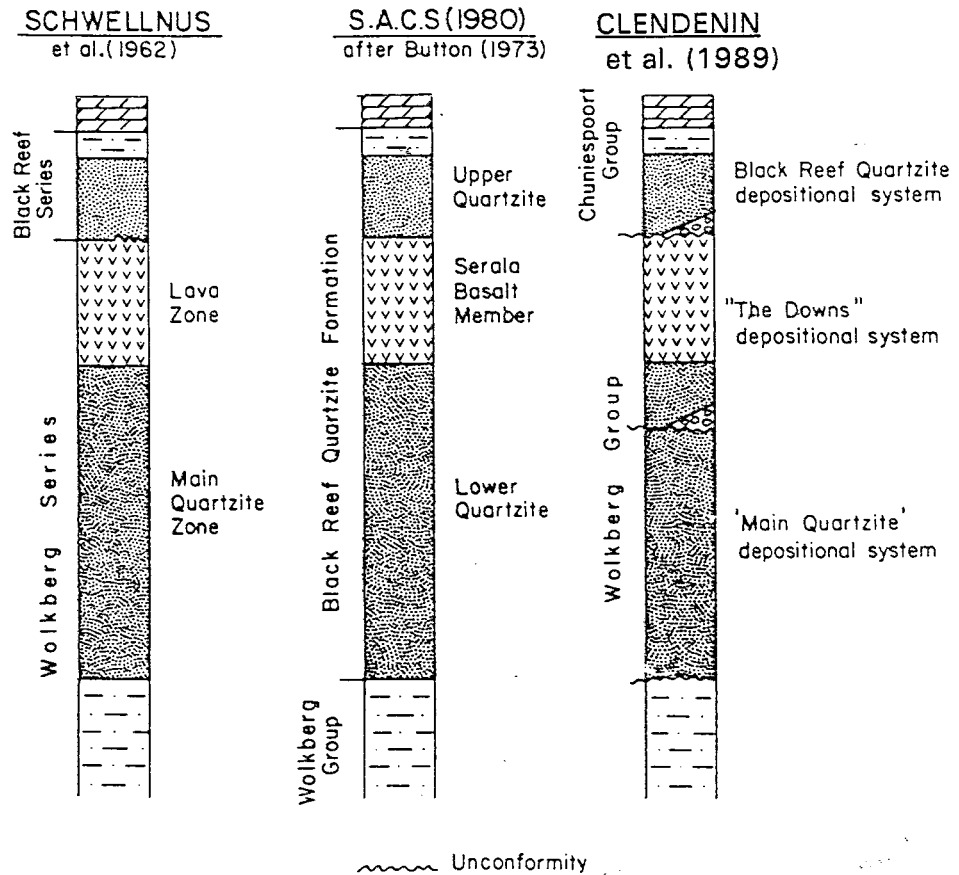


Fig. 8.7. Stratigraphic sections for the Selati trough area showing previous and present interpretations of correlations between the Wolkberg and Black Reef Quartzite Formation stratigraphic packages (Clendenin et al., 1989).

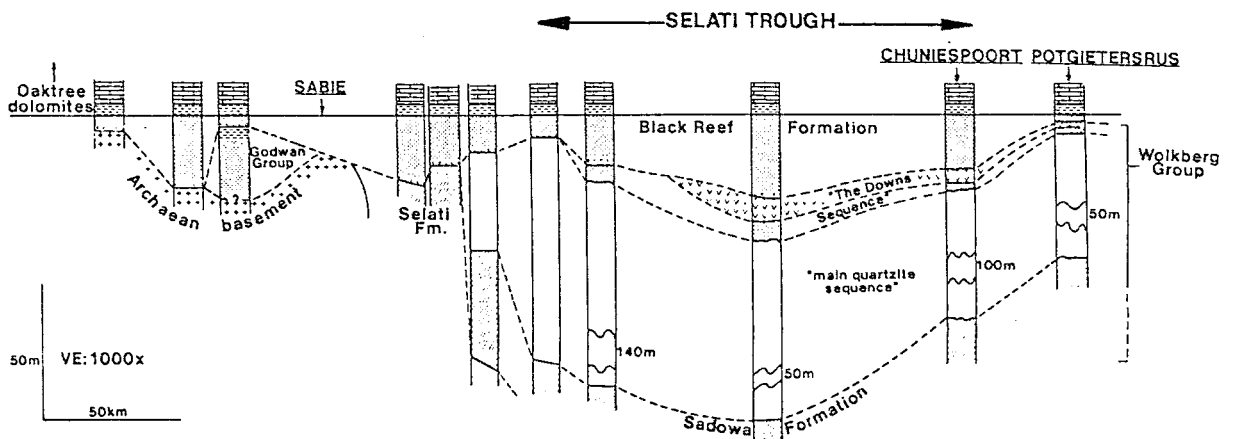


Fig. 8.8. Detailed lithostratigraphy of the upper part of the Wolkberg Group (sensu lato) illustrating the relationship of the Black Reef Quartzite Formation with the underlying units. Modified after Clendenin et al. (1991) (in Eriksson et al., 1993).

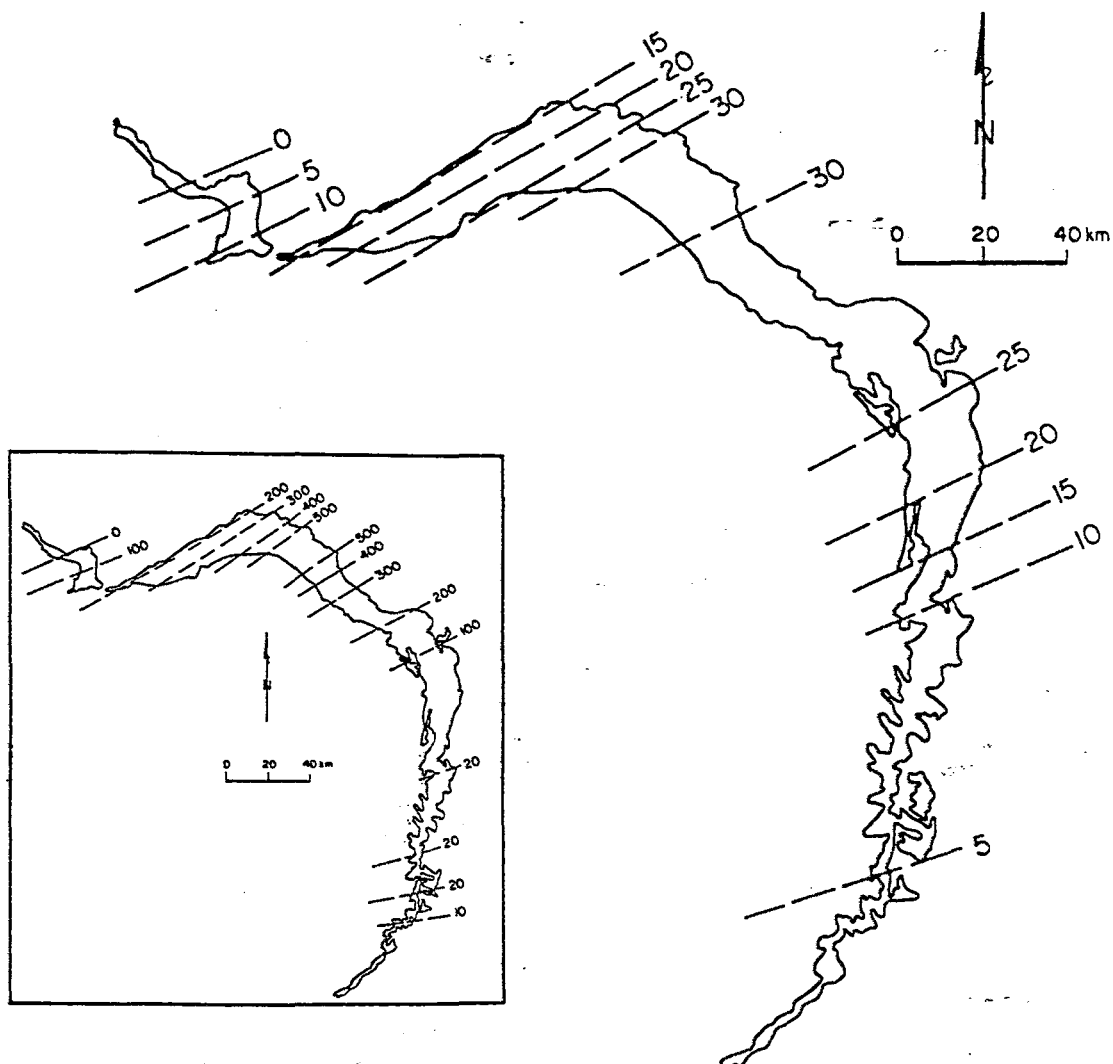


Fig. 8.9. Isopach map showing thickness of the Black Reef Quartzite Formation stratigraphic package (according to Clendenin et al., 1989) in the eastern Transvaal compared to Button's (1973a and c) isopach map (in inset). (after Clendenin et al., 1989).

8.6 Pre - Black Reef Palaeotopography

Over much of the eastern Transvaal, the BRQF conformably overlies the Wolkberg succession, which previously, had buried much of the primary, uneven topography of the basin (Button, 1973c). The footwall would

therefore have been fairly even to gently rolling in the area (fig. 8.4) except where wedging out against basement highs occurred. Locally derived Black Reef conglomerates are developed around these basement highs. "In granitic areas, palaeohills have been mapped" (Button, 1986). Towards the south, over the inhomogeneous Archaean basement, where the Black Reef was channelised, the footwall was incised and irregular (Button, 1973c).

8.7 Stratigraphy

8.7.1 Black Reef Footwall Succession in the Kaapsehoop Area

In the Kaapsehoop area the footwall of the Black Reef consists of Kaap Valley Granite, parts of the Jamestown Schist Belt and the Godwan Formation which up to date has been correlated with the Pongola System. The Godwan Formation is post - Archaean and pre - Black Reef (Visser, 1956).

The 1500 m thick Godwan formation has a mainly northeast strike and a 15° to 80° dip to the northwest (Button, 1978). The arenaceous and volcanic succession of the Godwan Formation (fig. 8.2) has suffered pre - Black Reef folding, faulting and sill intrusion, unlike the Wolkberg Group further to the north. Therefore it is probably not a correlative of this group but may be the easternmost outcrop of the upper Witwatersrand basin (Button, 1978) whereas Hall (1929) proposed it may be a Ventersdorp equivalent (quartzite and shale overlain by amygdaloidal lava).

8.7.2 Black Reef Quartzite Formation

According to Henry et al. (1990), the formation consists predominantly of quartz arenite with minor shales and conglomerate. Button (1973a and c) describes the Black Reef Quartzite (Formation) as being predominantly mature, trough cross - bedded quartzite with minor gritty and conglomeratic phases which includes the basaltic, lensoid - shaped Serala

Member. The sporadic conglomerate is developed where an erosional surface is present. Initiation of footwall erosion took place during or after uplift in the southeast (Bosch, 1991) with a northerly tilt (Clendenin et al, 1989).

According to Clendenin et al (1989) the BRQF in the eastern Transvaal is a thin package of fluvial siliclastics, underlying the Chunniespoort carbonates and enclosed by regionally correlatable stratal surfaces. The footwall Archaean basement and Wolkberg Group forms a subtle angular unconformity with the younger BRQF (Bosch, 1991). In the Selati Trough, a newly identified "The Downs stratigraphic unit" separates the BRQF from the Wolkberg Group (fig. 8.7 and 8.8) thereby showing that the BRQF is not conformable with the Wolkberg Group in the Selati Trough (Clendenin et al, 1989). The authors consider the quartzite occurring between the Serala Member basalts and the Malmani dolomite to represent the BRQF exclusively, whilst the quartzites underlying the Serala Member basalts and overlying the Wolkberg Group is the newly identified unit. Eriksson et al (1993) include this new unit and the Serala Member basalts in the Wolkberg Group.

In the Kaapsehoop area, the BRQF has an anomalous +30 m thickness (fig. 8.6) (Button, 1978) which Visser (1956) estimated to be up to 45 m locally. This suggested to Button (1978) that it is an area of relatively rapid subsidence during deposition.

8.7.2.1 Black Reef Quartzite

This medium - grained, occasionally gritty or pebbly quartzite consists mostly of quartz with common carbonaceous speckling and pyrite specks. Variations in carbonaceous matter give the rock a banded appearance, on fresh surfaces, in various shades of white, grey and black. In arid areas, the quartzite bleaches white with an internal pink, yellowish or orange colour.

In wetter areas, it weathers to a grey, crumbly sandstone which may be re-silicified on exposed surfaces (Button, 1973c).

The quartzite commonly contains 10 to 50 cm trough cross - bed sets and occasional 1 m thick tabular cross - beds. Ripple - marks and planar, often centimetre scale bedding is less commonly found (Button, 1973c).

8.7.2.2 Black Reef

The composition of the basal conglomeratic "Black Reef" phase depends largely on the nature of the footwall rocks. Where it overlies the Selati Formation shales, angular shale clasts of up to 30 cm in size are included with the vein quartz and chert normally present. In the Sabie Falls area, where the very coarse - grained Sekororo Formation forms the footwall, the Black reef consists of a poorly packed, cobbly conglomerate. Seventy percent of the clasts are quartzite with the remaining 30 percent consisting of equal amounts of vein quartz, black chert and aplite granite. Southwards of Sabie, where the footwall consists of Archaean basement, intermittent, mostly small pebble conglomerates or grits of predominantly quartz pebbles occur (Button, 1973).

In the Kaapsehoop area, cobbly conglomerates were deposited locally in incised channels (Button, 1973c; Clendenin et al, 1989), the overlying palaeocurrents in the quartzite indicating a transport direction from east to west (Button, 1973c). At the basement contact, 5 m of arkosic sediments are present. A basal conglomerate up to 6 m thick is intermittently developed (Visser et al, 1956). Channels are a few metres to hundreds of metres in width and contain cobbles up to 18 cm in size. Where channels are not present a small pebble conglomerate or cross - laminated quartzarenite unconformably overlies basement granite (Clendenin et al, 1989).

8.8 Depositional Facies

Henry et al (1990) compiled a composite vertical sedimentary column for the BRQF (fig. 8.10) from 30 measured sedimentary profiles taken between Badplaas in the south and the Blyde River Canyon to the north. Miall's (1978) facies code scheme was used to compile 5 facies descriptions. These are:

a. Conglomerate facies (GMC and Gmm):

This facies occurs as <5 cm to 5 m thick, lenticular, discontinuous beds, usually developed on the unconformity with an erosive contact. Both clast (Gmc) and matrix - supported (Gmm) types occur and may grade into each other. Clasts commonly consist of vein quartz and quartzite. Massive and banded chert, shale and felsic volcanics occur locally. Sorting of the subangular to subrounded clasts is generally poor and set in a coarse matrix.

b. Trough cross - bedded quartz arenite facies (St):

This most common facies, comprises fine- to coarse - grained quartz arenite. Up to 10 % feldspar is locally abundant. Cross - beds occur as small (<10 cm), medium (<50 cm) and large (up to 150 cm thick). sets which commonly stack into beds up to 10 m thick.

c. Planar tabular cross - bedded quartz arenite facies (Sp):

This facies occurs as uncommon, 30 cm to 50 cm beds of medium- to coarse - grained quartz arenite.

d. Plane laminated arenite facies (Sh):

Coarse- and more commonly fine-grained varieties are found. At one locality, a 2 m thick quartz arenite was found. The common variety consists of up to 1.5 m, very fine - grained quartz arenite to siltstone.

e. Mudrock facies (F1):

This consist of poorly exposed, negatively weathering, black (carbonaceous) to dark grey, finely laminated shale and siltstone. Observed thickness range from a few centimetres to 3 m.

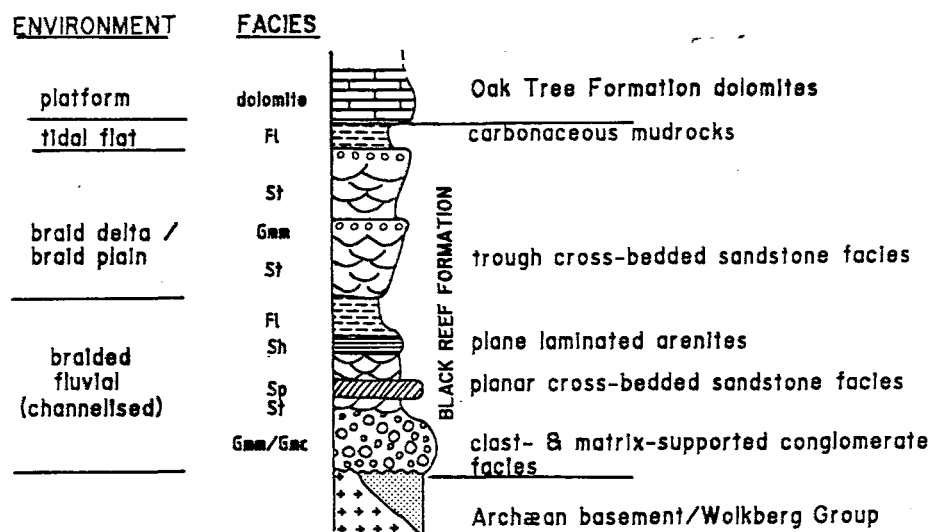


Fig. 8.10. Composite sedimentological log showing interpreted palaeoenvironmental settings and facies sequence of the Black Reef Quartzite Formation in the eastern Transvaal basin. Compiled from Henry et al. (1990) and Eriksson and Clendenin (1990).

8.8.1 Vertical Facies Sequence

The basal facies consists of a channel conglomerate overlain by medium to large scale cross - bedded quartz arenite with isolated, intercalated, planar tabular sets. A fine - grained, plane laminated facies and mudrock may top off the sequence. The sequence is fining upwards (Henry et al, 1990).

One or more, upward coarsening sequences may occur above the basal sequence. These consist of medium to large scale, trough cross - bedded, quartz arenite facies which may grade into small pebble (1-2 cm clast size) conglomerate or thin granulestone. A mudrock facies often completes this succession (Henry et al, 1990).

8.8.2 Lateral Facies Changes

The basal, fining upwards sequence is sporadic and extremely variably developed. The upward coarsening sequence(s) has a widespread, sheetlike morphology which can be followed around the full 450 km length of the eastern Transvaal basin (Henry et al, 1990).

8.9 Palaeocurrent Directions

Palaeocurrent measurements on cross - bed foresets of the Wolkberg Group (fig. 8.11) in the northern parts of the area, indicate that deposition of the succession was southwards into the Selati trough (Button, 1973c) from a source area partly overlying the Limpopo Belt (Button, 1986). To the south of the trough, sediments were transported from the northeast and east (Button, 1973a). The direction of transport is consistently directed towards the centre of the basin and away from the surrounding basement rocks (Button, 1973c).

Button (1973a) collected palaeocurrent data at 11 stations around the perimeter of the basin on the BRQF (fig. 8.6). These were predominantly southwards, southwestwards and westwards respectively, from north to south around the basin. The currents were usually unimodal and the "whole eastern Transvaal was influenced by one and the same mega - dispersal pattern of sand (Button, 1973a). Palaeocurrent directions determined from trough axes on the upper "widespread upward coarsening sequence" of the BRQF around the basin rim are mostly east - west (Henry et al, 1990).

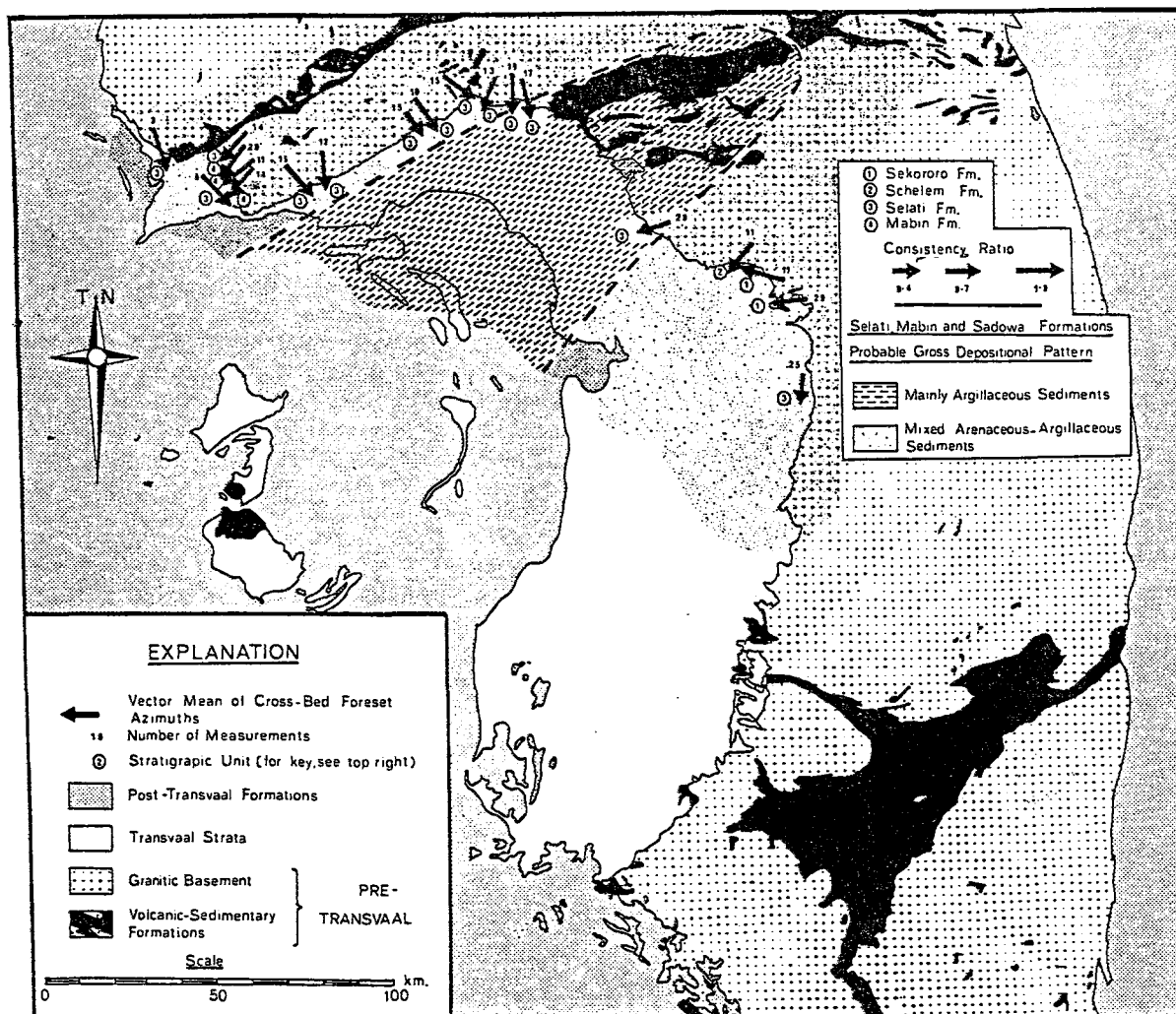


Fig. 8.11. Map showing Wolkberg palaeocurrent determinations and a tentative reconstruction of the gross depositional pattern for Selati to Sedowa times (Button, 1973a).

8.10 Depositional Environment

In the Eastern Transvaal, where deposition of the Black Reef took place on an erosional surface, a localised initial braided stream phase was deposited in channels incised into the pre - Black Reef basement (Button, 1973c; Bosch, 1991). Henry et al (1990) are in agreement with this interpretation, but in addition, describe the basal unit as "predominantly sandy, upward fining with minor conglomerate lag deposits".

The upper, coarsening upwards, extensive sheet sand facies with its "large scale trough cross - bedding" and unimodal palaeocurrent direction is indicative of a prograding braid delta or braided plain environment. The shale facies overlying the Black Reef quartzite is indicative of transgressive conditions in a tidal flat depositional environment and the onset of initial carbonate deposition in the eastern Transvaal (Henry et al, 1990).

Button (1973) interprets the upper part of the quartzite facies to have been deposited in a shallow marine shelf environment (subtidal sheet sand). It was developed in the primary phase of the epeiric "Malmani Sea" (Tankard et al, 1982), which had a U - shaped geometry, open to the west and southwest (the Transvaal dolomites thicken and contain less, interbedded clastic sediments towards the west). A series of deltas to the northeast supplied sediments to this sea, which swept these sediments clockwise, from the northeast to the south and thence eastwards past the southern shoreline towards the open ocean further to the west (Button, 1973c).

The transition from Black Reef quartzites to Malmani dolomites is regarded as a classical marine transgression (Button, 1973c; Clendenin et al, 1988). Alternately, sediment starvation, resulting from a lack of source material, due to the northeast boundary of the basin having been eroded down to near base level, would have resulted in the clear water conditions necessary for carbonate precipitation (Button, 1973c).

8.11 Mining History

The eastern Transvaal has a long history of gold mining activity which reaches back to 1869. A fair amount of gold was produced from the Black Reef along the escarpment in the eastern Transvaal (Whiteside et al, 1976). Most of this gold is associated with the "hydrothermal" vein - type Black Reef mineralisation (Hammerbeck, 1976) which is "probably" related to post - Transvaal structures (Schwellnus et al, 1962) and is genetically

associated with emplacement of the Bushveld Complex (Duane et al, 1991). This gold occurs in shale beds in the transition zone at the top of the Black Reef Quartzite Formation (Harley and Charlesworth, 1990) (Duane et al, 1991). Palaeoplacer gold is of lesser importance (Hammerbeck, 1976).

Mining of placer gold on any scale has taken place in only two areas. These are the Kaapsehoop area towards the south (Sohnge, 1986) and the Haenertsburg Goldfield towards the north (fig. 8.1). In the Sabie - Pilgrims Rest area, placer gold was not mined although auriferous Black Reef conglomerate occurs on Rietvallei 256 JT and on other farms (Hammerbeck, 1976). Northwards of Sabie, along the escarpment of the Strydpoort and Drakensberg, the Black Reef Quartzite Formation carries gold in places (Hall, 1914) (Hammerbeck, 1976).

8.11.1 Kaapsehoop Area

The extensive prospecting undertaken in the Kaapsehoop area (fig. 8.1) in the past has left large numbers of prospecting trenches and adits along the Black Reef outcrop. In the area, placer gold has been recovered from the Black Reef on Kaapsche Hoop 483 JT (five workings are present). Similar operations occur on The Narrows 482 JT and Coetzeestroom 479 JT where 25 stoped out adits and 3 shafts occur. On the latter farm, a sample of 9.5 g/t Au over 175 cm was taken on basal quartzite of the Black Reef (Hammerbeck, 1976).

The mineralisation of the area is generally sporadic and low grade, although highly payable local concentrations do exist, e.g. at Kaapsche Hoop 483 JT, values of 10.8 g/t over 110 cm of conglomerate have been obtained (Hammerbeck, 1976). Alluvial and eluvial gold, derived from the Black Reef, dominated production in the area and included some of the largest nuggets found in South Africa. Any new discoveries will probably be small and relatively low grade (Whiteside et al, 1976).

At Kaapsehoop, the Black Reef is mineralised with pyrite, gold and uranium (Visser 1956: De Waal and Herzberg 1969 in Button, 1978). The gold is concentrated at the base of the conglomerates. Pebbles consist of vein quartz as well as jasper, chert, quartzite. It is assumed that these come from the Archaean basement (Button, 1973c). Black Reef mineralization at Kaapsehoop is from erosion of the pre - Black Reef Godwan Formation Au - U conglomerates. These conglomerates may be preserved under Black Reef cover west and southwest of the Godwan outcrop belt (Button, 1978). Some of the quartzite is uraninite bearing (De Waal and Herzberg, 1969 in Button, 1973c).

8.11.2 Haenertsburg Goldfield

This area lies between the Malips and Olifants Rivers, and the Strydpoort and Drakensberg escarpments (fig. 8.1) and is almost completely overlain by the BRQF and the Dolomite Plateau. The terrain is extremely rugged and mining has therefore been sporadic up to date (Hall, 1914). Extensive prospecting has occurred in the past in the goldfield (Hammerbeck, 1976) and a number of small mines, located in the Wolkberg and BRQF successions, were active in the area. These were the Rocky Thompson, Silver Wedding, Pretoria Reefs, St Louis and Pennefather mines. Quartz veins associated with northeast trending faults in the area were mostly worked (Schwellnus et al, 1962). Gold was possibly mined in conglomerates at the St. Louis Mine (Schwellnus et al, 1962: Hammerbeck, 1976). At the old Pennefather mine, gold was mined in conglomerates (Hammerbeck, 1976) until 1908. These occurred near the base of the Wolkberg Group (Schwellnus et al, 1976). This contradicts Hall (1914) who identified the conglomerates as Black Reef (see paragraph below).

Small scale alluvial gold mining took place in a small stream on Wolkberg 634 LT (Schwellnus et al, 1962) which was probably derived from the conglomerate near the base of the lower quartzite that was mined at the Pennefather mine (Hall, 1914). More extensive alluvial mining took place

in the Mhlapitsi River valley on Aden 1 KT (Schwellnus et al, 1962; Hall, 1914).

Minor mining activity also took place in 1973 on the Black Reef on Amatava 41, 12 km northeast of Potgietersrus (Hammerbeck, 1976). Here the BRQF consists of coarse- and fine- grained quartzite and conglomerate, which decreases in thickness westwards. The formation is well exposed on dipslopes overlying arenaceous Swaziland Supergroup rocks (Willemse, 1938).

CONCLUSIONS

The Black Reef is a sporadically developed, locally economic, erratically mineralised conglomeratic package. It has been successfully mined at a few places only. The areas of successful economic exploitation of the Black Reef are the East Rand and the West Rand. The Klerksdorp area was only partially successful, the unoxidised Black reef at depth, giving metallurgical problems.

Economic Black Reef in the Transvaal basin, is strongly associated with the following factors:

a). The Black Reef is associated with proximal and footwall, auriferous formations. These are the auriferous Central Rand Group formations, specifically the Kimberley - Elsburg Reefs of the Witwatersrand Supergroup, which border the northern fringes of the subsidiary basin overlying the Witwatersrand Supergroup. Smaller, less economic to uneconomic placers border the major Transvaal 'Bushveld' basin, apparently deriving most of their gold from the Archaean greenstones in the general vicinity.

b) Economic Black Reef occurs predominantly in channelised conglomerates, overlying unconformities. Footwall palaeotopography controlled locations of the channels. The different forms of this palaeotopography, is in turn, largely due to the nature of the footwall successions. Strike direction, steepness of dip, faulting and differential erosion of these successions and occasionally dykes, dictates the type of palaeotopography generated. Competent quartzite beds tend to develop slightly undulating surfaces, resulting in broad shallow channels. They also tend to form topographic highs which border channels, whilst these channels, which may be incised, anastomosing, braided or have a trellis drainage pattern, tend to overlie topographically negative topography which preferentially develops over the softer formations, such as the Booyens

shales. Depths of channels, and therefore conglomerate thicknesses, were controlled by this palaeotopography. On the West Rand, Black Reef channels follow the softer, topographically negative, north-south trending, steeply dipping successions, such as the Booyens shales. On the East Rand, Black Reef channels trend parallel to the shallow dip of the strata, the competent, topographically positive quartzites, diverting the channels onto the softer, shale successions.

c) In the southwestern Transvaal, the Black reef is associated with a southwest trending series of horsts and grabens. The eroded horsts, which consisted of gold bearing Witwatersrand sediments, were the source of the conglomerates and gold of the Black Reef, whilst the Black Reef channel beds were limited to the grabens inbetween. On the East Rand, narrow, incised channels are cut into northwest trending fault zones through competent quartzitic units, resulting in rugged terrain with development of thick conglomerate packages. In the Booyens shales, faulting has aided rapid erosion of this soft formation. On the Geduld property, channels follow negatively eroded dykes.

On the East and West Rand areas, the overlying sheetlike Black Reef Quartzite, carries consistent but low grade gold values (~0.1 g/t),

Economic Black Reef has mostly been found in channels of varying sizes and gold grades. Widths of channels vary from a few metres to 600m. Channels vary from a few tens of metres up to many kilometres in length. Depths vary from a few centimetres up to 13 m. Gold values range from trace, up to hundreds of g/t.

There does not appear to be much potential for finding economic Black Reef, outside the confines or border areas of the Witwatersrand basin. The two most successful areas to be mined lie on top of Witwatersrand auriferous sediments and conglomerates. The third most successful area is Klerksdorp, which is also proximal to eroded Witwatersrand sediments.

Gold accumulation in the Black Reef areas of the main Transvaal 'Bushveld' basin are mostly uneconomic. Much of the Black reef appears to be relatively immature, with no repeated reworking of conglomerates on the scale of many of the Witwatersrand conglomerates. The fineness of the gold in the Black Reef may have caused problems, in the sense that the gold may have often dispersed (been floated off), rather than being concentrated (Papenfus, 1964).

Theoretically at least, potential for exploitation of Black Reef should exist on the deep Witwatersrand gold mines. Unoxidised Black Reef, with its high carbon content, cannot be mixed with ore from Witwatersrand conglomerates, due to resultant, metallurgical problems in the plant. The erratic and often limited extent of mineralisation, militates against a purely Black Reef producing mine at depth., as was shown by the erratic success of the Machavie Mine in the Klerksdorp area.

The erratic nature of the Black Reef and its mineralisation, make it a difficult exploration target. Outcrop potential is not necessarily an indication of downdip potential. Fairly large areas, with relatively thin soil cover along the northern rim (Rand Anticline) of the Witwatersrand basin, may not have been properly assessed in the past. The best potential for exploitation of the Black Reef lies in small scale, opencast to shallow mining operations. Economic viability can be assessed by high density, shallow drilling, as applied on Lindum reefs, where close-spaced drilling is used to assess the target area. The oxidised nature of the Black Reef near surface, does not cause insurmountable metallurgical problems.

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Table 7.1. Facies description for Black Reef eastern (NEP Shaft) channel.

A. Channel Facies. Pouroulis (1988).	Description
a. Protoquartzite	Medium- to coarse - grained, dirty, dark grey to greenish grey. Sericitic and chloritic interstitial fine fraction. Abundant facies type, occurs as interboulder material. Poorly developed to absent primary sedimentary structures. Horizontal and drape - like stratification. Random but abundant pyrite (often buckshot) mineralisation. Common chromite grains with accessory sphene, rare sphalerite grains
b. Conglomerate	Polymictic, clast - supported spc to lpc with arenaceous matrix. Occurs as basal pebble lag, as clusters or laterally uniform layers. Well rounded moderately sorted clasts, a few mm's 5 cm in size, ~2.0 - 2.5 cm. Largest clasts occur at base. Clasts: Predominantly vein quartz with smokey quartz and green, angular shale. Random but abundant pyrite (often buckshot) mineralisation.
c. Graphitic Mudstone	Finely laminated, very fine-grained, black, graphitic, brittle mud. Contains occasional smokey quartz clasts. Occurs throughout as thin drapes, sometimes caps channel sediments as 20 - 30 cm thick drape.
d. Calcareous Siltstone	Dark grey to black , laminated siltstone. Occurs as a drape or series of drapes within and on top of the channel.
e. Boulders	Subangular to well - rounded boulders up to 3 m in size (Papenfus, 1964). Derived from Witwatersrand footwall succession (Bird Conglomerate and Kimberley Quartzite Formations). Mostly pebbly quartzite with clasts of smokey and vein quartz, chert and banded chert Occurs extensively throughout channels.
B. Channel Facies Spellman (1986).	
a. Layered Pyrite	Up to 3.5 m thick unit. Multiple bands of rounded pyrites in medium - grained quartz matrix. Up to 80% pyrite in bands with interstitial quartzite and recrystallised quartz. May carry spectacular gold values. Occasional quartzite clasts up to small cobble (64 - 128 mm size) at lateral margins and basal contact.
b. Major Channel Conglomerate	20 cm to 2.5 m thick, well packed, well rounded, medium to coarse (8 - 32 mm size) pabble conglomerate. Clean quartzite matrix, highly pyritic with associated gold. Common Booyesen shale chips. Cobbles and boulders on basal contact when present.

c. Minor Channel Conglomerate	2 to 20 cm thick, moderately packed, medium to coarse pebble conglomerate. high pyrite content, occurs as disseminated, foreset stringers and lags. High but variable gold content Occurs in sporadic, up to 50 cm deep channels.
d. Talus	Occurs on the flanks of channels associated with Kimberley scarp. Consists of Kimberley boulders from 26 to 1200 cm in size. Small boulders are rounded, large boulders are angular. Contains interstitial argillaceous quartzites and shales, but closer to the channel, major channel conglomerates and layered pyrite facies are found.
e. Incised Channel	Steep sided channels filled with large rounded boulders and general Black Reef molasse. Can be stratified with layered pyrite bands and quartzite.
Blanket Facies ?	
f. Overbank Argillaceous Quartzite	Fine-grained argillaceous quartzite grading into shales.
C. Blanket Facies. Pouroulis (1988)	Description
a. Quartzarenite	Dark grey, medium grained, glassy quartzite. Contains stringers, minor disseminated specks and rare buckshot pyrite. No sedimentary structures present. Fine interstitial fraction comprises biotite, sericite, chlorite and minor carbonaceous material. Accessory sphene, sphalerite, chromite.
b. Bedded Conglomerate	Clast supported bands. Moderate to well - sorted, rounded to well rounded clasts of vein and smokey quartz, average size is 1.5 - 2.0 cm. Large buckshot, disseminated and occasional stringers of pyrite. Facies not always present.
c. Graphitic Mudstone	Minor facies similar to that occurring in Channel Facies. Laminated black graphitic mud, occurs as drapes or intercalated with pisolithic pyrite bands.
d. Pisolithic Pyrite	2 to 30 cm thick bands of rounded to elongate, buckshot pyrite (up to 15 mm in size) with interstitial fine pyrite and pyritic mud. Occurs as single or multiple bands intercalated with graphitic mudstone. Occasional vein quartz clasts present. Fine fraction consists of quartz, chlorite and carbon. Gold associated with sphalerite, pyrite and siliceous fraction, also in pyrite grains.
e. Boulders	Minor facies similar to that in Channel Facies (see A.e. above)

Table 7.2: General features of the Black Reef "Series" in comparison to the corresponding rocks in the Witwatersrand Supergroup.

a. Quartzites	Commonly distinctly bluish or darker in colour. Whitish varieties as in Kimberley - Elsburg rocks are absent. More highly siliceous and finer grained. Becomes more smooth and polished on exposed surfaces. Grits are rare and occur in thin bands when present.
b. Shales	Several, relatively thick, shiny, black, carbonaceous shale bands are characteristic.
c. Conglomerates	Highly pyritic, resulting in darker red or brown on oxidation than Witwatersrand equivalent.
d. Clasts	Smaller (~1.9 cm) and less well rounded. Polished, well - rounded or elliptical varieties uncommon. Small pebble conglomerates commonly occur over large areas.
e. Clast Types	Mostly very similar. Amygdales and Ventersdorp lava clasts typical in Klerksdorp area but absent on East Rand. Quartz porphyry and angular black carbonaceous common on East Rand. May be arkosic in character over granite terrain. Very high buckshot / pebbly pyrite content characteristic.
f. Matrix	Much higher percentage pyrite, commonly over 50 %. Darker grey in colour due to high carbon content may be dark green due to high chlorite content. Very little mica.
g. Microscopic Features	Rare to absent chloritoid. More chlorite and less sericite and muscovite than typical blanket. Unaltered feldspar present and also more common. Tourmaline is rare in the Black Reef whilst carbon is more abundant
h. Drilling	Much darker drill sludge (most distinctive feature for practical purposes).

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