ECONOMIC GEOLOGY RESEARCH UNIT

University of the Witwatersrand
Johannesburg

THE GEOLOGY OF THE SHEBA HILLS AREA OF THE BARBERTON MOUNTAIN LAND, SOUTH AFRICA, WITH PARTICULAR REFERENCE TO THE EUREKA SYNCLINE

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by

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ABSTRACT

In 1885 Edwin Bray found gold in the Sheba Hills, a rugged tract of country to the northeast of the town of Barberton. His discovery eventually led him to the famous Golden Quarry ore body and sparked off a resurgent gold rush which culminated in the establishment of Eureka City (now a ghost town).

Ever since the discovery of gold in the region, mining operations have continued unabated, and today, most of the small workings have been amalgamated to form either the Sheba or Fairview gold mines. The area, with its colourful historical and mining background is equally fascinating geologically and has been subjected to the scrutiny of a number of investigators in the past.

This paper attempts to synthesize the regional geology of the Sheba Hills, special attention being devoted to the stratigraphy, structure, and gold mineralization of the area as a whole, and of the Eureka Syncline in particular.

The Moodies stratigraphy in the Eureka Syncline is subdivided into three formations, the latter overlain by a unit afforded member status. Sedimentological criteria suggest that the Moodies stratigraphy was deposited mainly under shallow water, fluvio-deltaic conditions, in sharp contrast to the deeper water, turbidite, depositional style of the older Fig Tree sediments.

Structural investigations confirmed the presence of at least four phases of deformation in the Sheba Hills. Minor structures and pebble deformation data suggest that granite diapirism was largely responsible for much of the tectonic activity in the region, particularly the arcuation of the Eureka and Ulundi synclines.

Finally, the relationship of gold mineralization to the structural history of the region is discussed, and gold production data for mines in the area are tabulated.

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1. INTRODUCTION

The Eureka Syncline, forming probably one of the most impressive geological structures in the Barberton Mountain Land, is situated immediately northeast of Barberton and constitutes part of the area known locally as the Sheba Hills (Figure 1, Plate 1A). The geology of the Sheba

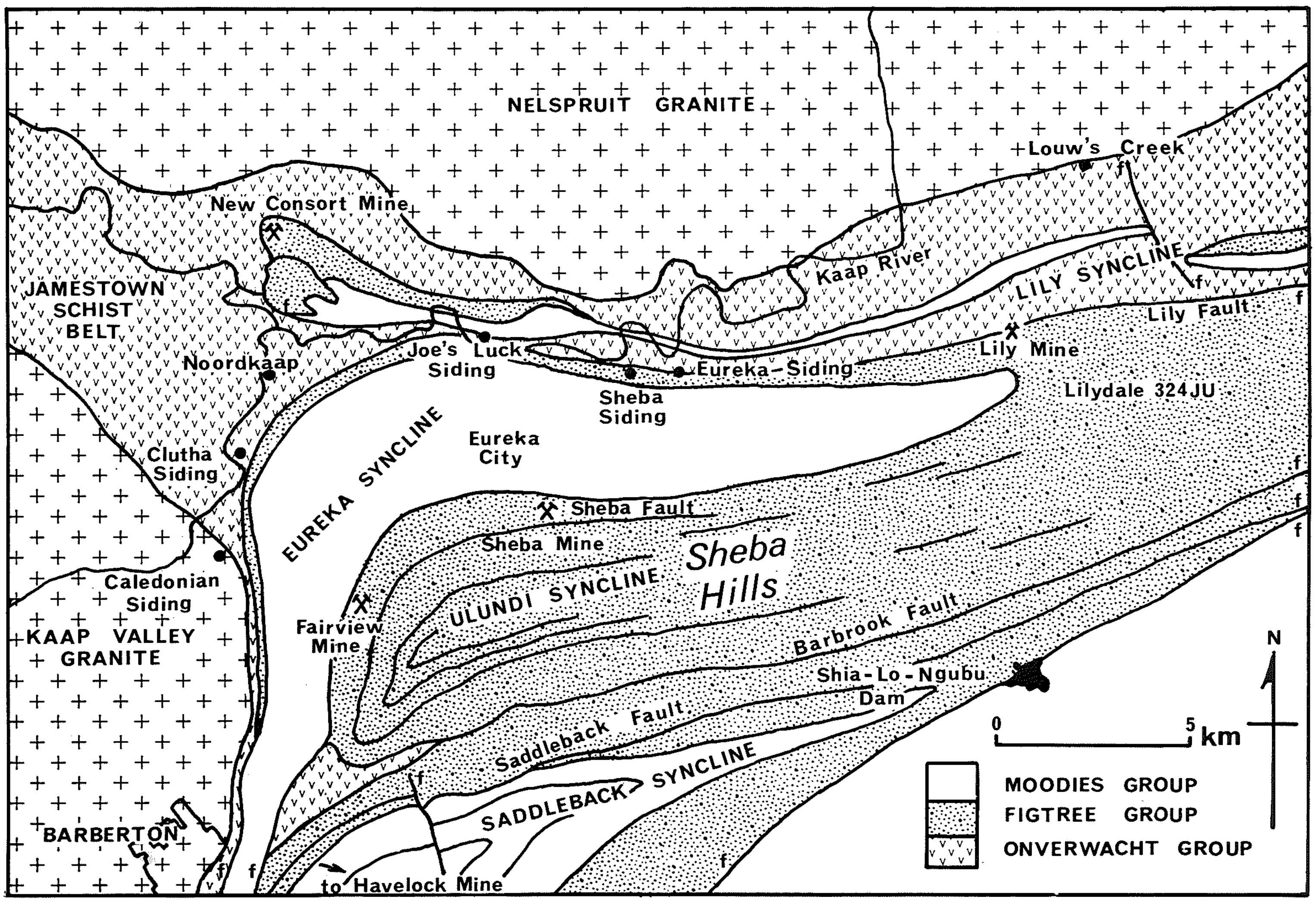


Figure 1 : General geological map of the Sheba Hills area of the Barberton Mountain Land

Hills area has attracted attention for a great many years, principally because much of the significant gold mineralization of the Barberton greenstone belt has been located in this area. Hall (1918), provided the first geological account of the region but it was van Eeden (1941) who outlined in greater detail the stratigraphy of the area and his work was subsequently incorporated into the special publication on the Barberton area by the Geological Survey (Visser et al., 1956). Later the area was examined by Ramsay (1963) who undertook structural investigations in the Barberton Mountain Land. Apart from numerous unpublished company reports on the geology of some of the gold workings and prospects in the region (reports in the files of Eastern Transvaal Consolidated Mines Limited, Barberton, and Federale Mynbou Beperk, Fairview Gold Mine) some local detail of the geology of the Fairview Mine area was made available by Steyn (1965). In addition, detailed mapping of the Ulundi Syncline was carried out in 1962 by C.J.J. van Vuuren, the results of which have been incorporated by the writer into the compilation map of the Sheba Hills area (Figure 2)*. The geology of the Ulundi Syncline was described in an unpublished report by van Vuuren (1964).

The influence of structure on the control of the gold mineralization in the Sheba Hills area became evident as mining activities proceeded in the mountainous terrain. No attempt, however, was made to co-ordinate the known structure with the mineral deposits in the area. The present study was therefore aimed at a more intensive investigation of the overall geology of the Eureka Syncline, particular emphasis being placed on the structural aspects of the area and the part played by the structure in localizing the gold mineralization. Work in the area was commenced by the writer in 1964 and formed part of a systematic study programme, undertaken by the Economic Geology Research Unit, Johannesburg. The findings, together with information obtained from other areas on the north-west flank of the Barberton Mountain Land, formed part of a Ph.D. dissertation entitled "The Stratigraphy, Structure, and Gold Mineralization of the Jamestown and Sheba Hills Areas of the Barberton Mountain Land" (Anhaeusser, 1969a).

2. GENERAL GEOLOGY OF THE SHEBA HILLS

Two major fold structures, the Eureka and Ulundi Synclines, build the rugged terrain of the Sheba Hills. The Eureka Syncline, consisting mainly of Moodies Group sediments, can be traced uninterruptedly from Barberton, northwards for a distance of 14 km to Noordkaap, and from there eastwards for approximately 20 km towards Louw's Creek (Figure 1). The Ulundi Syncline occupies the area to the south and east of the Eureka fold (inner arc) and consists predominantly of sediments of the Fig Tree Group.

The Eureka structure is bounded on the north and west by the Lily Fault, and on the south and east by the Sheba Fault. These two major faults separate the Eureka Syncline from the Lily Syncline in the north and the Ulundi Syncline in the south. The Ulundi structure is, in turn, separated from the Saddleback Syncline in the south by the Barbrook and Saddleback faults (Figures 1 and 2).

The Geological Survey (Visser et al., 1956), following their regional mapping of the Barberton Mountain Land, concluded that the greatest succession of Moodies sediments is preserved in the Eureka-Moodies Syncline located northeast and southwest of Barberton. The Eureka Syncline was singled out, however, as having the most complete succession of Moodies stratigraphy and has come to be regarded as the type-locality for the Moodies Group. The Ulundi Syncline was likewise regarded by the Geological Survey as the type-locality for the Fig Tree Group, although subsequent investigations by Reimer (1967) led him to conclude that the Fig Tree Group could best be subdivided into three formations in the southwestern part of the Mountain Land (the Stolzburg Syncline region). These, in ascending order, were named the Sheba, Belvue Road, and Schoongezicht formations, and Reimer was able to trace them eastwards into the Ulundi Syncline (Figure 3).

Although Moodies sediments predominate in the Eureka Syncline there are subordinate Fig Tree and Onverwacht assemblages lying stratigraphically lower in the sequence and which outcrop mainly around the outer arc of the fold (Figures 1 and 2). Similarly in the Ulundi Syncline, which consists predominantly of Fig Tree assemblages, there are members of the underlying Onverwacht Group (Swartkoppie Formation) exposed underground and on surface as a result of intense isoclinal folding of the successions.

Although the Onverwacht, Fig Tree, and Moodies groups appear to be conformable, this relationship is essentially structurally influenced as it can be demonstrated elsewhere in the Barberton Mountain Land that local unconformities do exist (Visser et al., 1956). Furthermore, the vastly differing characteristics of the three groups comprising the Swaziland Supergroup

Footnote : * Figure 2 appears as a foldout map at the rear of the Information Circular.

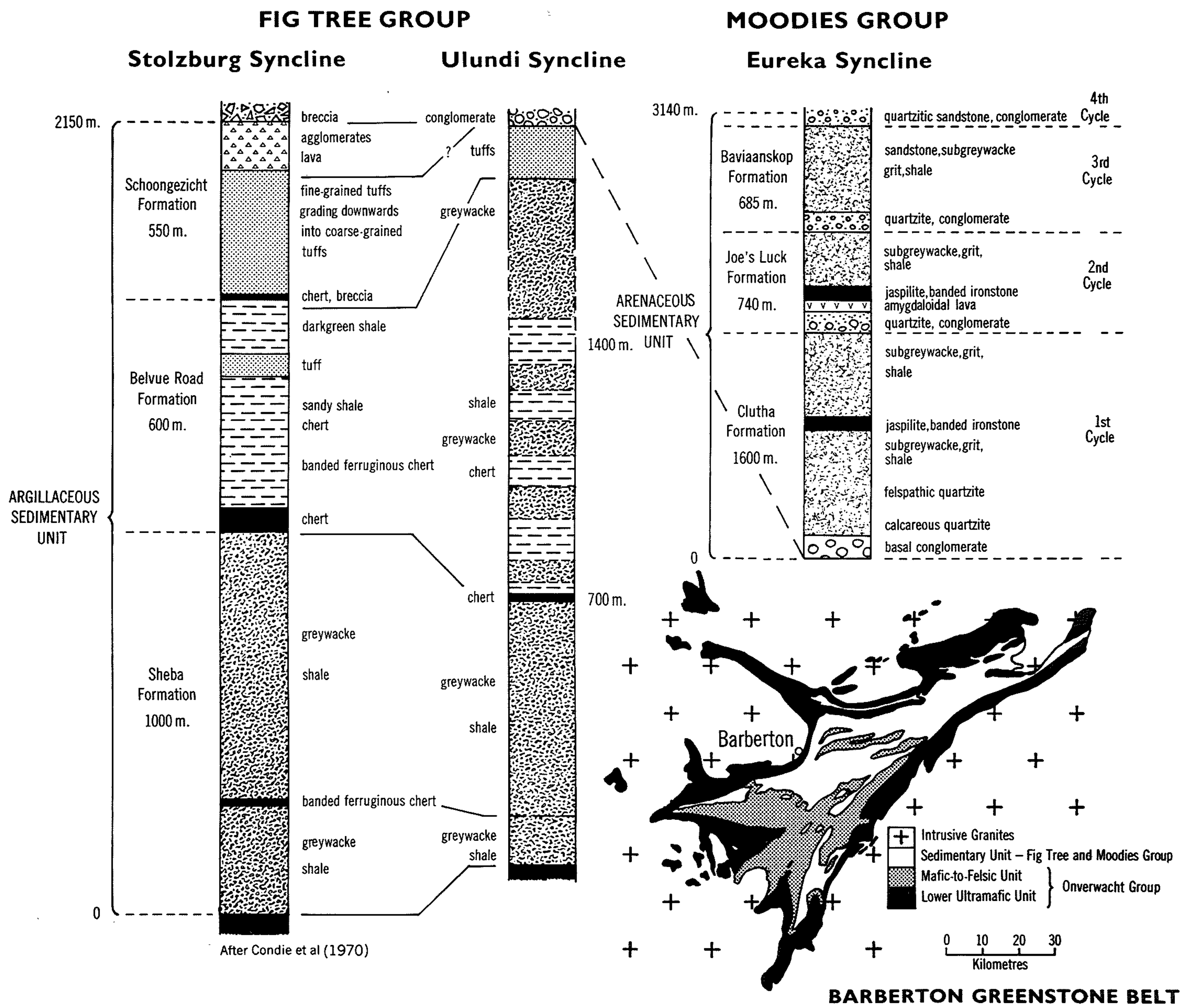


Figure 3 : Stratigraphic sections depicting the sedimentary successions of the Fig Tree and Moodies groups in the Barberton Mountain Land. The inset general geological map shows the distribution of the various components of the Swaziland Supergroup in the Barberton greenstone belt (adapted from Anhaeusser, 1973a).

(formerly referred to as the Swaziland Sequence) leave little doubt that considerable environmental disparity prevailed throughout the depositional history of the area.

In the following sections, brief account is given of the stratigraphy of the Sheba Hills area, with particular attention being devoted to the Moodies Group. Aspects of the structure and gold mineralization, particularly of the Eureka Syncline, are also discussed.

3. STRATIGRAPHY

Following the initial regional investigations of the geology of the Barberton area by the Geological Survey (Visser et al., 1956), a number of subsequent studies, undertaken in the region, have led to significant changes being made to the stratigraphic classification and nomenclature of the rocks constituting the Swaziland Supergroup. Evidence invalidating the previously held concept of the intrusive *Jamestown Igneous Complex* (Anhaeusser and Viljoen, 1965, Viljoen and Viljoen, 1967) led to the eventual redefinition of the basal volcanic suite of the Onverwacht Group (Viljoen and Viljoen, 1969a; 1971). As already mentioned, modifications were similarly made to the classification and definition of the Fig Tree Group by Reimer (1967) whose proposals have attained precedence over those of van Vuuren (1964) and Steyn (1965), both of whom also advocated changes to the scheme outlined earlier by Visser et al., (1956). The Moodies Group, in contrast, has remained essentially unaltered although minor modifications were suggested by Anhaeusser (1969a; 1973a).

THE ONVERWACHT GROUP

Rocks correlated with the Onverwacht Group (Anhaeusser and Viljoen, 1965; Anhaeusser, Viljoen and Viljoen, 1966; Anhaeusser, 1969a) are developed immediately north of Barberton in a narrow belt between the Kaap Valley Granite and the western limb of the Eureka Syncline as well as in the area south and east of Noordkaap, and in the region adjacent to the Sheba Fault between the Sheba Mine and the Barberton-Havelock road (Figures 1 and 2).

The Onverwacht rocks between Barberton and Noordkaap consist of a variable assemblage of mafic and ultramafic schists, and serpentinites. Along the contact with the Kaap Valley Granite, antinolite and actinolite-hornblende schists have been recorded but, as the grade of metamorphism is generally low (greenschist facies), the dominant rock-types are chlorite-actinolite, talc-chlorite, talc-carbonate and talc-chlorite-carbonate schists. In places, massive lensoid bodies of serpentinite occur together with a variety of ultramafic schists and carbonate-rich (dolomitic) rocks. Outcrops are generally poor in this area making it difficult to correlate these rocks with any particular formation of the Onverwacht Group. East of Caledonian Siding, however, a thin unit of banded chert and laminated shale is developed within the mafic schists. These cherts and slaty shales resemble similar rock types described from the Jamestown Schist Belt (Anhaeusser, 1972) where they are considered to represent part of the Theespruit Formation. Despite poor exposures in the region separating the eastern half of the Jamestown Schist Belt from the schists exposed along the western limb of the Eureka Syncline, it is likely that stratigraphic continuity exists between the two areas.

South of the Woodstock Mine (Figure 2, C1) a variety talcose and dolomitic rocks occur together with serpentinites but the successions are poorly preserved and not well-exposed. North of the Woodstock "Bar", which is a mylonitized fault zone (Viljoen, 1964), contorted and crenulated greenish-coloured schists are developed, the latter resembling the quartz-sericite-fuchsite-schists described from the Theespruit Formation (Viljoen and Viljoen, 1969a; Anhaeusser, 1969a; 1972). These schists can be traced sporadically along the northern arc of the Eureka Syncline as far east as Louw's Creek, where they form prominent ridges and constitute part of the southern limb of the Lily Syncline (Anhaeusser, 1964).

In the Clutha Mine area (Figure 2, B2), and south of the Woodstock Mine, dolomitic rocks were first noted by Hall (1918). These occur together with talc- talc-carbonate, and tremolite schists, as well as lensoid bodies of serpentinite. The serpentinites, which outcrop intermittently, can be traced around the outer arc of the Eureka fold and are considered to form part of the same stratigraphy as that developed in the Handsup-Mundt's Concession areas of the eastern part of the Jamestown Schist Belt (Anhaeusser, 1972).

Several gold prospects are located in the schists between the Woodstock Mine and Caledonian Siding. Apart from the Victoria Gold Mine (Figure 2, A3), none of these deposits produced any appreciable quantities of gold.

Additional exposures of Onverwacht rocks are located within the inner arc of the Eureka fold, along the Sheba Fault zone (Figure 2). These rocks, consisting of carbonate-chlorite-talc rocks, quartz-sericite schists and banded, green, black, and white cherts, were regarded as part of the Fig Tree assemblage by the Geological Survey (Visser et al., 1956) and Steyn (1965). Van Vuuren (1964) also grouped these rocks with the lower part of the Fig Tree Group but indicated that they were difficult to distinguish from the metamorphosed products of the Onverwacht Group. It is now considered expedient, however, to regard this hitherto controversial assemblage as part of the Zwartkoppie Formation of the Onverwacht Group (Reimer, 1967; Anhaeusser, 1969a; Viljoen and Viljoen, 1969a, b).

Zwartkoppie rocks outcrop on both limbs of the Ulundi Syncline (in reality a synclinorium) and have been exposed on surface as a consequence of isoclinal folding. Further Onverwacht exposures occur to the southwest of the Ulundi fold closure on the farm Dycedale 368 JU (van Vuuren, 1964; Steyn, 1965; Anhaeusser, 1969a). These rocks are best developed in the Hislop's Creek valley (Figure 2, C8) but exposures are generally poor and the area is overgrown with a particularly dense growth of trees, bush, and creepers. Near the Cheval de Course Gold Mine (Figure 2, B8), outcrops of serpentinite and talc schist occur together with talc-carbonate and dolomitic rocks. In addition, a massive black and white banded chert member is associated with these rocks and can be traced southwards from Hislop's Creek to the Barberton-Havelock road and beyond. These Onverwacht assemblages, which occur to the east of the Sheba Fault, probably represent part of the Zwartkoppie Formation. The old workings of the May Gold Mine (Figure 2, B9) are located in this setting.

In the Ulundi Syncline, assemblages now grouped with the Zwartkoppie Formation were described by van Vuuren, (1964). At the base of this formation is a unit referred to locally as the *Zwartkoppie "Horizon"*. According to van Vuuren, this unit consists of : 1. *Carbonate-chlorite-talc rocks,* the latter frequently occupying the cores of anticlinal structures and having been derived from ultrabasic rocks, and 2. *Quartz-sericitic rocks or "green schists",* (0-35 m thick) occurring stratigraphically below banded cherts. The "green schists" are in places transitional into carbonate rocks and are then referred to locally as "grey schists".

Overlying the Zwartkoppie "Horizon" is the *Swartkoppie Band* which occurs as a marker to the latter unit. It consists mainly of alternating banded chert layers, and dark, slightly ferruginous and carbonaceous shale members. The unit is variable in thickness but averages about 7 m in the area shown in Figure 2. Where greater thicknesses are encountered, these are generally due to tectonic duplication. The Zwartkoppie Band is wider elsewhere in the Mountain Land, being between 120-150 m thick near the Daylight Mine which is situated approximately 10 km east of the Sheba Hills. Furthermore, the resistant nature of the banded cherts generally causes the Zwartkoppie Band to form conspicuous topographic features.

In the top few centimetres of the Zwartkoppie Band and occurring generally in dark, massive chert, are thin intercalations of pyritic bands measuring from a few millimetres to about 2,5 cm thick. Termed the *Sulphide Band* by van Vuuren, (1964), this unit consists either of solid sulphide or of scattered pyrite grains. The wide extent of the sulphide band, coupled with the fact that the layer follows contortions in the chert, led van Vuuren to suggest that the sulphides were of syngenetic origin.

Above the Zwartkoppie and Sulphide Bands, van Vuuren, (1964), found a 1-2 m wide unit which he called the *Carbonate-bearing Granular Sandy Phyllite Zone*. Lying above this unit or, where the latter is absent, lying on the Zwartkoppie Band, is a thin layer (0,2-0,8 m thick) of light greenish-grey, sago-like nodules. Termed the *Pseudo-Oolitic Layer* by van Vuuren, these nodules vary from spherical, to oval, to completely flattened and attenuated. The nodules, or oolites, vary from 1-3 mm in diameter. Similar oolites in chert have been reported from the central part of the Mountain Land, between Geluk, Skokohla, and Emlembe (T. Heinrich and T. Reimer, personal communication, 1970). Here the oolite layers provide useful marker beds and the individual oolites sometimes exceed 10 mm in diameter.

The oolites in the Ulundi Syncline were described by several workers (Hearn, 1943; Koen, 1947; Visser et al., 1956; Ramsay, 1963). Hearn (1943) regarded them as replacement oolites and Ramsay (1963) suggested they were organic in origin. Van Vuuren (1964) pointed out that whatever their origin, the oolites had been extensively replaced by silica, carbonate, felspar, and zeolite, and the only features which could be regarded as acceptably original are their concentric spherical form and their size.

THE FIG TREE GROUP

Rocks of the Fig Tree Group form part of the stratigraphy of the Eureka Syncline on the western, northern, and far eastern portions of the structure (Figures 1 and 2). On the inner arc of the fold, between the Royal Sheba Gold Mine (Figure 2, G4) and the Oratava Gold Mine (Figure 2, C7), Fig Tree assemblages also constitute the greater part of the Ulundi Syncline.

Fig Tree Stratigraphy in the Eureka Syncline

Between Barberton and Caledonian Siding, a thin zone of banded iron formation, chert, and shale underlies the basal conglomerate of the Moodies Group. South of here the succession thins considerably and is absent in the area north of the Barberton-Havelock road. The disappearance of these rocks in this area may be ascribed to one or more of the following factors. Either, the Fig Tree sediments were not deposited in this region or, they were eliminated by faulting or flattening caused by the emplacement of the adjacent diapiric Kaap Valley Granite pluton.

To the north of Caledonian Siding the banded iron formations can be traced to the Clutha Gold Mine but are covered in places by scree from the steep slopes of the mountainous northwest flank of the Eureka Syncline. The best sections across the Fig Tree succession can be seen in the Clutha Mine area near Noordkaap. Southeast of the Lily Fault, which separates Fig Tree from Onverwacht rocks, the succession comprises banded cherts and banded iron formations, strongly cleaved shales, locally developed small-pebble conglomerates, greywackes, felspathic tuffaceous greywackes, and a greywacke conglomerate layer that immediately underlies the Moodies basal conglomerate. The intraformational small-pebble conglomerates consist of coarse gritty material, at times grading into a very coarse gravel. Prominent constituents include platy slivers and flakes of black shale and black chert fragments, all in a matrix of coarse greywacke or greywacke-grit. The conglomerates lense out along strike into greywacke or shale units.

At the top of the Fig Tree succession and immediately underlying the Moodies conglomerates are rocks regarded by van Eeden (1941) and the Geological Survey (Visser et al., 1956) as lavas. Also in this position are rocks possessing a nodular or blocky structure. The light and dark grey nodular masses (Plate 1B) in places resemble pebbles or boulders in a conglomerate. These, van Eeden (1941), and Visser et al., (1956), termed "autoliths". Anhaeusser and Viljoen (1963), Anhaeusser (1964; 1969a) and Viljoen (1964), argued that the so-called "lavas" were in fact felspathic tuffaceous greywackes while the "autolith zone" was considered to be a greywacke conglomerate or agglomerate. Some lavas were reported in the Stolzburg Syncline by Reimer (1967) and Condie et al., (1970), but it would appear that tuffs and agglomerates are the most common volcanic rock types developed in the Fig Tree Group.

Typically, the tuffaceous greywackes consist of large (0,5-2 mm), often partly sericitized and zoned, plagioclase and microcline crystals in a fine-grained dark groundmass of chloritic material. The greywacke conglomerates, apart from containing nodular greywacke boulders, also display chert, jasper, and porphyry pebbles. Plate 1C illustrates a specimen of deformed greywacke conglomerate found below the Moodies basal conglomerate south of Eureka Siding. Tuffaceous greywackes and greywacke conglomerates and agglomerates are well-exposed in the road cutting at Ezzy's Pass Figure 2, G2) near Sheba Siding, and have been described by Anhaeusser (1964). Further good exposures of a similar nature are to be found in the Ulundi Syncline in the area northeast of the Royal Sheba Gold Mine, being exposed intermittently for several kilometres eastwards along the southern rim of the Eureka Syncline. Fig Tree rocks of pyroclastic origin were described from the area east of the Clutha Gold Mine (Visser et al., 1956) while further examples (Plate 2A) were noted by Anhaeusser (1969a) in the region south of this mine and on the farm Hayward 310 JU (Figure 2, B3).

Fig Tree Stratigraphy in the Ulundi Syncline

In the Sheba Hills the greatest development of Fig Tree assemblages is located within the Ulundi Syncline. Details of the stratigraphy of this region have been given by a number of investigators (van Eeden, 1941; Hearn, 1943; Koen, 1947; Visser et al., 1956). In 1962, C.J.J. van Vuuren completed the remapping of the syncline and divided the Fig Tree stratigraphy into three parts (van Vuuren, 1964). His lower division included assemblages which, as has previously been explained, are now grouped with the Zwartkoppie Formation of the Onverwacht Group. The middle division (now further sub-divided into the Sheba and Belvue Road Formations) comprises greywackes, shales, grits, chert bands, and banded iron formations, while the upper division (now the Schoongezicht Formation) consists of a reworked unconformable grit unit and a succession of volcanic rocks, the latter, according to van Vuuren, appearing to belong structurally to the overlying Moodies Group.

(a) The Sheba Formation

Overlying the Zwartkoppie Formation is a succession of greywackes, shales, grits, and thin chert bands, calculated by van Vuuren (1964) to be approximately 900 m thick. Condie et al., (1970), however, estimated this formation to be 700 m thick. The greywackes consist mainly of angular and subangular fragments (average size 1 mm) of quartz, chert, felspar, black shale, and muscovite. The shales are black when fresh and are well-bedded. Chemical analyses of a typical greywacke and black shale from this formation are listed in Table 1. Further details of the major and trace element geochemistry of the Fig Tree greywackes is given by Condie et al., (1970).

The sediments display characteristics of turbidite deposition with features such as graded bedding, sole markings, flute-casts, slide-marks, load-casts, and flame-structures, having been reported (Kuenen, 1963; Visser et al., 1956; van Vuuren, 1964). The nature of the sediments and the sedimentary structures found in the Fig Tree Group suggests that deposition took place rapidly in a relatively deep water environment (Visser et al., 1956; Anhaeusser et al., 1968; 1969).

Assemblages grouped within the Sheba Formation have not been differentiated on the accompanying geological map of the Ulundi Syncline (Figure 2). However, this formation is developed between the Zwartkoppie Formation and the Ulundi Bar (Figure 2, E5) in the Sheba Mine area, and can be traced around the Ulundi fold, being well-developed in the nose of the structure as well as on the southern limb.

(b) The Belvue Road Formation

From the Ulundi Bar upwards van Vuuren (1964) reported that the greywackes become finer-textured than lower in the succession, and that more shale is encountered. In addition, there are approximately six prominent banded chert and banded iron formation units developed in the core of the structure (Figure 2). The banded chert and iron formations vary in thickness from a few centimetres to about 15 m and bear a strong resemblance to the chert units of the Zwartkoppie Formation. However, they are distinguished from the latter in that they are more shaly, and less affected by secondary chertification. They are also more ferruginous, the iron formations being locally enriched by surficial weathering processes. Although no iron ore deposits occur in this region, similar formations 55 km to the south, in Swaziland, are the host stratigraphy to the Ngwenya Iron Ore deposit described by Bursill et al., (1964).

The Belvue Road Formation was calculated by van Vuuren (1964) to be about 700 m thick, this figure being arrived at after allowing for between 30 and 45 per cent flattening of different parts of the Ulundi Syncline. Condie et al., (1970) suggest a different figure of approximately 1 050 m for the thickness of the formation. These discrepancies illustrate the difficulties involved in estimating stratigraphic thicknesses in isoclinally folded strata that have suffered superimposed flattening deformation.

(c) The Schoongezicht Formation

Absent in the core of the Ulundi fold, but developed north of the Zwartkoppie Formation in the Sheba Mine area, are a series of grits, shales, banded cherts, iron formations, and volcanic rocks (pyroclasts), which are considered to belong to the highest stratigraphic level of the Fig Tree Group (van Eeden, 1941; Visser et al., 1956; van Vuuren, 1964). Folding and faulting is considered responsible for the development of this assemblage in this position in the narrow wedge occupying the area between the Sheba Fault and the Zwartkoppie Band between the Fairview and Royal Sheba gold mines (Figure 2, D4, E4, F4, G4).

The stratigraphy of this formation, according to van Vuuren (1964), commences with thin banded chert and iron formation together with brown and greenish shales. A distinctive feature is the presence of red jaspery chert and lenticular chert and jasper layers in the shales. Overlying this assemblage is a zone of greywacke-grits characteristically containing large (1-5 mm) rounded grains of clear quartz. van Vuuren considered the grit zone represented a reworked sediment heralding the advent of shallow water deposition and local erosion prior to the development of the Moodies Group.

Above the grit zone, but only developed to the east of the Royal Sheba Gold Mine, are the volcanic rocks (tuffs and agglomerates) discussed earlier. Little is known of the geochemistry

TABLE 1

CHEMICAL ANALYSES OF SELECTED ROCKS IN AND ADJACENT TO THE SHEBA HILLS AREA OF THE BARBERTON MOUNTAIN LAND

	1	2	3	4	5	6	7	8	9
				MDL 1	MDL 2	Average	135		GS 2
SiO_2	57.71	54.11	63.32	53.86	55.43	54.65	49.59	64.84	72.30
Al_2O_3	13.73	17.54	10.79	17.14	17.05	17.10	10.08	15.44	13.15
Fe_2O_3	1.78	1.43	0.95	1.66	1.11	1.39	7.48	1.80	1.12
FeO	3.28	7.45	6.01	10.18	10.80	10.49	-	2.44	1.29
MgO	3.87	6.97	5.67	3.53	3.69	3.61	15.18	2.60	0.84
CaO	4.88	0.22	1.95	0.85	0.96	0.91	6.92	4.25	1.57
Na_2O	5.08	2.14	2.09	5.15	4.33	4.74	1.67	4.93	4.34
K_2O	3.29	2.72	1.44	1.18	1.09	1.14	0.73	1.53	4.23
H_2O^-	0.02	0.24	0.06	0.19	0.03	0.11	0.23	0.20	0.24
H_2O^+	0.63	5.14	3.51	3.23	2.43	2.83	1.52	0.90	0.20
CO_2	3.36	0.09	3.19	0.38	0.43	0.40	5.08	-	0.70
TiO_2	0.75	1.00	0.59	1.49	1.36	1.43	0.21	0.49	0.33
P_2O_5	0.24	0.14	0.11	0.18	0.21	0.19	0.04	0.18	0.13
MnO	0.11	0.08	0.28	0.06	0.06	0.06	0.13	0.04	0.05
NiO	-	-	-	-	-	-	0.17	-	-
C	-	0.33	-	-	-	-	-	-	-
Totals	98.73	99.60	99.96	99.08	98.98		99.03		

Column 1 : Trachyandesite (soda trachyte) from Sheba Siding. Schoongezicht Formation, Fig Tree Group (Visser et al., 1956).

Column 2 : Black shale, associated with greywackes. Sheba Formation, Fig Tree Group (Visser et al., 1956).

Column 3 : Greywacke from Sheba Formation (Visser et al., 1956).

Column 4 : Basaltic lava from the Lava Adit of the Rose Reef Gold Mine (Figure 2, C6). Joe's Luck Formation, Moodies Group (Analysts : National Institute for Metallurgy, Johannesburg).

Column 5 : Joe's Luck Formation basaltic lava from same locality as 4 above (Analysts : National Institute for Metallurgy, Johannesburg.

Column 6 : Average of two samples (MDL 1 and MDL 2) of Moodies basaltic lava.

Column 7 : Olivine gabbro. Part of a differentiated dyke intruded into the Eureka Syncline on the farm Bickenhall 346 JU (Figure 2, B8). Average of 3 comparative XRF and wet chemical analyses (Analysts : National Institute for Metallurgy and Corner House Laboratories).

Column 8 : Hornblende-biotite tonalite. Average of 4 analyses of Kaap Valley Granite (Anhaeusser, 1972).

Column 9 : Composite sample of Nelspruit migmatites, from various localities in the Nelspruit area (van Eeden and Marshall, 1965).

of the Fig Tree volcanics. A single analysis by Visser et al., (1956) suggests that the rocks may be regarded as soda trachytes or trachyandesites (Table 1).

The thickness of the Schoongezicht Formation in the Ulundi Syncline remains uncertain although Condie et al., (1970) suggest that it measures approximately 130 m.

THE MOODIES GROUP IN THE EUREKA SYNCLINE

Van Eeden (1941) provided the first detailed map of the Eureka Syncline and his work was incorporated into the regional study undertaken in the Barberton region by Visser et al., (1956). Since then the Eureka Syncline, or parts thereof, have been remapped and studied by Ramsay (1963), Steyn (1965) and Anhaeusser (1969a). In this section a revised account of the stratigraphy of the region is provided.

The Moodies succession, as developed in the Eureka Syncline, consists of repeated cycles of arenaceous rocks which alternate with argillaceous sediments. In addition there is a lava horizon and several jaspilitic iron formation units. The complete Moodies sequence is summarized in the simplified stratigraphic column provided in Table 2.

In view of the recent changes that have been made in stratigraphic terminology and nomenclature in South Africa, it has been considered advisable to define the Moodies Group in terms of three formations. At the base is the Clutha Formation, and this is overlain, in turn, by the Joe's Luck and Baviaanskop formations. In addition, a mappable unit which is restricted in its development to the core of the Eureka Syncline and which has not been reported elsewhere in the Mountain Land, has been given member status and is referred to as the Bickenhall Member.

The previous geological sub-division given by the Geological Survey (Visser et al., 1956) merely provided a lithogical breakdown of the stratigraphy, there being no attempt to emphasize the repetitive or cyclical nature of the sedimentary assemblages. In terms of the South African Code of Stratigraphic Terminology and Nomenclature (1971), the units outlined by the Geological Survey could qualify for formal naming as members. The writer has, however, elected to retain lithologic names that relate to the dominant rock type of each unit.

The Clutha Formation

(a) The Basal Conglomerate

The basal conglomerate is developed nearly everywhere at the base of the Moodies succession. It is absent, but for a few scattered localities, on the inner arc of the Eureka Syncline, between the Royal Sheba Gold Mine and the Barberton-Havelock road, where it has been eliminated by the Sheba Fault. The conglomerate does not always comprise one uninterrupted sequence of pebbles but in places consists of pebble bands separated, the one from the other, by interlayers of impure quartzites, calcareous and felspathic quartzites, or subgreywackes, in all of which isolated pebbles may be found randomly distributed, or lying on bedding planes. In some cases, graded sedimentary units commence with a single pebble layer and grade, within the space of centimetres, through grits, coarse sandstones, fine sandstones, and thin shale bands.

The pebbles comprising the basal conglomerate are made up of a great variety of rock types. Most common are chert pebbles which vary in colour from black, grey, and white, to banded varieties, some of which are contorted. Other pebble-types comprise red banded jaspilite, quartz and felspar porphyries, quartzites, granite, greywacke, and even conglomerate pebbles. An example of a pebble of conglomerate can be seen in Plate 2B. The latter contains ill-sorted, angular, fragments of leached, banded and massive chert and was probably derived from the erosion of a conglomeratic unit in the Fig Tree succession.

The conglomerate pebbles have suffered severe deformation, particularly along the outer arc of the Eureka fold. These deformed pebbles have been used to calculate the degree of flattening suffered by the rocks in the Eureka Syncline and this aspect of the structure of the area is dealt with in a later section.

TABLE 2

STRATIGRAPHIC COLUMN OF THE MOODIES GROUP IN THE EUREKA SYNCLINE

Map Reference Code	Unit-Stratotype	Rock Types	Lithostratigraphic Units
MdQ4	Sandstone	sandstones, grits, small-pebble conglomerates	Bickenhall Member
MdS3	Shale	subgreywackes, coarse and fine sand-stones, grits, shales, phyllites	Baviaanskop Formation
MdQ3	Quartzite	conglomerates, grits, quartzite, shaly partings	
MdS2	Shale	shales, phyllites, subgreywackes, dark shaly quartzites	Joe's Luck Formation
MdI2	Jaspilitic Iron Formation	banded magnetic jaspilite, banded iron formation, ferruginous and magnetic shales	
MdL2	Basaltic Lava	massive and amygdaloidal lava	
MdQ2	Quartzite	conglomerates, gravel, grits, sand-stones, quartzites	
MdI1	Jaspilitic Iron Formation	banded magnetic jaspilites, banded iron formation, ferruginous and magnetic shales	Clutha Formation
MdS1	Shale	subgreywackes, sandy shales, finely laminated shales, dark shaly quartzites	
MdQ1	Felspathic Quartzite	conglomerates, grits, felspathic quartzites, sandstones	
MdCq	Calcareous Quartzite	carbonate-rich quartzites, marble, quartzo-felspathic sandstones	
MdB	Basal Conglomerate	conglomerates, quartzites, subgreywackes	

(b) Calcareous Quartzite

Carbonate-rich quartzites are best developed in the eastern part of the Eureka Syncline, particularly between Fig Tree Creek (Figure 2, G5) and the fold closure on the farm Lilydale 324 JU (Figure 1). In this region, calcareous and felspathic quartzites make up by far the greater part of the stratigraphy of the area. The calcareous quartzites together with some narrow, impure dolomitic or marble bands can be traced uninterruptedly along the northern edge of the Eureka fold from Lilydale 324 JU, west to the Clutha Gold Mine, and then south to a point just east of Caledonian Siding. No calcareous quartzites were found south of this point. They were either not deposited in the area or they have been eliminated by faulting, as is the case on the eastern limb of the Eureka fold.

The calcareous quartzites vary considerably in their carbonate contents, and are felspathic in places. Along shear zones or fault traces the carbonate content of the quartzites increases markedly, and in places the weathered outcrop surfaces of the rocks is dark brown in colour. Fresh surfaces are almost pure white, the rocks containing abundant calcium and magnesium carbonate as well as quartz. Partial analyses of two samples rich in carbonate are given in Table 3.

TABLE 3

PARTIAL ANALYSES OF TWO SAMPLES OF CALCAREOUS QUARTZITE FROM THE EASTERN PART OF THE EUREKA SYNCLINE

Constituent		Samples (weight per cent)	
		S 169	S 178
MgO		6.52	17.82
CaO		10.16	26.92
CO_2		15.95	41.45
SrO		0.04	0.02
	Totals	32.67	86.21

Analysts : National Institute for Metallurgy, Johannesburg.

Samples S 169 and S 178 were collected from the area northeast of the Royal Sheba Gold Mine where a shear zone, extending from the Bonanza and Lochiel Gold Mines (Figure 2, G3, G4), continues eastwards across Fig Tree Creek into the eastern half of the Eureka Syncline. The calcareous quartzites become progressively more enriched in carbonate as the shear zone is approached both from the north and south. The gradual change in the carbonate content is particularly evident in thin section analyses of the rocks in the area. Far away from the enriched zones the average calcareous quartzites contain mainly quartz, albite, microcline, sericite, muscovite, perthite, and carbonate, all in a matrix of micro-crystalline quartz and carbonate. Sample S 169 consists of an almost pure-white rock with a granular texture. A few small black crystals in the carbonate rock are invariably surrounded by bright greenish-coloured stains. The black mineral is considered to be either chromite or nickeliferous magnetite and was presumably derived from the ultramafic assemblages of the Onverwacht Group. Similar greenish stains associated with black opaque minerals have been reported in the quartzites of the Stolzburg Syncline southwest of Barberton by Reimer (1967). In thin section, the rock contains abundant carbonate, together with subordinate amounts of quartz, oligoclase and albite, microcline, perthite, sericite, and the opaque black mineral already mentioned.

Sample S 178 showed similar characteristics but possessed even greater amounts of carbonate. This was borne out by the analysis which showed that the rock contained about 68 per cent combined CaO and CO_2. The high magnesium content of the rock suggests that the carbonate is dolomitic in composition.

Two modal analyses of "average" calcareous quartzites are given in Table 4. The results show that the amounts of carbonate present in these rocks is extremely variable. Sample 185 is from the northern limb of the Eureka Syncline, near the Thistle Gold Mine (Figure 2, F2), while sample E6 is from the southern limb of the fold, in the area northeast of the Royal Sheba Gold Mine.

The source of the carbonate in these formations is obscure. Carbonate minerals are found in practically all the formations in the Barberton area and are generally the result of secondary introduction. The carbonate in the lower part of the succession in the Eureka Syncline appears to have been introduced at the time of deposition of the sediments. Had the carbonate been introduced later it most certainly would have pervaded all the sedimentary successions in the area. Areas of enrichment presumably resulted from the local dissolution and reprecipitation of carbonate by hydrothermal processes that were particularly active along faults and shear zones.

The calcareous quartzites are generally well-bedded and often display cross-bedding and graded-bedding, both of which can be used to determine the facing directions of the sediments.

TABLE 4

MODAL ANALYSES OF CALCAREOUS QUARTZITES IN VOLUME PER CENT

	Sample 185	Sample E6
Quartz	41.72	43.18
Plagioclase	12.65	20.70
Microcline	2.08	0.54
Carbonate	43.53	15.53
Chert	-	20.02

Conglomeratic zones occur in places, the latter probably representing the local reworking of the underlying basal conglomerate unit. Plate 2C illustrates two well-rounded pebbles in the calcareous quartzites near the Thistle Gold Mine (Figure 2, F2). One is a quartzite pebble (metamorphosed, recrystallized chert), the other a quartz and felspar porphyry pebble.

The porphyry pebbles found in the Moodies can be unmistakably matched with the typical quartz and felspar porphyry bodies intrusive into the Onverwacht Group in the Jamestown Schist Belt and elsewhere in the Barberton Mountain Land. This evidence is used in support of the contention that some of the porphyry bodies were intruded very early on in the history of the area, and that many of them are not directly related in any way to the granites which intruded in post-Moodies times.

(c) Felspathic Quartzite

Immediately overlying the calcareous quartzites is a substantial development of felspathic quartzite, quartzo-felspathic sandstone, massive pure and impure quartzite, and minor local intraformational shale units. The distribution of these rocks follows much the same pattern as that described for the underlying calcareous quartzites except that bands of this horizon have been found on the western limb of the Eureka Syncline extending south from Caledonian Siding. Faulting has once again eliminated these rocks on the inner arc of the fold. The best development of these rocks lies in the areas north of the Sheba Gold Mine, from the Eureka City area (Figure 2, E3) east to Fig Tree Creek, and beyond. An excellent section of steeply dipping felspathic quartzites is present in Hollebrand's Pass in Fig Tree Creek (Figure 2, G3). Small-scale trough cross-bedding,with cross-bed foresets accentuated by carbonaceous partings, is exposed in the old road cutting (Plate 2D). Also in this cutting, but now largely destroyed by the widening of the roadway, are exposures of interference or cross-ripples (Plate 3A),like those commonly developed in shallow water environments, (e.g. in the tidal channels of estuaries).

Although variable from one place to another in the Eureka Syncline, the felspathic quartzites are generally pale greyish-white or buff coloured, medium textured rocks, usually not as indurated or consolidated as the quartzite units developed in the overlying successions. In thin section, the rocks contain abundant quartz, chert, and felspar, the latter very often partly or completely sericitized. The modal analysis of a sample collected north of the Bonanza Gold Mine is given in Table 5.

TABLE 5

MODAL ANALYSIS OF FELSPATHIC QUARTZITE

Sample No. 156	Volume per cent
Quartz	64.39
Plagioclase	13.22
Sericite	14.20
Biotite	5.05
Microcline	2.52
Opaque Minerals	0.58

An interesting feature of the quartzites and sandstones is their high content of material obviously derived from a granitic source area. Supporting this is the abundant quartz, perthite, oligoclase-albite, and microcline found in these rocks.

(d) Shale

Overlying the felspathic quartzite unit there occurs a zone of finely bedded reddish-brown shales or sandy shales. Near the base, except in the area east of the Clutha Gold Mine, is a band of magnetic shale and jaspilitic iron formation (see later) which forms a persistent marker band throughout most of the Eureka Syncline. The shale unit continues above the iron formation marker, enveloping the latter and eventually becoming partly arenaceous near the top, where sub-greywackes and lenses of impure quartzite are developed below the basal quartzite unit of the Joe's Luck Formation.

In the Stolzburg Syncline, Reimer (1967) reported the presence of a lava bed (MdL1) overlying the shales. This lava band is not capped by a true jaspilite unit, but by magnetic ferruginous shales. No evidence was found of this lava bed in the Eureka Syncline although its presence is strongly suspected. Scree cover or poor exposure due to decomposition or weathering may account for the apparent absence of this volcanic unit in the area north of Barberton.

The frequent occurrence of the typical early Precambrian banded iron formations and ferruginous cherts with volcanic rocks, greywackes, and shales, suggests that there is a genetic relationship between these rocks and volcanism. Volcanic activity appears to have contributed both the iron and the silica to these formations (Gross, 1965).

(e) Jaspilitic Iron Formation

As mentioned above the shale unit in the Clutha Formation contains a well-developed banded magnetic shale and jaspilite member the latter forming a useful marker, traceable throughout most of the northern areas of the Eureka Syncline, but which is absent on the western and eastern limbs of the structure. Near the Cheval de Course Gold Mine (Figure 2, B8) two jaspilitic bands appear to be present but the area is strongly faulted and some duplication may have taken place.

The jaspilitic iron formations are distinctive rock-types and are clearly distinguishable from banded iron formations of the Fig Tree Group. Some of the jasper is bright red in colour and forms in bands several centimetres wide, separated by ferruginous shales and magnetite layers. Frequently the banded magnetic jaspilites are intricately folded and contorted.

The jaspilite zone passes transitionally into the overlying ferruginous, finely bedded, shales which extend upwards to the top of the Clutha Formation.

The Joe's Luck Formation

(a) Quartzite

The basal member of the Joe's Luck Formation is a prominent quartzite unit that can be traced almost uninterruptedly on both limbs of the Eureka Syncline. Between Caledonian Siding and the Barberton-Havelock road the quartzite unit is, however, poorly developed or is entirely absent in places. The absence or poor development of the stratigraphic units on the western limb of the Eureka fold is probably due, as has been mentioned previously, to the structural effects consequent on the emplacement of the adjacent diapiric Kaap Valley granite pluton.

The quartzite unit reaches its maximum development near the Joe's Luck and Thomas Gold Mines (Figure 2, E3) where it is approximately 300 m thick. On the northern limb of the Eureka fold the quartzite unit is not as thick as its southern counterpart, a feature in keeping with the general tendency for the formations of the southern limb to be better developed (thicker) than the same formations on the opposite side of the fold.

The steeply dipping quartzite member builds a resistant range of hills as can be seen on the aerial photograph of the Eureka Syncline (Plate 1A), while the surrounding shales have suffered erosion and form the deeply incised valleys. The quartzite unit forms an impressive fold closure near the Bar 10 trigonometrical beacon (Figure 2, G3), south of Ezzy's Pass.

The quartzite member of the Joe's Luck Formation consists essentially of massive, well-bedded quartzites but local conglomeratic lenses and gravel beds also occur. An unusual gravel layer was found in the area east of the Joe's Luck Gold Mine and is illustrated in Plate 3B. Similar rocks were found west of the Fairview Mine top section workings, near the mountain road (Figure 2, C4). The quartzites frequently display cross-bedding as well as graded-bedding, and directions of younging can easily be ascertained from these rocks. In Plate 3C cross-bedding and graded-bedding are illustrated in the same specimen.

The quartzites generally appear free of impurities and consist mainly of quartz, having only accessory amounts of felspar, iron ores, and biotite. The quartz grains are frequently welded together as a result of regional metamorphism.

(b) Basaltic Lava

The quartzite unit described above is generally overlain by shales and a poorly exposed lava band containing amygdales filled with quartz and carbonate. According to Visser et al., (1956) the lava is mineralized with pyrite and gold but this could not be confirmed by the writer. Probably the best surface exposures of the volcanic unit occur in the nose of the fold near the Bar 10 trigonometrical beacon (Figure 2, G3), where the lava band has been altered to a chlorite-actinolite schist. Biotite is also present in places. The lava band can also be seen on the eastern limb of the Eureka Syncline in the road cutting west of the Kidson and Blue Rock gold mines (Figure 2, C5). The amygdaloidal lava unit is generally absent on the western limb of the Eureka fold but some outcrops were found in the area south of Elephant's Kloof (Figure 2, B6).

The rocks are generally badly weathered on surface and cannot be traced continuously around the Eureka Syncline. Actinolite and chlorite are the main minerals seen in thin section together with variable quantities of biotite, carbonate, plagioclase (albite), iron ores, sulphides, tourmaline, sericite, and quartz. No material suitable for geochemical study could be obtained from surface exposures but fresh samples of massive and amygdaloidal lava were obtained from an adit in the Rose Reef Gold Mine (Figure 2, C6).

Analyses of two samples from the Rose Reef workings are provided in Table 1. The rock is basaltic in composition but has anomalously low CaO values, the reasons for which are obscure. The lava also possesses a relatively high percentage of combined alkalis (with Na_2O particularly prominent). The high total iron (particularly FeO) suggests, furthermore, that there may be a genetic relationship between the lava unit and the overlying ferruginous shale and jaspilitic iron formation unit.

(c) Jaspilitic Iron Formation

Overlying the amygdaloidal lava unit (Figures 2 and 3), is a second prominent banded magnetic jaspilite, together with ferruginous shales and magnetite bands, which can be traced almost continuously right the way around the Eureka Syncline. In appearance and general characteristics there is much similarity between these rocks and the first jaspilite unit (MdI1, Table 2) described earlier. The jaspilite also grades upwards into reddish weathering shales and subgreywackes. In some places,finely bedded shales separate the banded magnetite and jasper layers from the amygdaloidal lava zone beneath. This relationship can be seen along the road crossing the eastern limb of the Eureka structure (Figure 2, C5).

(d) Shale

Stratigraphically above the jaspilitic unit of the Joe's Luck Formation is a succession of red and brown weathering shales and subgreywackes that differ little in appearance from the shales described from the Clutha Formation. In places, lenses of dark coloured shaly quartzites and siliceous argillites occur interlayered with the shales. In the area north and northwest of the Joe's Luck and Thomas gold mines, the finely bedded shales display strong oblique slaty cleavage.

The Baviaanskop Formation

(a) *Quartzite*

At the base of the Baviaanskop Formation a prominent quartzite member overlies the shale unit of the Joe's Luck Formation and builds a series of ridges that form some of the most topographically elevated parts of the Eureka Syncline (Plate 1A). Southwest of Noordkaap the massive, steeply dipping, quartzite unit reaches an elevation of 1 153 m (3 793 feet) at the Baviaanskop trigonometrical beacon (Figure 2, C3).

The quartzite unit is best developed in the north-south trending section of the Eureka structure, between the Barberton-Havelock road and Noordkaap, where it forms prominent ridges that constitute part of the eastern and western limbs of the great fold structure. These two parallel ridges sweep gradually around the arcuate structure and form a fold closure in the area north of the Joe's Luck Gold Mine (Figure 2, E2).

The Baviaanskop Formation quartzite contains locally developed conglomerates, both at the base of the unit as well as higher in the succession. It consists, however, mainly of pure and impure quartzites, grits, and, in places, a few intraformational shaly layers. The quartzites are generally hard, massive, pale grey, white, or buff-coloured, and frequently display cross-bedding and graded-bedding.

Scour-trough casts and current markings were noted in some of the gritty quartzites at the base of the unit near the bends in the mountain road,west of the Fairview Gold Mine (Figure 2, C5). The example shown in Plate 3D has, unfortunately, been destroyed recently with the widening of the road cutting.

Thin sections reveal that the clear quartzites consist mainly of quartz and chert grains, with accessory amounts of felspar, zircon, and iron ores. Impure quartzites contain prominent amounts of felspar, chlorite, and iron ores, the latter in places consisting of pyrite. Arsenopyrite, probably introduced along fracture planes in the quartzites, weathers to produce dirty yellow-green stains in places.

The quartzite on the western limb has been affected by the metamorphism resulting from the emplacement of the Kaap Valley Granite and in thin section the sutured boundaries of welded quartz grains are conspicuous. In Plate 4, A and B, microphotographs of quartzites from the eastern and western limbs of the Eureka fold are shown side by side for comparison. Modal analyses of these two thin sections are provided in Table 6.

TABLE 6

MODAL ANALYSES OF TWO SAMPLES OF BAVIAANSKOP QUARTZITE
(Volume per cent)

	Sample 1A (eastern limb)	Sample 3A (western limb)
Quartz	49.09	57.78
Chert	40.47	30.47
Felspar/sericite	9.38	11.47
Microcline	0.28	-
Opaque minerals	0.75	0.26

Well-developed conglomerates occur in the Baviaanskop quartzite unit on both limbs of the syncline in the area south of Elephants Kloof (Figure 2, B6). The pebbles in these conglomerates consist mainly of chert and have been extensively flattened. Good outcrops of flattened conglomerates also occur in the area southeast of the Bar 15 trigonometrical beacon (Figure 2, B8).

(b) Shale

The upper unit of the Baviaanskop Formation consists of a substantial development of shales, subgreywackes, carbonaceous argillites, argillaceous quartzites, grits, and sandstones. The full succession can be seen in road cuttings along the mountain road which crosses the Eureka Syncline between Caledonian Siding and the Fairview Mine top section workings (Figure 2, B5, B4 and C5). Here a monotonous succession of dirty grey and brown shales and subgreywackes is broken in a few localities by the presence of black, indurated, argillaceous quartzites which form locally resistant outcrops. These beds cannot be followed continuously as they occur in strongly dissected mountainous terrain, having a dendritic drainage pattern. Several bands produce fold closures in area southeast of the Baviaanskop trigonometrical beacon (Figure 2, C3). Some of the argillaceous quartzites contain abundant biotite and this, together with carbonaceous shaly material is responsible for the dark colouration of many of these beds. A modal analysis of a typical argillaceous quartzite is given in Table 7.

TABLE 7

MODAL ANALYSIS OF ARGILLACEOUS QUARTZITE

Sample 11	Volume per cent
Quartz	27.49
Chert	33.88
Sericite	20.40
Biotite	12.25
Felspar	2.97
Iron ores	1.66
Carbonate	1.31

The Baviaanskop Formation shales are affected by a strong oblique cleavage, the latter developed particularly in the area southeast of the Baviaanskop beacon. Some shales are, in places, magnetic and strongly contorted, but are unlike the iron formations in the Clutha and Joe's Luck formations in that they do not contain the distinctive red, or purplish-red coloured jasper bands found with the latter sediments. Outcrops of Baviaanskop magnetic shales can be seen along the mountain road mentioned above. The magnetic shales have not been differentiated on the accompanying map (Figure 2), but may be located near the broad bend in the road (top left of map reference square C5, where it adjoins reference square B5).

The Bickenhall Member

The shaly succession of the Baviaanskop Formation is capped by a pale buff-coloured sandstone unit, here termed the Bickenhall Member. This unit is only locally developed, being found in the core of the Eureka Syncline and then only on the elevated dividing ridges separating streams flowing from east to west out of the Sheba Hills and into the De Kaap Valley. On the tops of the ridges the Bickenhall Member forms oval or boat-shaped outcrop patterns (Figure 2, B4, B6, B8 and A9), and the sediments must originally have occupied only the narrow central portion of the basin in which they were deposited.

The Bickenhall sandstone unit contains small pebbles and angular fragments of white chert and bright red jasper. The pebbles occur randomly distributed throughout the arkosic sandstones and do not form conglomeratic bands or lenses.

In Table 8, a modal analysis is provided of a typical quartzitic sandstone.

TABLE 8

MODAL ANALYSIS OF A QUARTZITIC SANDSTONE FROM THE BICKENHALL MEMBER

Sample 2A	Volume per cent
Quartz	47.73
Chert	33.33
Sericite	17.21
Biotite	1.56
Opaque minerals	0.15

CYCLIC SEDIMENTATION OF THE MOODIES GROUP

In the Eureka Syncline three major cycles of Moodies sedimentation can be recognized. These cycles coincide with the three formations discussed in the preceding sections. The cyclic nature of the sedimentation is further illustrated in Figure 3, where it is shown that each cycle commences with conglomerates and/or quartzites, and terminates with shales and subgreywackes. Two of the cycles (Clutha and Joe's Luck formations) have prominent jaspilitic iron formation members while the third (Baviaanskop Formation) has minor developments of banded magnetic shale (not differentiated in Figure 2 and 3), that could be regarded as pseudo-iron formation. Only the Joe's Luck Formation has a recognizable volcanic unit although, as has been mentioned, a similar lava bed may be present in the underlying Clutha Formation.

Apart from the three major cycles, an embryonic fourth cycle is also apparent at the top of the Moodies succession in parts of the Eureka Syncline. This corresponds to the Bickenhall Member with its small-pebble conglomerate-grit-sandstone assemblage.

The Moodies succession in the Eureka Syncline is estimated to be over 3 000 m thick. It is difficult to provide accurate thicknesses of individual units as structural deformation is not uniformly consistent within the Eureka structure. It is evident from Figure 3, however, that the formations, or cycles, in the Eureka Syncline become progressively smaller with increasing stratigraphic height.

CONDITIONS OF DEPOSITION OF THE MOODIES GROUP

The overall character of the Moodies sedimentary sequence prompted Anhaeusser (1964), Viljoen (1964), and Anhaeusser et al., (1968) to suggest, initially, that the great development of conglomerates, quartzites, sandstones, and shales could be equated with a molasse assemblage of a geosyncline. Although some of the sediments are molasse-like in character, continued work in the Barberton area led to the abandonment of the concepts which imply association with "geosynclines" and "orogeny" in the classical Alpine sense of the terms (Anhaeusser et al., 1969).

In general, the Moodies quartzites consist of relatively mature, in places, cross-bedded and ripple-marked sediments. Mud-cracks also occur in the shales. Trough cross-bedding is particularly prominent in some areas and appears to be indicative of transportation of the sediments in braided stream channels. Graded-bedding and the cross-stratification can frequently be used to determine the directions of sedimentary younging. Bedding is clearly evident in all rock-types although in some of the shales it is obscured by a strong cleavage developed oblique to the stratification. The sedimentary structures, together with the conglomerates which display poor sorting, are indicative (gross assessment) of shallow water sedimentation.

Much of the Moodies sedimentation can be ascribed to the denuding of pre-existing Fig Tree and Onverwacht Group rocks. Evidence suggesting that the Fig Tree succession had been subjected to folding prior to the deposition of the Moodies Group was outlined by Visser et al., (1956) who reported the presence of contorted banded chert pebbles in the Moodies conglomerates. These contorted banded cherts are, however, not entirely diagnostic of an earlier deformation, as they could have been formed by slumping within the depository itself. The polymictic nature of the basal conglomerates is ascribed to the influx of pebbles of black chert, quartz porphyry and quartz-sericite-schists from denuded Onverwacht successions, while the banded iron formation, jasper, grit, and banded chert pebbles were most probably derived from the Fig Tree Group.

The presence of granitic, micropegmatitic, and quartz porphyry pebbles, as well as the abundance of sodic and potassic felspar (albite, oligoclase, microcline, perthite) and quartz, clearly indicates that at the time of Moodies sedimentation there existed an elevated granitic/ metamorphic terrane from which these and other sediments (sandstones, subgreywackes, grits, arkoses, felspathic quartzites) were derived. This terrane is considered by some investigators (Hunter, 1970; Condie et al., 1970) to represent the original basement upon which the volcanics and sediments of the Swaziland Supergroup were deposited. Anhaeusser (1973a) suggested, however, that the early crust in southern Africa had initially been ensimatic in character and that an ensialic crust had evolved only during the later stages of the development of the Onverwacht Group. Among other aspects, it was argued that no clastic detrital sedimentation had occurred in the approximately 15 km thick Onverwacht stratigraphic pile. Instead, the first sediments to be derived from an ensialic source were deposited in the Fig Tree Group, while later, more intense, sedimentation of this type occurred during Moodies deposition.

Although much of the material in the Moodies succession appears to be essentially the product of a high-energy depositional environment, there must have been short periods of quiescence in which the banded magnetic shales and jaspilites and other finely laminated shales were deposited. The depositional cycle was also interrupted by periods of volcanism, during which times the amygdaloidal lavas were extruded. In contrast to the Fig Tree sedimentation, which took place in relatively deep water, associated with turbidity flows, the Moodies sedimentation appears to have been continental in character. The various Moodies stratigraphic units are thus not unlike those developed in the interior or cratonic-type basins (e.g. the Pongola, Witwatersrand, or Transvaal basins).

The gross sedimentational pattern of the Moodies appears to be transgressive in character, the thickest and coarsest arenaceous units being developed near the base, becoming, on average, progressively finer upwards in the succession. The pattern of cyclical sedimentation, manifested by the alternation of arenaceous and argillaceous units, is similar to a fluvio-deltaic situation with the arenaceous units representing the products of regressive periods, during which times sands, gravels, and conglomerates were deposited by fluvial systems built out over argillaceous sediments, the latter representing deltaic, or possibly shallow marine deposits.

4. IGNEOUS INTRUSIVE ROCKS

In the area under discussion rocks of an igneous intrusive character can be divided into three main categories. Some of the oldest intrusive rocks include a variety of porphyries and porphyritic granite bodies. These are considered to pre-date the emplacement of the Kaap Valley diapiric granite pluton as well as the Nelspruit granites, gneisses, and migmatites. Finally, at a later stage in the evolution of the region, an assortment of mafic dykes, of variable geological age, were intruded into the rocks of the Barberton granite-greenstone terrane.

PORPHYRIES

In addition to the various mafic, ultramafic, and siliceous schists and dolomitic rocks found in the area between Barberton and Noordkaap, there are a number of intrusive bodies of quartz and felspar porphyry (Figure 2). The largest of these porphyry bodies occurs in the area between Clutha Siding and the Woodstock Gold Mine, southeast of Noordkaap. Several other lensoid porphyry bodies lie concordantly within the Onverwacht schists to the south of the Fairview Mine offices.

Descriptions of the various porphyry and porphyritic granite bodies north of Barberton have been given by Visser et al., (1956) and Anhaeusser (1969a; 1972). It appears that more than one generation of quartz and felspar porphyry or porphyritic granite is developed in the area. One variety is related to the Kaap Valley Granite but it has been shown that some porphyry bodies predate this event and represent discrete intrusives displaying evidence of deformation, the latter caused by the emplacement of the Kaap Valley Granite (Anhaeusser, 1965; 1969a; 1972).

Petrologically no distinctive differences between the two varieties is apparent. Both types contain large felspar phenocrysts, many over 5 mm in length. The rocks consist primarily of albite and oligoclase with some microcline, hornblende, and accessory amounts of chlorite, apatite, muscovite, carbonate, magnetite, and other oxides of iron. These are set in a microcrystalline matrix of quartz, sericite, and chlorite. The chlorite is presumably the alteration product of hornblende. The felspar crystals are sometimes zoned and in most cases they are almost entirely sericitized. Hybridized rocks in the Clutha area appear to be partly dolomitized granite porphyries. They contain much the same mineral assemblage as described above, although very often they are devoid of amphibole. The carbonate content varies considerably and, at times, the composition of the rocks approach that of a dolomite or marble.

The porphyritic granite occurrence near the Clutha Gold Mine was regarded by the Geological Survey (Visser et al., 1956) as an intrusive tongue of porphyritic hornblende granite, associated with the Kaap Valley Granite. Ramsay (1963) also noted this thick, persistent sheet of deformed granite, and expressed the view that some of its features, particularly the porphyritic felspar crystals, seemed to resemble more closely those of the Nelspruit Granite. The writer favours the Geological Survey viewpoint and further suggested (Anhaeusser, 1969a; 1972) that the porphyry body had been injected into a zone of tension created by the detachment (decollément) of competent Moodies and Fig Tree formations from underlying, less competent, Onverwacht schists. The décollement, marked approximately by the trace of the Lily Fault southeast of Noordkaap, developed as the Eureka Syncline underwent inflection about a northwest trending fold axis and was thrust in this direction over the Onverwacht rocks of the eastern part of the Jamestown Schist Belt.

GRANITIC ROCKS

To the north and west of the Sheba Hills are the granite masses referred to locally as the Nelspruit and Kaap Valley granite bodies (Figure 1). Numerous accounts of these granites are available (Anhaeusser, 1966, 1969a, 1972; Roering, 1967; van Eeden, 1941; van Eeden and Marshall, 1965; Viljoen and Viljoen, 1969c, d) and they will not be described here in any detail.

The Kaap Valley Granite has yielded U-Pb ages of 3310 ± 40 m.y. (Oosthuyzen, 1970) whereas the Nelspruit granite-gneiss terrane has provided Rb-Sr ages of 2992 ± 70 m.y. (de Gasparis, 1967) and U-Pb ages of 3160 ± 50 m.y. (Oosthuyzen, 1970).

The granitic rocks from the two regions are also distinctively different in appearance, mode of occurrence, and geochemical characteristics. The Kaap Valley Granite, which is a hornblende-biotite tonalite (Table 1), was emplaced as a diapiric pluton. The Nelspruit granitic rocks are compositionally more variable, consisting of granodioritic or adamellitic gneisses, migmatites and homogeneous granites (Table 1). In addition, pegmatites occur prominently in places (e.g. near the New Consort Gold Mine; see Allsopp et al., 1968).

The emplacement of the granitic rocks in the area north of Barberton was responsible for most of the structural deformation suffered by the rocks of the Swaziland Supergroup (Anhaeusser, 1969a; 1972; 1973b). This aspect will be dealt with in a later section on the structure of the Sheba Hills region.

DYKES

A variety of hypabyssal rocks, in the form of dykes or sheets, intrude the successions in the Sheba Hills. By far the most common variety are the diabase dykes which show considerable variation in texture and mineralogical composition. In the area mapped (Figure 2) these dykes show no preferred orientation although regionally a northwest-southeast strike appears dominant (Visser et al., 1956).

Less common are the porphyritic diabase dykes containing large phenocrysts of plagioclase, some of which are saussuritized to epidote. One dyke of this nature cuts across the Eureka Syncline in the area east of Fig Tree Creek, and south of Eureka Siding. Further dykes of this type occur in the nose of the Ulundi fold (Figure 2, C7 and C8).

A single example of what is considered to be a Karroo dolerite dyke (Visser et al., 1956; van Vuuren, 1964) is also located in the nose of the Ulundi Syncline and extends from north to south across the Barbrook Fault in the Hislop's Creek area (Figure 2, C8). This dyke can be traced for approximately 15 km southwards into the central core of the Barberton Mountain Land.

Further dyke variations were encountered by Anhaeusser (1969a) in the Eureka Syncline, north of the Barberton-Havelock road (Figure 2, A8 and B8). The Geological Survey (Visser et al., 1956) had earlier reported that on the farm Bickenhall 346 JU, several small bodies of Kaap Valley Granite had intruded both the basic rocks as well as the sediments of the Moodies Group. Investigations of the bodies found in the Eureka Syncline revealed, however, that the rocks were massive, structureless, dyke or sill-like bodies of quartz-diorite or gabbro, most of which diaplay granophyric textures. In thin sections, these rocks consist essentially of relic hornblende (the latter mainly altered to chlorite), plagioclase (andesine), biotite, apatite, sericite, and quartz. Graphic intergrowth textures of quartz and felspar were also observed. One body was of particular interest in that the quartz-diorite and granophyric phases appeared to be the more felsic differentiates of a massive basic dyke or sheet. In the area south of the Bar 15 trigonometrical beacon (Figure 2, B8) the dyke has a variable composition ranging from a peridotite (containing mainly olivine and some accessory amounts of carbonate, magnetite, sericite, quartz, iddingsite and serpophite) to an olivine gabbro (containing labradorite, ortho- and clino-pyroxene, olivine, apatite, quartz, magnetite, and sericite). Compositionally, the differentiated body further demonstrates gabbroic, diabasic, quartz-dioritic, and granophyric phases.

It is of interest to note that Daly and Barth (quoted in Turner and Verhoogen, 1960) found granophyric rocks at the margins of diabase sills intruded into sediments of the Karroo Supergroup. These granophyres were generally formed by gravitational differentiation but, some were considered to have formed by the reaction of the diabase magma with the invaded siltstones.

It appears, therefore, that the more felsic bodies in the Eureka Syncline represents late-phase differentiates of massive dyke-like bodies that reacted with some of the Moodies sediments through which they were injected. In Table 1, a chemical analysis of the more mafic fraction of the dyke clearly demonstrates that the rock is not related to the Kaap Valley Granite.

5. STRUCTURE OF THE EUREKA SYNCLINE

INTRODUCTION

The first structural investigation of the Sheba Hills area was carried out by van Eeden (1941). He concluded that only one period of deformation had affected the Barberton Mountain Land, the stresses involved being directed from the northwest and southeast. The Kaap Valley Granite he considered to be a solid mass which did not yield to deformation but which acted as a resistant buttress against which the less competent schists and bedded rocks were compressed and deformed, (see also van Eeden, 1972). The major stress, he maintained, was directed from the southeast. This resulted in the overfolding of the rocks to the northwest, and the major inflection in the Eureka Syncline which, he postulated, developed as the beds were pushed to the northwest. Ramsay (1963) was able to establish the presence of three successive periods of deformation for the same area. He maintained that each successive deformation led to the imprinting of both large- and small-scale structures on the pre-existing structures and led also to the deformation of the old structures.

GENERAL STRUCTURE OF THE EUREKA SYNCLINE

The Eureka Syncline is one of many major folds that developed very early on in the history of the Barberton greenstone belt. The fold, the original traces of which probably trended NE-SW or NNE-SSW, now has a curving axial plane which dips steeply to the south, southeast, or east. The structure, made up principally of rocks of the Moodies assemblage, consists of several prominent, and resistant, formations that clearly outline the shape of the fold, both in the field and on aerial photographs (Plate 1A). Apart from the fold closure on the western part of the farm Lilydale 324 JU (Figure 1), there are several other clearly defined closures of units developed within the Eureka structure. The most prominent of these are the quartzite units described in an earlier section. The fold closure of the Joe's Luck quartzite unit lies immediately west of Fig Tree Creek (Figure 2, G3), while the fold closure of the Baviaanskop quartzite unit occurs north of the Joe's Luck Gold Mine (Figure 2, E2). The Bickenhall sandstone unit forms a fold closure that can be seen along the road between Caledonian Siding and the Fiarview Mine top section workings (Figure 2, B4).

The Eureka Syncline is narrowest in the region immediately east of the Kaap Valley Granite. East of Barberton it is only about 800 m wide. This narrowing is mainly a result of tectonic thinning caused by faulting and flattening, but may also be partly due to original sedimentary thinning of the successions in this area.

The structure attains a maximum outcrop width of just over 3 km in the area where the greatest arcuation, or change of strike, of the fold axial plane takes place, between the Clutha-Woodstock Gold Mines and the Fairview Mine top section workings.

The fold structure is asymmetrical about its axial plane with the southern and eastern limbs better developed than their northern and western counterparts. The Geological Survey (Visser et al., 1956) indicated that the thickness of sediments on the northern limb amounted to some 1 980 m while those on the southern limb amounted to 3 140 m. Ramsay (1963) considered that the original sedimentary thickness of the southern limb had been of the order of about 4 570 m but had been reduced by flattening deformations. This value for the southern limb is probably excessive because, as will be shown later, the degree of flattening of the rocks on the southern limb of the fold is not as great as the estimated 60 per cent combined shortening and flattening experienced by the successions on the northern limb of the fold (Anhaeusser, 1969a).

The southern and eastern limbs of the Eureka Syncline are overturned to the north, northwest, and west, the whole structure being concave to the southeast where the Ulundi Syncline abuts against the Sheba Fault. The Ulundi structure also constitutes a refolded syncline with dimensions comparable to those of the Eureka Syncline and has been structurally mapped by Ramsay (1963), and van Vuuren (1964).

MINOR STRUCTURES

Bedding

Bedding plane data was collected throughout the entire area of development of the Eureka Syncline. For convenience, the Eureka structure was subdivided into six sub-areas and stereographic projections were compiled depicting the poles to bedding planes (Figure 4). Bedding plane data from both Fig Tree and Moodies assemblages are plotted together, the latter greatly predominating. It can be seen from the stereoplots that the bedding is generally steep with most of the strata dipping either east (sub-areas A, B, and C), southeast (sub-areas C and D) or south (sub-areas D, E, and F). The greatest spread of bedding poles occur in sub-areas D and F, corresponding to the inner arc of the fold. Here some of the calcareous and felspathic quartzites of the Clutha Formation dip to the southeast and south at angles of less than 50 degrees. Elsewhere, bedding is generally in excess of this amount, with an average value of approximately 70-75 degrees, the latter depicted in the two composite plots of poles to bedding. It can be seen too, that many beds are either vertically dipping or dip at high angles to the north, northwest, or west. These variations in bedding attitude are generally to be found in the shale horizons where irregularities are probably the result of intraformational folding and slumping. Data from the outer arc of the fold (sub-areas A + C + E) and from the inner arc (sub-areas B + D + F) shows that the dips on the southern limb are, in general, steeper than those on the northern limb. The southern limb also displays the greatest variation in dip orientations and this factor is partly responsible for the apparently greater thickness of the successions to the south of the fold axial plane.

In the area between Fig Tree Creek and the fold closure in the east, on the farm Lilydale 324 JU, additional bedding plane data was gathered. As with the area to the west, and described above, the bedding plane poles on the northern limb of the fold (Figure 5B) show the least spread, with dips generally to the south at steep angles (70-90°). The southern limb (Figure 5C) shows a wide variation of bedding plane poles and, here again, the apparent thickness of the southern limb of the structure is partly due to the less steeply inclined attitude of the formations.

EUREKA SYNCLINE BEDDING DATA

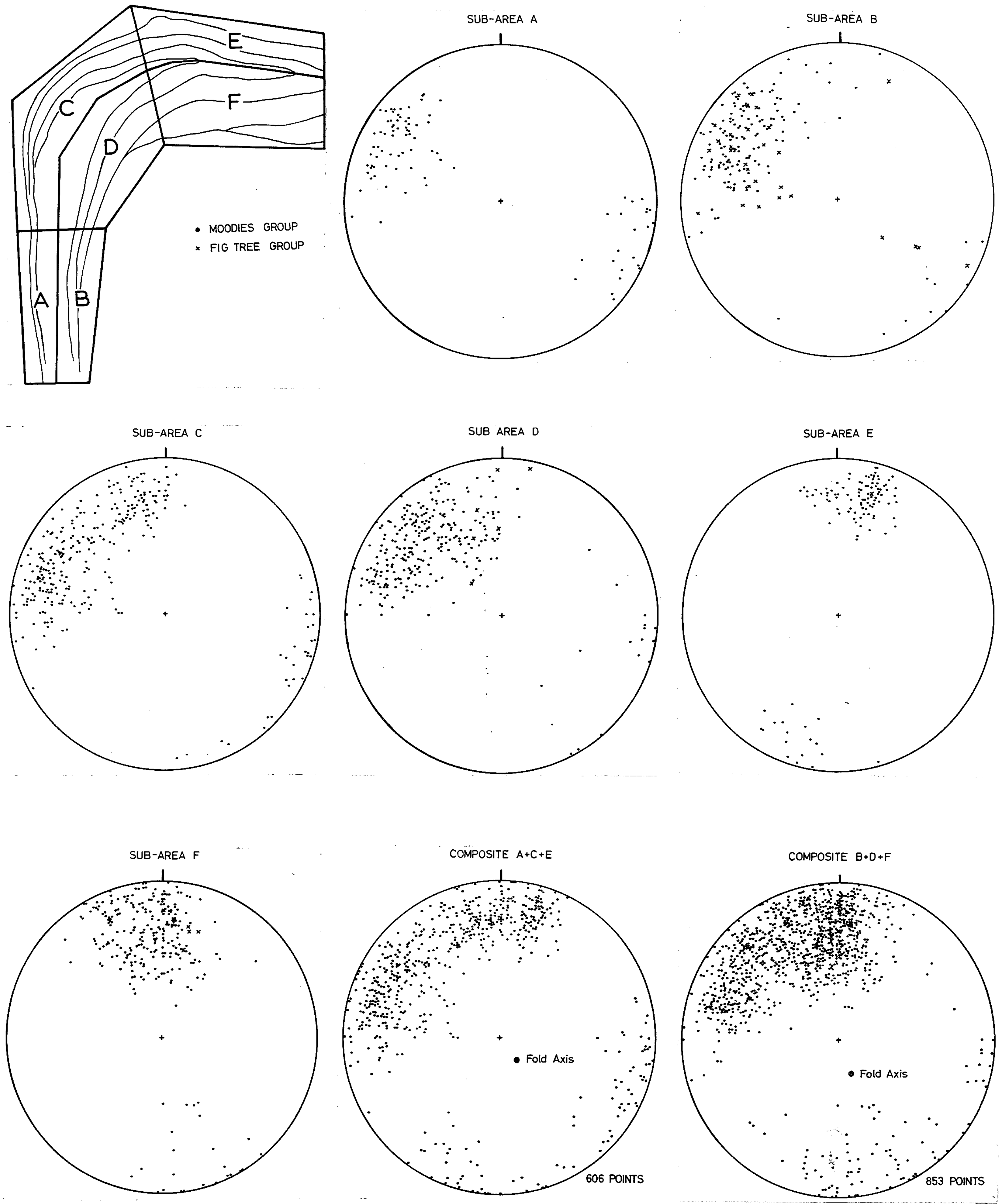


FIGURE 4 : Stereographic projections of bedding plane data from six sub-areas of the Eureka Syncline together with composite plots of poles to bedding on the inner and outer arcs of the fold structure.

A composite plot of the bedding plane data of the Fig Tree assemblages underlying the Moodies strata is given in Figure 5D. Comparison of this data with that of the composite bedding data plots of the Moodies stratigraphy (Figure 4) demonstrates the conformable nature of these two groups of rocks in the Eureka Syncline.

Cleavage

Ramsay (1963) was the first to examine the effects of the very prominent superimposed cleavage that can be found in the Sheba Hills area of the Barberton Mountain Land. He regarded the fabrics developed over the whole area as having resulted from the intense strain suffered by the rocks during his second, or F2, period of deformation. The slaty cleavage, which cuts obliquely across the bedding in the Eureka Syncline, is particularly evident in the area of greatest inflection of the major fold, where the intersection of bedding and cleavage planes is at a maximum. In general, the cleavage and bedding planes intersect one another at low angles, particularly to the east and south of the area of maximum inflection, whereas, in the nose of the Eureka fold, between Noordkaap and the Sheba and Fairview Mines, angles of intersection approaching 90 degrees were noted (Ramsay, 1963; Anhaeusser, 1969a). In the core of the fold, near the Caledonian Siding-Fairview Mine top section mountain road (Figure 2, B4), Ramsay recorded cross-bedding foresets, with truncating bedding surfaces intersecting at angles up to 60 degrees. He pointed out that, as the original angle of repose of the foreset beds, in water-deposited sandstones, could never have exceeded 30 degrees, the oversteepening must be entirely the result of internal deformation.

The slaty cleavage is particularly well-developed in the hard, brittle, shales in the Eureka Syncline and is not readily detectable in the massive quartzitic units. Good exposures of strongly cleaved Fig Tree shales and greywackes occur near the Clutha Gold Mine southeast of Noordkaap (Plate 4C) and in many localities within the Ulundi Syncline (Ramsay, 1963; van Vuuren, 1964).

Figure 5A shows the poles to cleavage planes observed in the area between the Havelock road and Fig Tree Creek. The cleavage poles, like the bedding poles in Figure 4, fall along a great circle indicating that the cleavage has been deformed by the F3 arcuation of the Eureka fold. Had the plot of the cleavage poles clustered together in a group, their development could have been ascribed to the same deformation that was responsible for the inflection of the Eureka Syncline about a NW-SE-trending fold axis. Clearly, therefore, the cleavage development, as has been pointed out by Ramsay (1963), was pre-arcuation in origin.

Ramsay further demonstrated that many of the arenaceous rocks of the Moodies and Fig Tree successions contain deformed clastic grains, and many pebbles in the conglomerates of the Moodies Group are strongly deformed. Earlier, van Eeden (1941) had recognized an 'a' elongation in the conglomerates and he observed that all the pebbles that were not round, lay with their long axes parallel to the dip of the beds. However, because he found elongated chert pebbles together with perfectly rounded granite pebbles he concluded that the conglomerates had undergone little or no deformation or flattening. The elongated chert pebbles were explained by him as having been deposited all with their long axes in one direction as a result of pebble imbrication. He regarded it as merely coincidental that all the pebbles should be lying in the 'a' direction of the folds but commented that differential movement between beds during folding might offer an explanation for their alignment.

Ramsay (1963) contended that "grains and pebbles are always flattened in the slaty cleavage and their long axes are usually fairly steeply inclined within the cleavage". He classified the slaty cleavage as one of his F2 structures, maintaining that it had been produced early in the tectonic history of the area by compression (before the arcuation of the Eureka fold), with the principal regional compressive strain oriented NNW-SSE. Between Joe's Luck Siding (Figure 2, E1), and the area east of Noordkaap, he found the long axes of pebbles to be aligned parallel to, or in the plane of, the slaty cleavage. The longest axes of 50 deformed pebbles, measured from a roadside exposure south of the Kaap River (near Joe's Luck Siding), indicated a strongly preferred linear pebble orientation, the latter lying in the plane of the slaty cleavage. This was interpreted as being the result of intense tectonic elongation overprinted on the initial sedimentary fabric.

Ramsay (1963) concluded that the cleavage development in the area was broadly synchronous to the emplacement of the Nelspruit Granite. His ideas on the relationship between the slaty cleavage and the structural state of the Kaap Valley Granite are, however, not clear and were considered contradictory by Anhaeusser and Viljoen (1963). On the one hand Ramsay regarded the Kaap Valley Granite as a competent mass with consolidation post-dating the slaty cleavage while elsewhere he states that the cleavage is also developed in the granite.

EUREKA SYNCLINE CLEAVAGE AND BEDDING PLANE DATA

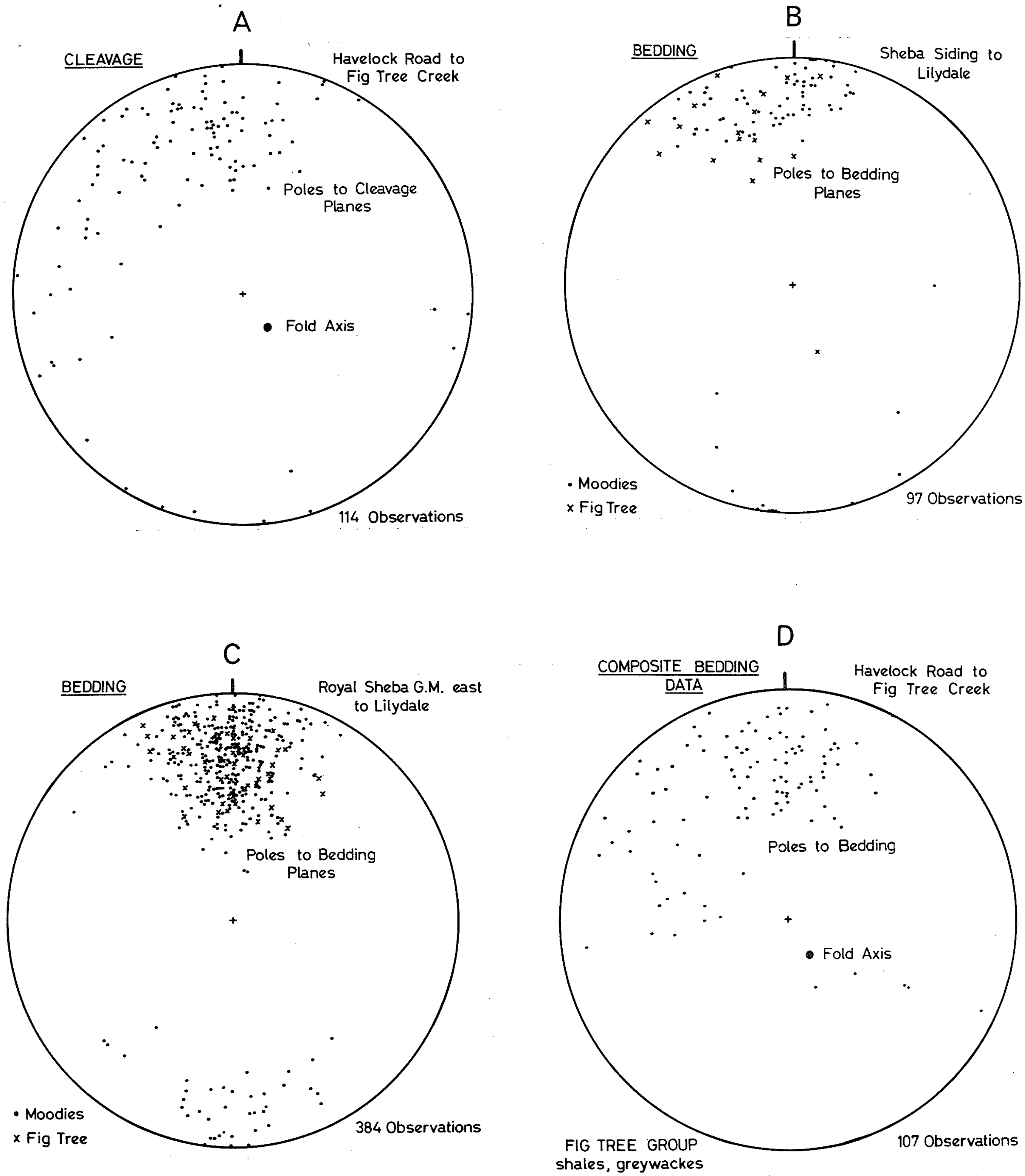


FIGURE 5 : Stereographic projections of cleavage data from the Eureka Syncline and bedding plane data from the northern and southern limbs of the far eastern extension of the major fold structure between Fig Tree Creek and the farm Lilydale 324 JU.

Several difficulties arise following the interpretation by Ramsay (1963) that the pebbles are always flattened in the plane of the slaty cleavage. In some areas on the southern limb of the Eureka Syncline, between the Royal Sheba Gold Mine and the fold closure on Lilydale 324 JU, conglomerate pebbles exist which appear to be relatively undeformed (Plate 4D). These undeformed pebbles do not have any preferred orientation and cannot be reconciled with the slaty cleavage which Ramsay considered was prevalent throughout the Sheba Hills area. A further difficulty arises when comparing the relative amounts of flattening experienced by the conglomerates in various parts of the Eureka Syncline. As will be shown later, the maximum degree of flattening of the conglomerate pebbles is in the areas immediately opposite and adjacent to the Nelspruit Granite in the north, and the Kaap Valley Granite in the west. The deformation that produced the cleavage in the Sheba Hills could not have been solely responsible for the flattened pebbles in the area. The cleavage is an all pervasive structure penetrating both the Eureka and Ulundi synclines while the flattened pebbles, are restricted in their development to the areas immediately flanking the granite contacts.

The following sequence of events, leading to the development of the flattened pebbles in the Eureka Syncline, is envisaged :

(i) The first folds in the Barberton Mountain Land developed with a NE-SW or NNE-SSW trend. The Eureka Syncline formed one of these structures close to the presently exposed northern margin of the greenstone belt.

(ii) Compression from the north-northwest led to the formation of a slaty cleavage which was superimposed obliquely across the earlier, or first fold trend.

(iii) The northern or northwestern flank of the Eureka fold, being in contact with or closest to the directed strain, underwent the greatest degree of deformation which resulted in the development of rock fabrics that were both planar (slaty cleavage), and linear (grain and pebble flattening and elongation).

(iv) The southern limb of the Eureka fold was relatively less deformed, although a planar fabric, weaker than that to the north, is still manifest, particularly in the finely bedded shales and greywackes of the Ulundi Syncline.

(v) With the intrusion of the diapiric Kaap Valley Granite pluton, and possibly the remobilized marginal zone of the Nelspruit Granite (Anhaeusser 1964; Viljoen, 1964) the first folds began to buckle, eventually resulting in the arcuation of the Eureka fold, and at the same time, the arcuation of the slaty cleavage.

(vi) The granites, as they intruded, provided a source of strain which was particularly directed at the western and northern limbs of the Eureka fold (outer arc). This resulted in added grain and pebble flattening and attenuation immediately adjacent to the granite contacts. The intrusive granites may have produced an additional planar fabric but, as the strata on the northern and western limbs of the Eureka fold were oriented at right angles to the strain, this slaty cleavage may be expected to lie within the plane of the bedding.

Lineations

Two varieties of lineation are developed in the area north of Barberton, the first being associated with the parallelism of small-scale fold axes, and the second caused by the linear alignment of platy inclusions, mineral grains, and elongated pebbles. The lineations associated with the small-scale folds are particularly prevalent in the brittle quartz-sericite schist horizons of the Onverwacht Group but their presence has also been noted in shales and subgreywackes of the Moodies Group (Plate 5A). Generally these lineations are associated with crenulation folds that developed during the latest tectonic events in the Barberton area. These folds produce fold axes that are almost horizontally inclined and the resulting lineations are also either horizontal or sub-horizontal in attitude.

The second type of lineation, produced by the stretching or elongation of rock components is, however, the more frequently encountered variety and occurs in practically all the rock successions in the area. The strongly foliated marginal zones of the Kaap Valley Granite are, for example, well-lineated in places. East of Caledonian Siding the lineations in the granites (Plate 5C) result from the alignment of the mineral components of the rock, particularly hornblende and its retrograde product chlorite. Immediately adjacent to the granite the schists of the Onverwacht Group possess identical "stretch" lineations, the latter produced by the parallel alignment of actinolite and chlorite crystals (Plate 5D).

Pebble elongation and alignment is particularly prominent in outcrops of basal conglomerate occurring around the outer arc of the Eureka Syncline. Good exposures of this type can be seen in road cuttings southwest of Joe's Luck Siding (Figure 2, E1; Plate 5B). Flattened and lineated pebbles also occur on the west limb of the Eureka Syncline, south of Caledonian Siding, where the elongated pebbles produce lineations that plunge to the north at steep angles. North of Caledonian Siding the flattened pebbles plunge steeply to the south.

The Baviaanskop quartzite unit also displays lineations that plunge to the north. These can be seen on the cliff faces at the site of the old Republic Gold Mine, near the Fairview Mine offices and roasting stack, and south of the Belfast Mine (Figure 2, B5, B6). The lineations in this region may represent cleavage-bedding intersections and might be unrelated to the lineations produced in, and adjacent to, the Kaap Valley Granite.

A combined plot of lineated granites, schists, and elongated pebbles is provided in Figure 6A. The points fall on a great circle coinciding with the schistosity, foliation, and bedding along the western edge of the Sheba Hills.

Northeast of Eureka Siding, well-developed lineations occur in the sheared quartz-sericite schists of the Onverwacht Group (Anhaeusser, 1964) and plunge to the west at angles varying between 20 and 70 degrees. Along the northern contact of the Eureka Syncline, between Noordkaap and the farm Lilydale 324 JU, the elongated pebbles of the Moodies basal conglomerate also produce a linear fabric. The pebbles, which have been flattened in the plane of the bedding, are elongated in the 'a' direction and plunge almost vertically throughout much of the area. These lineations plot on a great circle (Figure 6B) and have a wide spread, the latter possibly being indicative of deformation superimposed on an irregular surface. The great circle coincides with the axial plane cleavage, schistosity, and bedding, along the northern contact zone between the Consort Mine and Louw's Creek (Anhaeusser, 1964).

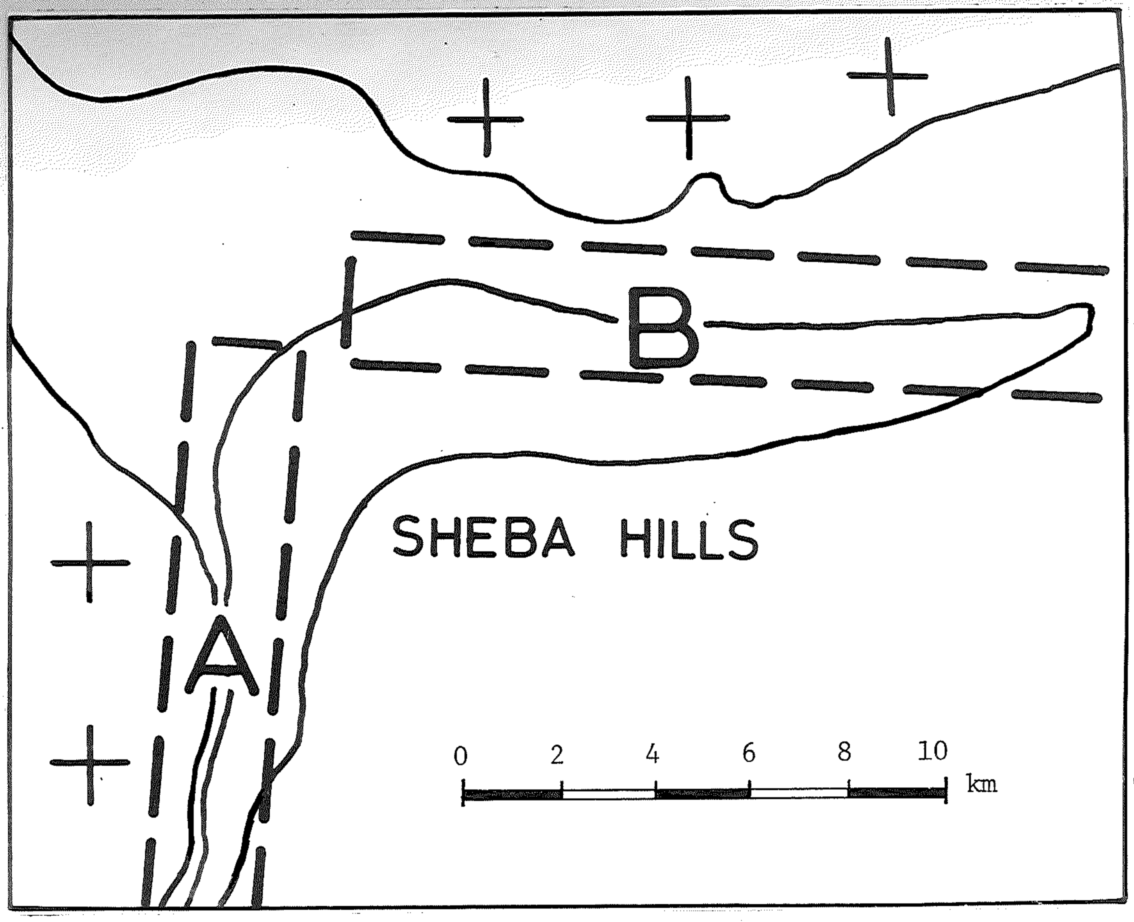
The stretch lineations, which can be traced in and adjacent to the Kaap Valley Granite, from the northwest-trending Jamestown Schist Belt (Anhaeusser, 1969a, 1972) into the north-south trending area flanking the Sheba Hills, were probably produced as a direct result of the emplacement of the diapiric granite pluton. The lineations that developed along the northern contact of the Eureka Syncline are considered to be associated with the intrusive border phase of the Nelspruit Granite.

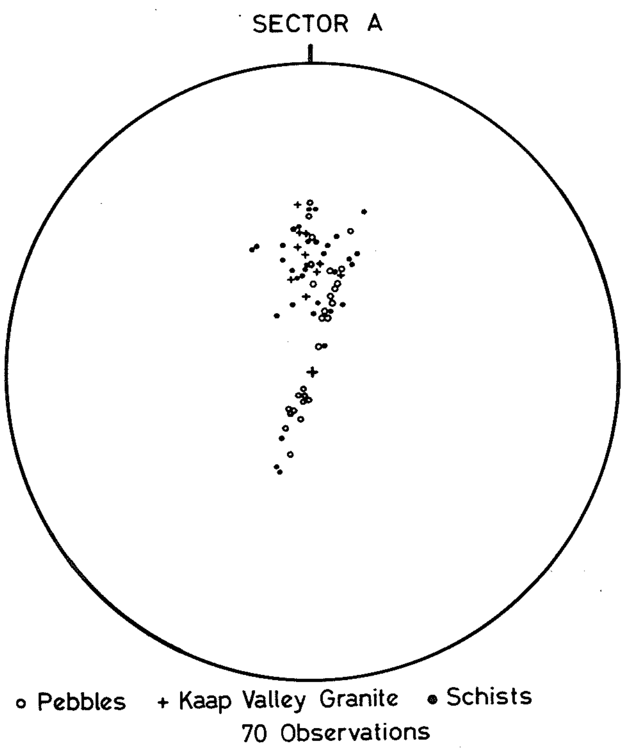
Minor Folds

A number of small-scale folds are developed in the Eureka Syncline, the attitudes of which are similar to those of the major folds developed in the area. Ramsay (1963) showed that the small-scale structures are not randomly orientated but are geometrically related to the large-scale structures. He demonstrated that a systematic analysis of minor structures was invaluable in deciphering the tectonic history of a complexly deformed fold-belt following his recognition of at least three deformations in the Sheba Hills, each of which led to the imprinting of both large- and small-scale structures in the area. Each successive deformation displays a set of minor structures characteristic of the particular structural event.

Minor folds in the Eureka Syncline vary in size from less than 1 cm, upwards to a metre or more, in amplitude. Some of the earliest folds are plotted in Figure 7, which also shows the Eureka Syncline subdivided, for convenience, into three sub-areas. In sub-area A, most of the minor folds plunge steeply to the southwest and south. The fold axes (spotted contours), although possessing a constant plunge direction (averaging about 218°) show a considerable variation in the angle of plunge from roughly 50° NE to 40° SW, with a few folds plunging at shallower angles in both directions. The fold axis maxima for the sub-area shows a plunge of about 65° to the south-southwest. In sub-area B, most of the minor folds plunge to the west or southwest, at angles varying between 20° and 75°. The third sub-area C, embraces the region on the inner arc of the Eureka Syncline. Here minor fold axes strike both east-west as well as west-southwest and the plunges of the folds range from horizontal to vertical.

LINEATIONS ON THE WESTERN AND NORTHERN FRINGE OF THE EUREKA SYNCLINE





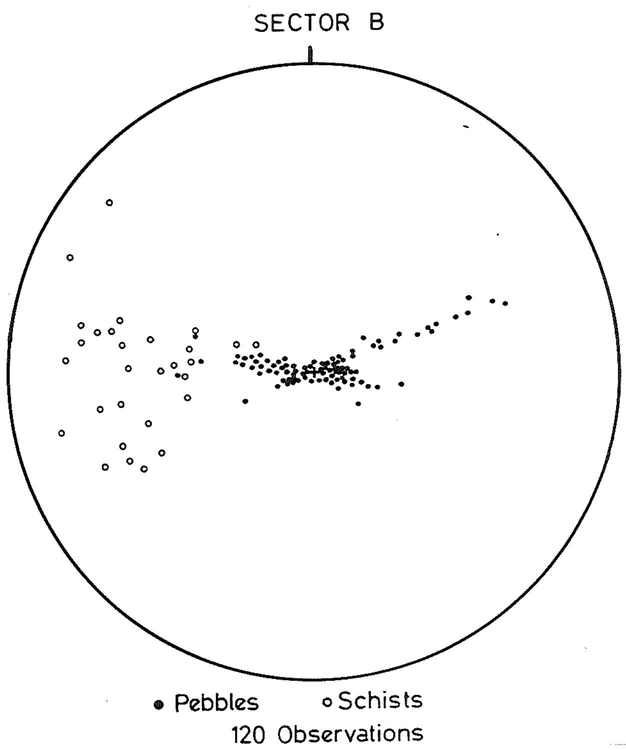


FIGURE 6 : Sector A : Plot of lineations developed in the Kaap Valley Granite, in the adjacent schists of the Onverwacht Group, and in the aligned pebbles of the basal conglomerate of the Moodies Group (Western limb of the Eureka Syncline).

Sector B : Plot of lineations developed in quartz-sericite schists of the Onverwacht Group and the preferred long axis alignment of Moodies basal conglomerate pebbles (Northern limb of the Eureka Syncline).

Note the strong correspondence of the linear fabric in all rock-types adjacent to the diapiric granite plutons.

MINOR FOLDS IN THE EUREKA SYNCLINE

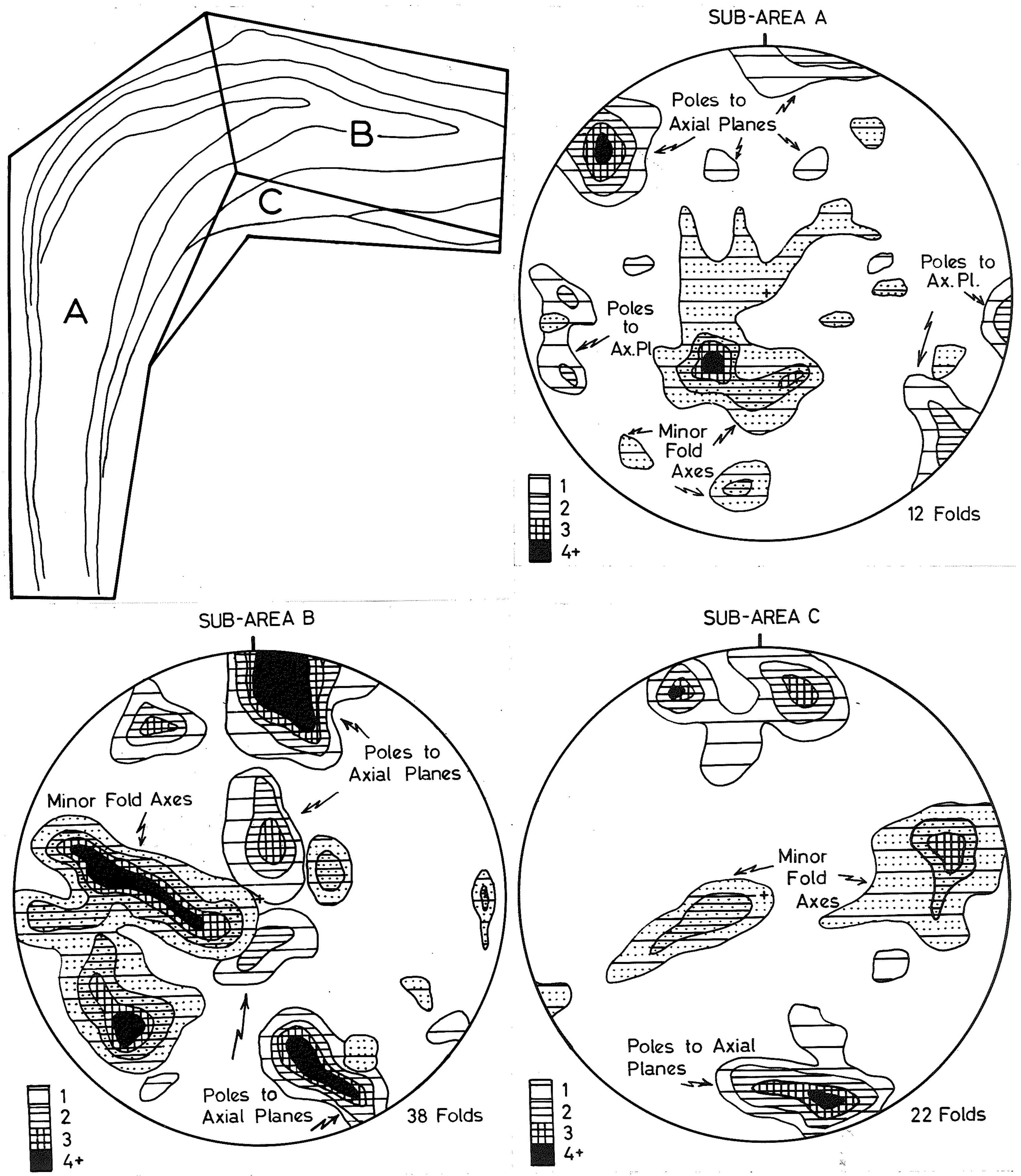


FIGURE 7 : Plot of 72 minor folds associated with the major Eureka fold structure. The minor folds indicate that the Eureka Syncline plunges to the west, southwest and south. Note the spread in the plunge of the minor fold axes. Some of the folds may represent a superimposed phase of deformation.

The data from the three sub-areas confirms Ramsay's (1963) contention that the Eureka Syncline plunges to the west, southwest, or south. Some of the irregularities, or data point scatter in Figure 7, may be due to folds produced by the cleavage deformational event (Ramsay's F2 structures). Ramsay (1963) found that the cleavage deformation had produced only a few major folds in the area, they being mostly small-scale structures. The relative paucity of folds associated with this deformation was considered by him to be due to the steep inclination of the strata before superimposition of the cleavage deformation.

The superimposition of the cleavage deformation on the earlier-formed folds produced complex interference structures similar to the small-scale basins and domes illustrated in Plate 6A and 6B. These structures develop where two fold trends intersect. Where anticlines cross earlier-formed anticlines, domes are developed, whereas intersecting synclines produce basin-like structures (Ramsay, 1962a).

The deformation resulting in the arcuation of the Eureka Syncline does not appear to have been accompanied by the development of any significant small-scale folding in the Sheba Hills area, although this period of deformation was responsible for the intense large- and small-scale folding described by Anhaeusser (1969a, 1972) in the New Consort Mine area, north of Noordkaap (Figure 1). The fold axis (F3 deformation) of the arcuate Eureka structure varies from place to place because a number of variably inclined surfaces on both limbs of the structure were involved in the fold deformation. Ramsay determined the orientation of the fold axes by plotting the poles to the bedding surfaces on a stereogram (the pi-diagram method). Similar procedures were undertaken by the writer using additional bedding plane data (see composite bedding plots, Figure 4). The results compared favourably with those obtained by Ramsay (1963).

The northern and western limb of the Eureka Syncline was found to have a fold axis plunging 70 degrees towards 141 degrees (Ramsay's finding 70 degrees towards 167 degrees), while the southern and eastern limbs were found to plunge 65 degrees on 150 degrees (Ramsay's findings 75 degrees towards 147 degrees). The folded slaty cleavage (Figure 5) has a fold axis plunging 70 degrees towards 143 degrees (Ramsay's findings 70 degrees towards 140 degrees).

Crenulation and Chevron Folds

Throughout the Eureka Syncline,as well as a great many other localities in the area north of Barberton, numerous minor structures are developed which are related to an almost vertical stress field. These folds are generally best developed in talc, chlorite, and sericite schists of the Onverwacht Group but occur in most formations present in the area. Small-scale flat lying crenulation folds (kink-band folds) occur in shales of the Baviaanskop Formation in cuttings along the Havelock road (Figure 2, 9A; Plate 5A). Folds similar to these are more commonly encountered in the quartz-sericite and quartz-chlorite-actinolite schists north of the Eureka Syncline and in the Jamestown Schist Belt (Viljoen, 1964; Anhaeusser, 1964, 1969a, 1972). The widespread distribution of these late folds is illustrated in a series of stereoplots of the minor folds found in the area north of Barberton. Figure 8A shows a plot of small-scale crenulation folds from the Havelock road area. The poles to axial planes all cluster near the centre of the diagram, indicating that the fold axial planes lie horizontally or slightly sub-horizontally. The stress field responsible for the generation of these folds must have been vertical or near vertical. In Figure 8A kink-band or crenulation folds from the area around Noordkaap show a similar relationship. Most of the minor folds in this area are developed in Onverwacht Group talc-chlorite schists (e.g. along the South Kaap River and in the railway cuttings north of Noordkaap, Figure 2, B1) or in brittle quartz-sericite schists (e.g. along the main road, east of Noordkaap, near the Woodstock Gold Mine, Figure 2, C1). Crenulation, accordion, and chevron folds, of a larger size, are developed in felspathic quartzites, east of Eureka City (Figure 2, E3; Plate 6C and D). The attitudes of these folds is shown in Figure 8C, and again illustrates the widespread distribution of the late flat folds. The writer (Anhaeusser, 1964) also reported crenulation folds with horizontal axial planes in the northeastern part of the Eureka Syncline and in the Lily Syncline, southwest of Louw's Creek. These observations are plotted in Figure 8D.

The flat folds represent the latest recognizable phase of deformation in the Barberton area and are often associated with conjugate folds. The crenulation folds deform all earlier structures. In some localities, three phases of deformation can be seen in one outcrop alone. This is the case, for example, in the talc-chlorite schist exposures along the South Kaap River, between Noordkaap and the low-level bridge to the Consort Gold Mine (Figure 2, B1). Here a

CRENULATION AND CHEVRON FOLDS IN THE AREA NORTH OF BARBERTON

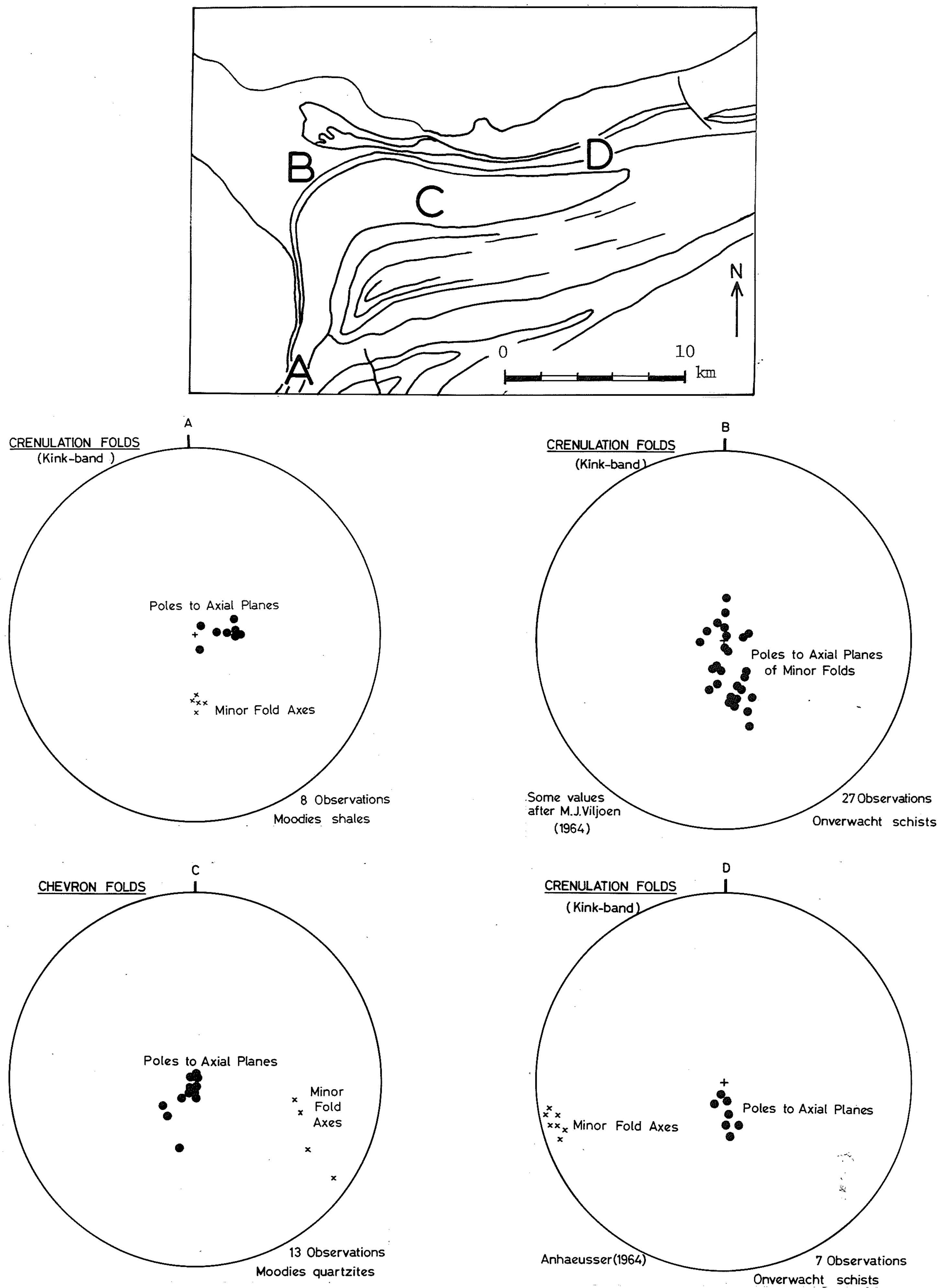


FIGURE 8 : Plot of late phase crenulation and chevron folds with near horizontal axial planes. Note the widespread distribution of this phase of deformation.

vertical lineation caused by micro-folding is superimposed on a strongly schistose surface. The vertical lineation is, in turn, folded about small-scale folds with flat axial planes.

Conjugate Folds

Commonly associated with the crenulation folds, described above, are conjugate folds. These structures consists of monoclinal folds which, when fully developed, are arranged in conjugate pairs. Ramsay (1962b) described a method whereby the principal axes of stress may be calculated as the result of failure of rock on two inclined shear surfaces. Using this method, a number of conjugate folds were measured and their three principal axes of stress were determined. These results are shown in Figure 9, and, from the key-map, it can be seen that, as with the crenulation folds, the conjugate folds are developed over a large area embracing much of the region to the north and northeast of Barberton. In each of the localities A to F in Figure 9, conjugate folds were measured and the maximum, minimum, and intermediate stress axes were plotted on stereographic projections. A composite plot of 27 conjugate folds clearly demonstrates a uniformly vertical stress field throughout the area examined.

Conjugate shear-folds generally develop as a result of the deformation of brittle rocks. In the Eureka Syncline, they were found in finely bedded Baviaanskop shale bands along the Havelock road (Figure 2, 9A; Plate 7A) and in felspathic quartzites of the Clutha Formation east of Eureka City (Figure 2, E3; Plate 7B). Elsewhere they were more commonly encountered in quartz-sericite-schist units of the Onverwacht Group.

The origin of the flat folds and the conjugate folds is uncertain. Ramsay (1963) suggested that their development may have been synchronous with the formation of the arcuate structure of the Eureka fold (his F3 deformation). He added, however, that their origin was obscure and that they may be related to a fourth period of deformation. The later work by Anhaeusser (1964), Viljoen (1964) and Anhaeusser and Viljoen (1965), clearly demonstrated that these folds were, in fact, a separate deformational event. These authors suggested that the vertical stress field might have been caused by the emplacement of the younger granite plutons (e.g. M'pageni and similar plutons in Swaziland).

Cooke (in : Roering, 1965) found evidence of a vertical stress, in the area south and west of Barberton, which appears to be directly related to the major longitudinal faults. As the flat lying folds only occur close to the faults they could represent a type of second-order structure developed adjacent to the fault planes. Roering (1965) further suggested that the flat folds might represent second-order phenomena related to the rising up of the Nelspruit Granite late in the tectonic history of the area.

Because the crenulation and conjugate folds are developed throughout a large area of the Barberton Mountain Land, and because the orientation of these structures is so consistent it is suspected that they were produced by a tectonic event of a regional nature. Many of the minor folds occur in close proximity to major regional faults and it is possible, therefore, that some interplay between granite emplacement and reactivation along the major fault planes in the Barberton greenstone belt may have occurred at a late stage in the tectonic history of the area.

Faults

The Eureka Syncline is bounded by two major longitudinal strike faults which were probably produced very early in the tectonic history of the Barberton Mountain Land. In the north, and extending from Louw's Creek westwards towards Noordkaap, is the Lily Fault, described by Anhaeusser (1964). Near the Woodstock Mine, the Woodstock "Bar" represents a silicified fault plane that appears to merge with the Lily Fault east of Joe's Luck Siding (Figure 2, D1). The Lily Fault follows the outer arc of the Eureka fold, passes close to the Clutha Gold Mine, and extends southwards, parallel to the western limb of the Eureka Syncline. The fault zone is not exposed in this area but probably continues further south and may link up with the Moodies Fault in the area southwest of Barberton (Anhaeusser, 1969a).

On the inner arc of the Eureka Syncline the Sheba Fault can be traced from the Royal Sheba Gold Mine westwards through the Sheba and Fairview mine areas and southwards towards Barberton. Generally the Sheba Fault is clearly definable, but locally, as for example near the Oratava Gold Mine (Figure 2, C7), the fault zone is of great complexity. In the Cheval de Course Mine area a

CONJUGATE FOLDS IN THE AREA NORTH OF BARBERTON

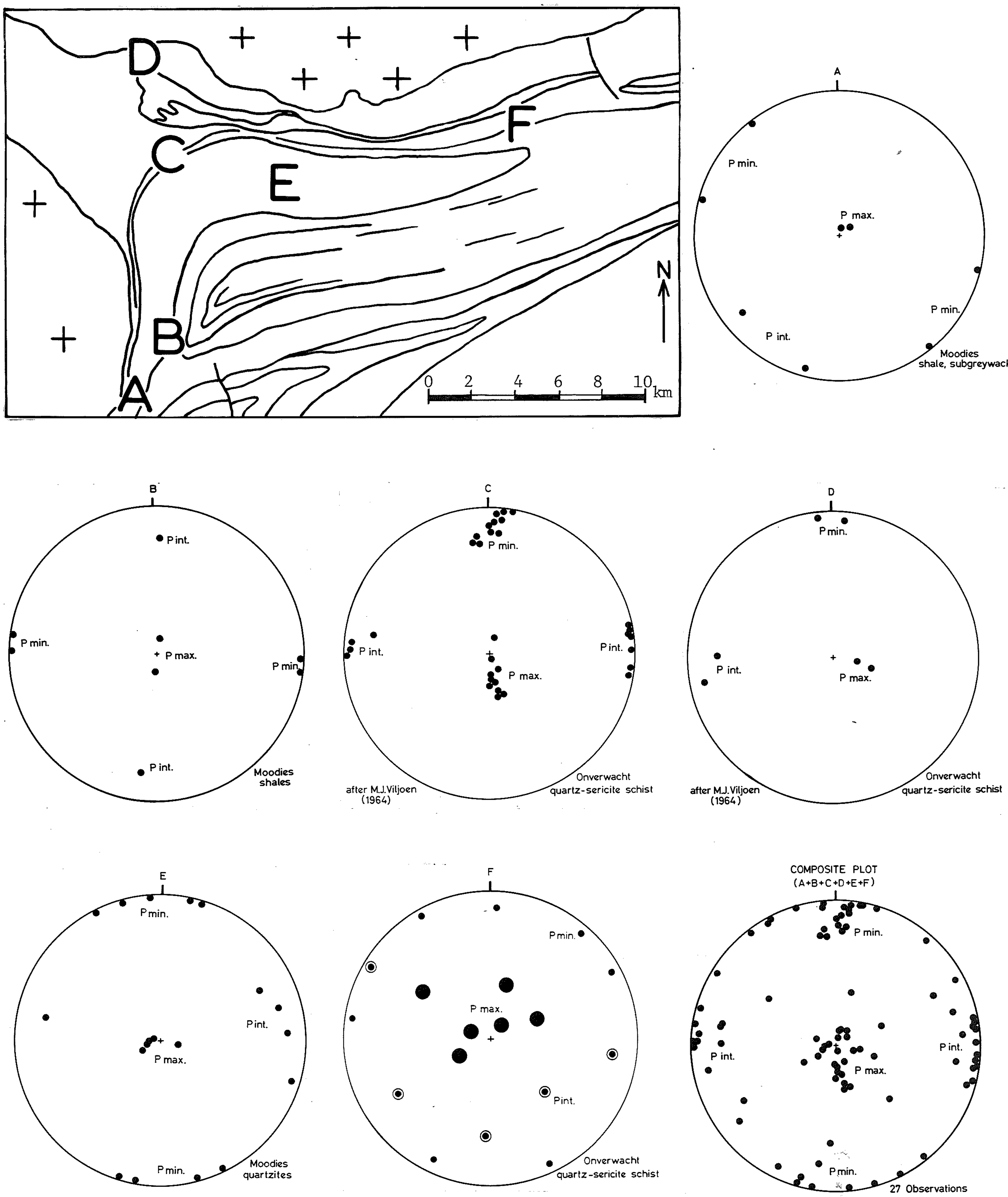


FIGURE 9 : Stress field calculated from conjugate folds developed in various rock-types of the Swaziland Sequence on the northwest flank of the Barberton Mountain Land. This late phase of deformation is developed over a large area.

large slab of Moodies quartzites, shales, and jaspilites is surrounded by, and strongly folded with, serpentinites, talc-carbonate schists, and dolomitic rocks of the Onverwacht Group. The main fault appears to have splayed into a number of separate dislocations and the areas seems to be a zone of fault imbrication.

From the Golden Quarry Gold Mine (Figure 2, E4) westwards to the Fairview Mine (Figure 2, D4) the Sheba Fault outcrops prominently as a white siliceous cherty "Bar". Situated in the footwall of this fault are several small gold mines. The Sheba Bar consists, in places, of a mylonitized and silicified fault breccia, ranging from a few metres to approximately 60 m in width. The silicified zone frequently consists of a honeycombed network of quartz veins and stringers (Plate 7C), but the fault trace may also be marked by massive black chert.

Both the Lily Fault and the Sheba Fault were folded at the same time as the inflection of the Eureka Syncline, and both faults generally dip steeply to the south, southeast, or east. However, in the core of the inner arc of the Eureka fold, the Sheba Fault dips less steeply than the Moodies and Fig Tree sediments in the area. An average value of dip of the Sheba "Bar" in this area is approximately 50-55 degrees towards the Ulundi Syncline.

The Ulundi and Eureka synclines are structurally juxtaposed and it would appear that the Sheba Fault has acted not only as an F1 longitudinal fault but has undergone several stages of reactivation. It is speculated that during the diapiric emplacement of the Kaap Valley Granite the Barbrook Fault (Figure 1) acted as a major plane of dislocation (décollement), on the northern side of which the inflection of the Ulundi and Eureka synclines took place. As the folding (F3) intensified the Ulundi Syncline appears to have been thrust from the southeast, onto the south and east dipping limbs of the Eureka Syncline. It is, however, possible that the Ulundi Syncline may have been juxtaposed to the Eureka Syncline during the F1 deformation as the faulting and isoclinal folding subdivided the Mountain Land into a series of structural compartments or domains.

A number of other faults, fractures, and shear zones occur in the Eureka Syncline. The majority of these structures were produced when inflection or arcuation of the Eureka fold took place. Most of the faults produced by this deformational event are tension fractures, generally developed at right angles to the strike of the formations. The faults and fractures are particularly well-developed in the hard, competent quartzite horizons where they occur as quartz-filled tension gashes varying from a millimetre upwards to about a metre or more in width. In some of the fractures quartz can be seen growing at right angles to the strike of the fracture plane and clearly crystallized under tensional conditions.

The dips of the fault or fracture planes cannot always be measured on surface but many of the quartz reefs contain economic quantities of gold and mining has revealed that these fractures are invariably steeply dipping, many of them being vertically inclined. The strike directions of all the faults is readily determinable in the field. To illustrate their attitude throughout the Eureka Syncline, 146 faults, fractures, and concentric shears were plotted in a statistical rose frequency diagram (Figure 10). The key-map shows the Eureka Syncline divided into three sectors. All faults and fractures occurring in ten degree sectors of the compass circle were counted, and a radial line was drawn representing them in the median bearing of each sector. The length of the radial line was determined by a scale of concentric circles. In sectors A, B, and C in Figure 10, the scale was drawn having two faults per circle. In the composite plot of the three sectors five faults per circle are depicted.

In sector A, the 33 faults measured gave variable strike directions. The slight north-south concentration of faults are represented in the field by fractures parallel to the strike of the bedding and may have been early faults associated with the deformation that produced the longitudinal strike faults in the area, or, they may be the products of intraformational dislocation generated at the time of arcuation of the Eureka Syncline. The remaining faults occur at right angles to the strike and are generally to be found in the area adjacent to sector B, where maximum arcuation of the fold takes place.

In sector B, 68 faults are plotted and illustrate a dominant NW-SE or NNW-SSE trend (145°-165°) corresponding approximately to the fold axial plane of the arcuate structure of the Eureka Syncline. A second, less prominent, strike direction is orientated in a WSW-ESE direction (105°). Most of the faults in sector B are tension faults. In sector C, 45 faults are plotted. One set of fractures has a preferred orientation striking NNW-SSE (165°) while two other fault maxima occur, the one trending NNE-SSW (30°), and the other trending approximately east-west (90°). The east-west striking faults in sector C occur mostly on the southern limb of the Eureka Syncline,

FAULT ROSE DIAGRAMS OF THE EUREKA SYNCLINE

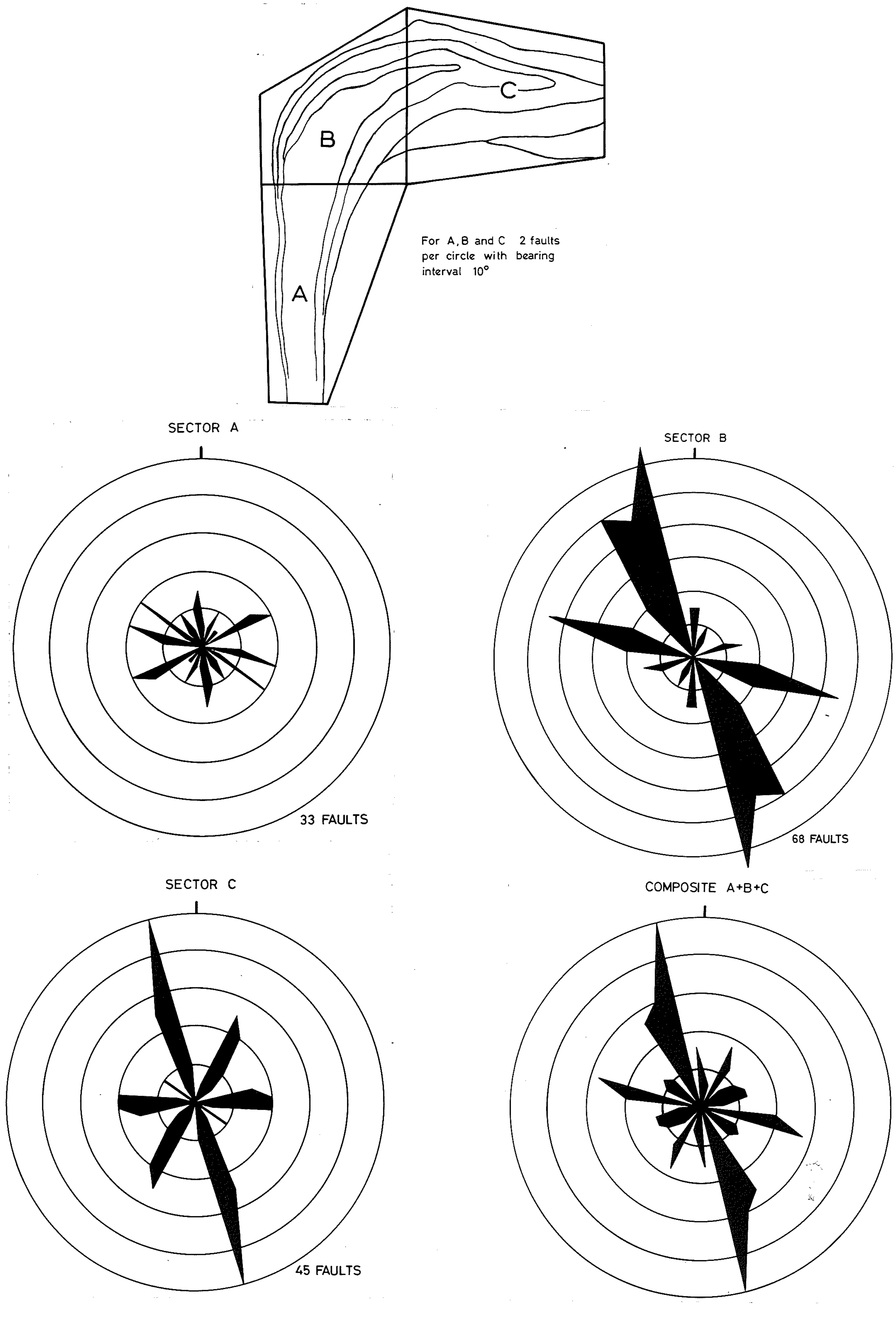


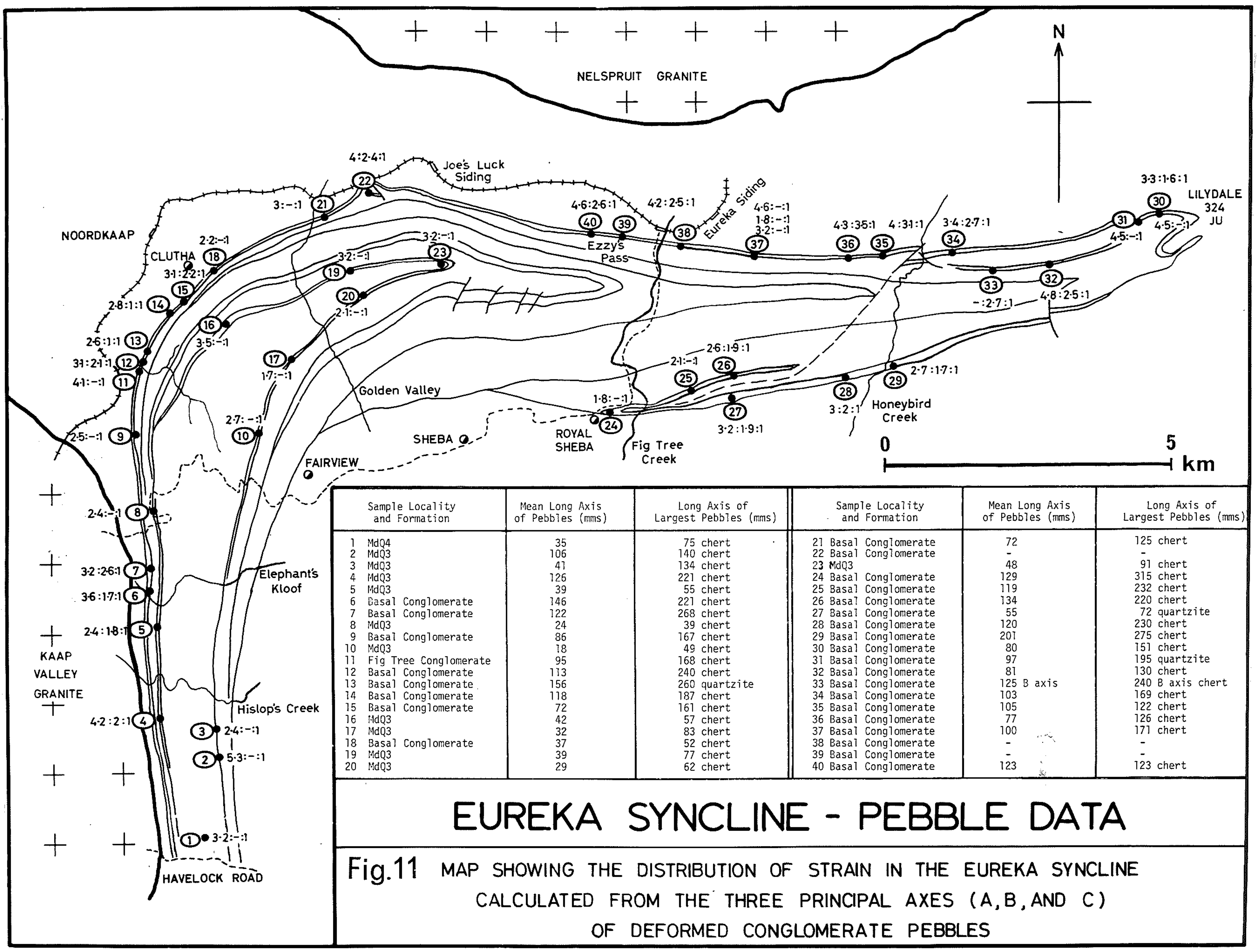
FIGURE 10 : Frequency-diagram showing strike directions of 146 faults, fractures and concentric shears in the three sectors A, B and C of the Eureka Syncline. The composite fault rose has bearing intervals of 10 degrees, with 5 faults per circle.

particularly in the core of the structure, where numerous concentric shears and fractures conform with the arcuate shape of the Eureka fold structure and the Sheba Fault. These faults are the result of compression on the inner arc of the Eureka Syncline during its inflection.

PEBBLE DATA FROM MOODIES CONGLOMERATES

Deformed pebbles from the Moodies conglomerates in the Barberton Mountain Land have been used to calculate the total finite strains experienced by the pebbles at a number of localities (Anhaeusser, 1964, 1969a, b; Gay, 1969; Ramsay, 1963; Viljoen, 1964). As part of an earlier study, the writer (Anhaeusser, 1969b) compared pebble and fold deformations along the northern edge of the Barberton greenstone belt. Pebbles of Moodies basal conglomerate from two localities, the one in the Lily Syncline and the other from the Eureka Syncline, were found to have been shortened and flattened by approximately 61 per cent. In a neighbouring area the combined shortening and flattening of isoclinal folds found in Fig Tree sediments of the Lily Gold Mine (Figure 1) was found to be 63 per cent.

During the mapping of the Eureka Syncline, numerous additional exposures of conglomerates were studied and data was collected relating to the size, shape, and orientation of the constituent pebbles. Most of the pebble data was obtained from the basal conglomerate unit (MdB), but some measurements were also made on pebbles from the Baviaanskop quartzite unit (MdQ3). A total of 40 sample localities were studied throughout the Eureka Syncline, the positions of which are plotted in Figure 11. At each station, the dimensions of the three principal axes of ten



Sample Locality and Formation	Mean Long Axis of Pebbles (mms)	Long Axis of Largest Pebbles (mms)	Sample Locality and Formation	Mean Long Axis of Pebbles (mms)	Long Axis of Largest Pebbles (mms)
1 MdQ4	35	75 chert	21 Basal Conglomerate	72	125 chert
2 MdQ3	106	140 chert	22 Basal Conglomerate	-	-
3 MdQ3	41	134 chert	23 MdQ3	48	91 chert
4 MdQ3	126	221 chert	24 Basal Conglomerate	129	315 chert
5 MdQ3	39	55 chert	25 Basal Conglomerate	119	232 chert
6 Basal Conglomerate	146	221 chert	26 Basal Conglomerate	134	220 chert
7 Basal Conglomerate	122	268 chert	27 Basal Conglomerate	55	72 quartzite
8 MdQ3	24	39 chert	28 Basal Conglomerate	120	230 chert
9 Basal Conglomerate	86	167 chert	29 Basal Conglomerate	201	275 chert
10 MdQ3	18	49 chert	30 Basal Conglomerate	80	151 chert
11 Fig Tree Conglomerate	95	168 chert	31 Basal Conglomerate	97	195 quartzite
12 Basal Conglomerate	113	240 chert	32 Basal Conglomerate	81	130 chert
13 Basal Conglomerate	156	260 quartzite	33 Basal Conglomerate	125 B axis	240 B axis chert
14 Basal Conglomerate	118	187 chert	34 Basal Conglomerate	103	169 chert
15 Basal Conglomerate	72	161 chert	35 Basal Conglomerate	105	122 chert
16 MdQ3	42	57 chert	36 Basal Conglomerate	77	126 chert
17 MdQ3	32	83 chert	37 Basal Conglomerate	100	171 chert
18 Basal Conglomerate	37	52 chert	38 Basal Conglomerate	-	-
19 MdQ3	39	77 chert	39 Basal Conglomerate	-	-
20 MdQ3	29	62 chert	40 Basal Conglomerate	123	123 chert

EUREKA SYNCLINE - PEBBLE DATA

Fig.11 MAP SHOWING THE DISTRIBUTION OF STRAIN IN THE EUREKA SYNCLINE CALCULATED FROM THE THREE PRINCIPAL AXES (A, B, AND C) OF DEFORMED CONGLOMERATE PEBBLES

pebbles were measured. In addition, the dimensions of the largest pebble occurring at each station was recorded. In many cases it was possible to extract the pebbles from the weathered conglomerates, but in some instances, where the pebbles were tightly cemented in the rocks, only two axes could be measured.

In Figure 11, the ratios of the three principal axes of the pebbles, measured at each locality, are plotted adjacent to the station locality. In most cases, only the ratios for the chert pebbles were calculated. At sample locality 37, near Eureka Siding, the long and the short axes of chert, granite, and quartzite pebbles are listed.

At a number of localities all three pebble axes could be measured. The percentage deformation suffered by the conglomerate pebbles is illustrated in Table 9.

TABLE 9

PERCENTAGE DEFORMATION OF THE THREE PRINCIPAL AXES (A, B AND C) OF CONGLOMERATE PEBBLES IN THE EUREKA SYNCLINE

Station Number and Locality in Figure 11	Long Axis (A)	Intermediate Axis (B)	Short Axis (C)
4. Hislop's Creek area	62	-4	-36
6. Elephant's Kloof area	51	-9	-26
12. Clutha Siding	30	10	-30
13. Clutha Siding area	35	-24	-3
15. Clutha Gold Mine	43	10	-29
22. Joe's Luck Siding area	47	11	-39
26. Royal Sheba Gold Mine area	19	9	-23
27. Royal Sheba Gold Mine area	26	2	-28
28. Honeybird Creek area	29	7	-23
29. Honeybird Creek area	32	0	-21
30. Lilydale 324 JU	48	-10	-25
32. Honeybird Creek area	64	7	-43
35. Honeybird Creek area	67	31	-44
38. Ezzy's Pass - Eureka 39. Siding area	49	12	-40

Note : Positive values represent the percentage elongation of the pebble axis while negative values indicate the percentage decrease of the pebble axis.

The main conclusions that can be drawn from the pebble deformation data are as follows : (i) Pebbles along the outer arc of the Eureka Syncline (northern and western limbs) are more deformed than those on the inner arc of the structure (southern limb). (ii) The greatest amount of elongation in the A axis of the pebbles can be found in conglomerates immediately opposite or adjacent to the Kaap Valley Granite contact in the west and the Nelspruit Granite in the north. This is strong evidence to suggest that the pebbles were not flattened solely by the slaty cleavage deformation but were influenced by the emplacement of the granite diapirs. Investigations undertaken by Gay (1969) support this view. A strain ellipsoid determined by him at a site near station 7 (Figure 11) approximates to a pure shear type. The amount of strain, being greater at this locality than elsewhere in the Eureka Syncline, led him to conclude, furthermore, that the rocks in this area had experienced an additional phase of deformation. (iii) Pebble deformation in places along the southern limb of the Eureka Syncline (between Fig Tree Creek and Honeybird Creek) is low and compares favourably with the relatively undeformed Moodies conglomerates found in the interior regions of the Barberton Mountain Land.

From the pebble data an attempt was made to ascertain the direction from which the material comprising the basal conglomerates was derived. In Figure 11, the mean long axis of the 10 pebbles measured at each sample locality is listed in one column, while the long axis of the largest pebble, also from each locality, is listed in another column. In general, the mean long axis measurements of the pebbles, from the area around the outer arc of the Eureka Syncline, are either equal to, or less than, the mean long axis dimensions of the pebbles along the southern limb of the Eureka Syncline between Fig Tree Creek and Honeybird Creek. Furthermore, the long axis measurements of the largest pebbles from the southern limb are generally equal to, or greater than, the long axis measurements of the pebbles from the outer arc of the fold. It has already been demonstrated that the pebbles around the outer arc of the fold have suffered the greatest degree of flattening, yet the elongated pebbles from these areas do not yield long axis measurements exceeding those of the pebbles from the relatively undeformed areas. Thus it appears that, despite the superimposition of the tectonic overprint, some indication of the original dimensions of the conglomerate pebbles can be arrived at.

Bearing in mind the limitations of sampling, and the density of observations,the data available suggests that the material comprising the Moodies basal conglomerate entered the basin of deposition mainly from the southeast or east-southeast. However, it would seem that sediments were also being derived from the northern and northwestern regions because the conglomerates developed along the outer arc of the Eureka Syncline appear to contain more granitic and quartz and felspar porphyry pebbles than do the conglomerates from the southern limb. This is, however, a purely subjective appraisal, there being no available quantitative modal data reflecting the relative distribution of the various components of the conglomerates in the Eureka Syncline.

6. GOLD MINERALIZATION IN THE SHEBA HILLS AREA

HISTORICAL

The discovery of gold in the De Kaap Valley led to the founding, in 1884, of the town of Barberton which grew within a short time from a small camp with only a few tents, to a large town (Plate 9A and B). As news of the goldfield spread, people hastened to the scene and started one of the most spectacular gold-rushes in South African history. Hundreds of reefs were found and worked, companies were formed with lavish capital, and minor discoveries were magnified beyond all reality. The first stock exchange in the Transvaal was erected in the town (Plate 9D) coinciding with the feverish activity in the district.

Following the initial gold discoveries in the Jamestown Schist Belt, and in the Moodies Hills area, southwest of Barberton, the next, and probably most important, event took place in the Sheba Hills to the northeast of the town. In the Sheba Valley one of the earliest gold discoveries was the Nil Desperandum Reef, located by Keiller, at the head of Sheba Creek (Mathers, 1887). The discovery of the Sheba Reef by Edwin Bray in May, 1885, eventually led to the opening up of the fabulously rich ore body known as the Golden Quarry, an event which heralded a resurgence of interest and activity that was to culminate in the establishment of Eureka City.

The Sheba Gold Mining Company was formed in 1886 to work the Golden Quarry ore body. The first mill was a 10 stamp stream battery on Fever Creek (in Sheba Valley) capable of crushing 12 to 14 tons of ore per day. Later a 20 stamp mill was installed but the water supply was insufficient and most of the milling was carried out along Fig Tree Creek at Charlestown, which was situated between the Royal Sheba Mine and the old Sheba cemetery (Figure 2, H4), and which was the site of the crushing plants for the mines further up Sheba Valley. Charlestown's existence was short-lived, for, as the tonnage of ore for the mills increased, so the water supplies became inadequate. The batteries were moved down to the Kaap River at Avoca (Figure 2, H2), and Charlestown became another ghost town.

An aerial cable-way was constructed in 1887 which ran from Fever Creek, over the mountains of the Eureka Syncline, to a point near Ezzy's Pass (Figure 2, G2), where some of the ore was milled. The cable-way, in turn, was superseded by a tramway (Plate 9F) conceived by Lewis and Sammy Marks. The tramline ran from Sheba Valley, down Fig Tree Creek, to Sheba Siding near the Kaap River.

From March, 1891, 60 stamps were in operation along the Kaap River near Sheba Siding (Bayley, 1894). Later 120 stamps were working, driven by steam and electricity, the latter generated by a hydroelectric plant on the south bank of the Kaap River. The settlement of Avoca, built to house the workers at the batteries, flourished for about six years, from 1887 to 1892. Thereafter, the companies started moving their recovery plants back to their properties in the Sheba Valley.

Situated near Charlestown was Brays Golden Quarry battery (20 stamps), the Capetown battery, the Sheba 10 stamp battery and the Nil Desperandum 10 stamp battery. North of the old Sheba cemetery on the west bank of Fig Tree Creek was situated Rau's Mill which he later sold to Golden Quarry Deep Level Company. Near Avoca, at the junction of Fig Tree Creek and the Kaap River, were Pechey's battery and the Oriental battery. The Pearl Central Milling Company was situated on the south bank of the Kaap River, somewhere near to the present Scotia Talc Mine (Figure 2, H1).

In December, 1885, J. Sherwood founded Eureka City (Plate 9C). The position of the "city", high on the Sheba Hills, afforded the inhabitants protection from the dreaded malarial fever so rampant in the lower lying areas. The settlement began with the establishment of a butchery and a hotel, known initially as the Queen of Sheba Hotel, but which was later renamed the Central Hotel. There were soon 12 canteens, 3 hotels, a chemist shop, a police post, a bakery, and a music hall. In addition, there existed a three furlong race-course. Mathers (1887) estimated the population of Eureka City to be between 600 and 700 people, most of them being engaged in mining activities in the Sheba Valley approximately one kilometre to the south.

The old, in places, deeply incised wagon tracks from Barberton to Eureka City can still be seen today crossing the Eureka Syncline. The 19 km journey, taking up to two and a half hours to cover on horseback, reportedly passed as many as 27 canteens along the way.

Apart from the activities in the Sheba Valley there was considerable interest displayed in the area where now is situated the Fairview Mine. Prospecting was centred about the workings of the Kidson, Blue Rock, and Equifa reefs, as well as the Victory Hills reefs. Several stamp mills were located along the headwaters of the stream running northwards into the Golden Valley. In this valley too, there was much activity, and many were the names of properties listed by Mathers (1887), that were receiving attention but which never amounted to anything.

In time, the flurry of activity died down and all but a few mines survived. The settlement at Eureka City eventually faltered and another ghost town resulted. Only a few ruins remain to be seen today. Restoration of the old ghost town has recently been undertaken by members of the Barberton and Districts Publicity Association.

Practically all the mines in the Sheba Valley were eventually acquired by Eastern Transvaal Consolidated Mines Limited, Barberton, in 1937. In 1953, this company also took over the Golden Quarry and, at present, all the mines in the Sheba Valley are referred to collectively as the Sheba Mines. Plate 8, A and B, compares an early photograph of the mining installations in Sheba Valley, with the view down the same valley today. All that remains are a few houses, the old treated dumps, and the gaping cavity of Edwin Bray's Golden Quarry on the southern slopes of the Eureka Syncline.

An aerial ropeway was constructed by E.T.C. Mines (Ltd.) to transport ore from the Sheba workings to the mill at the New Consort Gold Mine near Noordkaap. This haulage had one angle station sited just north of the trigonometrical beacon Bar 11, on the Sheba Hills (Figure 2, D4), and extended from there in a northwesterly direction, across the Eureka Syncline, to the Consort Mine, a distance of about 10 km. This aerial cableway was later dismantled and all the milling was undertaken at the Sheba Mine - only the concentrates being sent by road to the Consort Mine for final treatment.

The Fairview Gold Mine, as is the case with all the large gold producers in the Barberton Mountain Land, constitutes an amalgamation of a number of small properties, the names of which include the Little Kent, Kimberley-Sheba, Blue Rock, Kidson, Drummond, and Equifa workings. In 1912 Transvaal Consolidated Lands and Exploration Co. Ltd., worked the small properties until 1917, when Fairview was taken over by a company known as F.D.M. Ltd. In 1936, the property was worked by one of Barberton's pioneers, Mr. E.T.E. Andrews, and partners. They disposed of the property in 1941 to Barberton Mines (Pty.) Ltd. In 1955, Fairview Mine was acquired by Federale Mynbou Beperk. Considerable modifications and additions were made to the installations and a major development programme was instituted. The Fairview Mine is today the most modernly equipped gold producer in the Barberton area. The mine has recently become the largest single gold producer in South Africa outside the Witwatersrand and Orange Free State Goldfields.

GOLD MINERALIZATION IN THE EUREKA SYNCLINE

Although a large number of gold workings occur in the Eureka Syncline only a few of them are at present being mined. All the reefs currently exploited form sections of either the Fairview or the Sheba gold mines, and occur on the inner arc of the Eureka fold. The localities of most of the more significant mines are plotted on the geological map of the Sheba Hills (Figure 2) and all the available gold production data from circa 1882 to 1972, together with map localities, are listed in Table 10. The known mineral deposits in the Eureka Syncline owe their origin to structural control with faulting, in particular, playing the dominant role in determining the locations of the ore bodies. In an earlier section dealing with faults it was shown that a great number of tension fractures radiate about the arcuate fold structure. It is in most of these tension fractures that gold-quartz veins have been exploited in the past.

Also in the Eureka Syncline are numerous fractures that are orientated approximately parallel to the Sheba Fault. These occur mainly on the southern and eastern limbs of the Eureka fold, particularly in the core of the structure between the Fairview and Sheba groups of mines. The origin of these fractures is considered to be due to concentric shearing, the latter resulting from strike-slip movements between the folded stratigraphic units. The concentric shear surfaces, coupled with over-thrust movements from the southeast, provided suitable structures that were subsequently infiltrated by hydrothermal mineralizing solutions containing gold and vein quartz, with only small amounts of sulphide generally present (mainly pyrite and/or arsenopyrite).

Most mineralized deposits in the Eureka Syncline occur in the hard, competent, quartzitic units, where faulting and fracturing is best developed. Mining operations in the Fairview Mine have shown that fractures, strongly developed in the quartzites, also penetrate the surrounding shales but that these are almost invariably hairline breaks occupied, only sometimes, by thin quartz stringers, the latter being generally barren of gold or poorly mineralized (van Rensburg, personal communication, 1969).

Mineralized Occurrences on the Outer Arc of the Structure

Only a few mines are located around the outer arc of the Eureka Syncline, the largest being the Clutha Gold Mine southeast of Noordkaap. The mine consists of four separate workings. The main fractures in the Central Section of the mine are bedding plane shears in slaty quartzites (MdQl). In addition, numerous oblique shear fractures are well-mineralized. These fractures generally make acute angles of 30°-45° with the main bedding shears (Strauss, 1948). The movement direction of the shears may have had a vertical component, but it is clear, from drag and displacement of other fractures and dykes, that horizontal movement was the most important. The bedding plane shear locally referred to as the "clay seam" extends throughout the length of the mine in a NE-SW direction and dips steeply to the southeast. Oblique fractures diverging from this parent shear generally localized gold at the intersection of the fractures. The intersection of the two fracture planes produced linear ore-shoots in which quartz, gold, and arsenopyrite, occur together. Away from the fracture intersections mineralization rapidly dies out.

The Belfast and Republic gold mines occur near the Fairview Mine offices (Figure 2, B5 and B6), in shear zones parallel to the bedding in the Baviaanskop quartzite unit, whereas south of Joe's Luck Siding the Thistle Gold Mine is located at the contact between the calcareous and felspathic quartzites of the Clutha Formation.

All the mines located around the outer arc of the Eureka Syncline, including also the Woodstock, Victoria, and Mazeppa workings, are situated in close proximity to the Lily Fault.

TABLE 10

MINE LOCALITIES, AND GOLD AND SILVER PRODUCTION DATA FROM 29 DEPOSITS IN THE EUREKA SYNCLINE FOR THE PERIOD 1882 - 1972

Mine	Locality (Farm or Lot)	Map Locality (Figure 2)	Tonnage Milled	Gold (Kilograms)	Silver (Kilograms)
Agatha	Lot 156 Sect. A (K.B.)*	G4†	-	16,9	-
Annies Fortune	Lot 139 Sect. A (K.B.)	E4	-	22,7	-
Belfast	Bickenhall 346 JU	B5	2 479	580,4	4,3
Benoni Venture (Victory Hill)	Lots 136 and 137 Sect. A (K.B.)	C4	21 125	150,9	16,1
Blue Rock (Fairview)	Lot 138 Sect. A (K.B.)	C5	-	13,1	-
Bonanza	Lots 158, 162 and 166 Sect. A (K.B.)	G3	79 080	1 000,9	6,7
Cerisola Block	Lot 131 Sect. A (K.B.)	B2†	45	0,59	-
Cheval de Course	Dycedale 368 JU	B8	5 109	24,3	3,0
Clutha	Lot 131 Sect. A (K.B.)	B2	146 072	1 518,1	57,5
Golden Quarry	Lot 139 Sect. A (K.B.)	E4	241 027	2 586,6	180,6
Golden Vein	Lot 135 Sect. A (K.B.)	D2†	82	3,0	-
Great She	Lot 156 Sect. A (K.B.)	G4	5	3,4	-
Hislop's Reef	Bickenhall 346 JU	B7†	23	0,51	-
International	Hayward 310 JU	B3†	91	9,9	-
Joe's Luck and Thomas	Lot 156 Sect. A (K.B.)	E3	46 675	1 282,1	5,4
Kidson	Lot 138 Sect. A (K.B.)	C5	5 357	86,3	4,6
Lochiel	Lot 166 Sect. A (K.B.)	G4	2 677	9,3	0,71
Margaret	Lot 139 Sect. A (K.B.)	E3	13 853	79,2	4,0
Mazeppa	Bramber East 314 JU	A4	925	4,3	0,31
Mysidora	Dycedale 368 JU	B8†	1 916	9,9	-
New Callao and Trojan	Lot 137 Sect. A (K.B.)	D3†	63	5,1	-
New Clever (Clutha)	Lot 131 Sect. A (K.B.)	B2	28 783	481,6	-
New Primrose	Lot 139 Sect. A (K.B.)	E4†	140 483	2 521,8	-
North Star	Bickenhall 346 JU	C7	9 311	58,8	6,9
Oriental	Lot 139 Sect. A (K.B.)	E4	4 517	308,2	-
Pandora	Lot 136 Sect. A (K.B.)	C4†	68	0,17	-
Rose Reef	Bickenhall 346 JU	C6	29	0,23	0,03
Thistle	Camelot 320 JU	F2	2 890	20,9	0,45
Victory Hill	Lots 136, 137, Sect. A (K.B.)	C4	44 862	463,4	45,3
TOTAL			797 547	11 263,5	335,9

* K.B. = Kaap Block. For Lot localities refer to published 1:50 000 geological map of the Barberton area (Visser et al., 1956).

† exact field location uncertain.

Mineralized Occurrences on the Inner Arc of the Structure

Most of the remaining mines in the Eureka Syncline occur on the southern or eastern limbs of the structure and become progressively more important, in terms of production, as the Sheba Fault is approached. No notable gold mineralization has ever been located in the Baviaanskop quartzite unit. However, the Joe's Luck quartzite unit has supported some small-scale mining operations in the past. From south to north these include the North Star, Rose Reef, Victory Hill, Thomas, and Joe's Luck gold mines. In the quartzite units of the Clutha Formation, between the Fairview Mine and Fig Tree Creek, there are a great number of scattered workings. In this area some of the more important mines include the Golden Quarry, Bonanza, Lochiel, Great She, and Margaret, some of which are still being mined on a small-scale as sections of the Sheba Mine. In addition, a great number of tension fractures are, or have been, worked as sections of the Fairview Mine. Of the last-mentioned group, the Kimberley-Sheba, Strydom, Blue Rock, Kidson, Little Kent, and Equifa reefs, to name but a few, all occur in the massive quartzites adjacent to the Sheba Fault.

The Golden Quarry, one of the fabled discoveries of the early gold rush days, occurs adjacent to the Sheba Fault and was mined in later years as part of the Sheba Mine. The production figures listed in Table 10 do not, therefore, reflect the full amount of gold recovered from this deposit. In the Golden Quarry area numerous workings are to be found. Some of the main deposits include the Nil Desperandum, Oriental, Annie's Fortune, Mamba, Margaret, Tit Bits, Eureka, King Solomon's Mines, and Agatha workings. The region where these mines occur has suffered, possibly, the greatest degree of structural disturbance in the entire Eureka Syncline. The Sheba Fault was responsible for the disruption of the successions early in the history of the area. Subsequently, during the arcuation of the Eureka Syncline, the inner arc was subjected to intense compression as well as thrusting from the southeast, as arcuation and overriding of the Ulundi Syncline progressed. The Sheba Fault subsequently underwent several phases of reactivation, there being evidence of thrust and wrench faulting in addition to the numerous second-order structures that can be ascribed to the parent dislocation (Anhaeusser, 1965).

Some distance from the Sheba Fault, yet presumably still influenced by it, is the Bonanza Gold Mine. The geology of the mine, which occurs along a shear zone that parallels the strike of the Clutha Formation quartzites for several kilometres, has been described by van Vuuren (1960), and Voges (1961). Considerable structural disturbance occurs between two, steeply dipping, parallel longitudinal faults that are linked by second-order flat fractures. The mineralization, which consists essentially of quartz, gold, arsenopyrite, and pyrite, occurs in and adjacent to the fractures. A similar shear zone, to the southeast of the Bonanza workings, marks the location of the Lochiel Gold Mine.

In the Eureka Syncline, east of Fig Tree Creek, there are no known occurrences where gold has been mined, despite the numerous prospect shafts and trenches that occur throughout the entire region.

GOLD MINERALIZATION IN THE ULUNDI SYNCLINE

A comparison of the gold production data from the Sheba Hills (Tables 10 and 11) clearly shows that most of the mineralization recovered so far has come from the Ulundi Syncline. In particular, the Sheba and Fairview mines, between them, have produced over one-third of all the gold recovered from the entire Barberton greenstone belt.

These two mines which are located symmetrically about the F3 fold axis of the Eureka and Ulundi synclines (Anhaeusser, 1965), virtually merge into one another in the faulted, fractured, and isoclinally folded Onverwacht (Zwartkoppie) and Fig Tree successions developed in the Ulundi Syncline, southeast of the Sheba Fault. A number of studies have been carried out in and around these mines (Anhaeusser, 1965, 1969a; Gay, 1968; Gribnitz et al., 1961; Gribnitz, 1964; Hearn, 1943; Koen, 1947; Ramsay, 1963; Steyn, 1965; van Vuuren, 1964) and the reader is referred to these publications for further details.

A number of smaller mines and prospects occur scattered throughout the Ulundi structure, the production figures of some of which have been listed in Table 11. However, a few mines are known for which there are no available gold production records. These mines have been omitted from the table. Among them are the Hottentot Gold Mine (Figure 2, C7) and the Waggon Road Gold Mine (Figure 2, D6).

TABLE 11

MINE LOCALITIES, AND GOLD AND SILVER PRODUCTION DATA FROM 13 DEPOSITS IN THE ULUNDI SYNCLINE FOR THE PERIOD 1882 - 1970

Mine	Locality (Farm or Lot)	Map Locality (Figure 2)	Tonnage Milled	Gold (Kilograms)	Silver (Kilograms)
Alfström	Lot 119 Sect. A (K.B.)*	C8	6 447	6,23	0,80
Day Dawn	Lot 123 Sect. A (K.B.)	C6†	-	0,34	-
Fairview	Lots 123 and 138 Sect. A (K.B.) and Bickenhall 346 JU	D5	1 483 859Ψ	21 698,40	550,40
George and May	Dycedale 368 JU	B9†	22 096	253,42	-
Grieve (Fairview)	Lot 138 Sect. A (K.B.)	D5†	5	0,65	0,04
May	Dycedale 368 JU	B9	28 427	171,67	8,67
New Birthday (Sheba)	Lots 139 and 140 Sect. A (K.B.)	D4	-	42,30	-
Oratava	Bickenhall 346 JU	C7	8 499	99,81	1,15
Orion	Lots 139, 157, Sect. A (K.B.)	E4†	86 744	1 331,53	-
Royal Sheba	Lots 156, 157 and 169, Sect. A (K.B.)	G4	1 335 363	458,17	51,19
Sheba	Lots 137-140 and 157 Sect. A (K.B.)	E4	3 683 575	51 176,80	1 258,50
Sheba Maid	Lots 139 and 157, Sect. A (K.B.)	F4†	115 999	613,00	61,54
Ulundi	Lots 153, 141, Sect. A (K.B.)	E5	27 311	202,77	5,54
TOTAL			6 798 325	76 055,09	1 937,83

* K.B. = Kaap Block. For Lot localities refer to published 1:50 000 geological map of the Barberton area (Visser et al., 1956).

† exact field location uncertain.

Ψ excludes tonnages for period 1968-1970.

Although most of the mineralization, in its present setting, is clearly hydrothermal in character (since it occurs in fracture networks parallel to and cross-cutting the strata) some of the gold and sulphides may have been introduced contemporaneously with the enclosing rocks. Such a syngenetic origin warrants further investigation particularly in view of the presence of the stratiform Sulphide Band recorded by van Vuuren (1964) and discussed earlier. The position of much of the gold and sulphide mineralization in, or near to, the siliceous, cherty, zones of the Zwartkoppie Formation suggests that some of the mineralization may be genetically associated with the volcanism considered to be responsible for the development of this stratigraphic assemblage.

SUMMARY AND CONCLUSIONS

1. The Sheba Hills area offers some of the best exposures of Fig Tree and Moodies sediments in the Barberton Mountain Land and provides an obvious starting point for any future studies that would

entail detailed sedimentological investigations of the Archaean sediments in the Barberton greenstone belt.

2. Preliminary observations indicate that conditions of sedimentation varied considerably from Fig Tree to Moodies times. The gross depositional style of the Fig Tree Group suggests that the sediments were deposited in relatively deep water by turbidity action. By contrast, the Moodies sediments show evidence of having been deposited in shallower water with sedimentational conditions ranging from fluvial (responsible for the deposition of the conglomerates and coarse sediments) to fluvio-deltaic (responsible for the arenaceous units that grade into the argillaceous units). Some of the sediments, particularly the argillaceous units, may be representatives of deltaic or shallow marine situations.

3. The gross sedimentational pattern of the Moodies Group in the Eureka Syncline is one of transgression, with cyclical, upward fining, assemblages present in all three formations (Clutha, Joe's Luck and Baviaanskop formations) as well as in the Bickenhall Member, which terminates the stratigraphic succession in the area.

4. The Barberton greenstone belt underwent an initial regional tectonic event which produced major NE-SW striking folds and faults (F1 deformation). During this event the Eureka and Ulundi synclines were formed and were separated from the Lily Syncline in the north and the Saddleback Syncline in the south by the Lily and Barbrook/Saddleback faults respectively. The Sheba Fault separated the Eureka Syncline from the Ulundi Syncline.

5. The diapiric emplacement of the Kaap Valley Granite, in particular, was responsible for most of the subsequent phases of deformation recorded in the Sheba Hills region (deformations F2 - F4). The Nelspruit Granite body, between Kaapmuiden and the New Consort Gold Mine, may also represent a diapirically emplaced, dome-like, body, the latter embayed into the northern margin of the Barberton greenstone belt. This body appears to have influenced the structural evolution of the northern margin of the Sheba Hills.

6. The Eureka and Ulundi synclines were refolded about a NW-SE trending fold axis (F3 deformation). This event followed the emplacement of the Kaap Valley Granite diapir, the latter being responsible for the conversion of the Barbrook Fault into a zone of detachment (décollement). Inflection of the successions north of the detachment zone was accompanied by the thrusting, to the northwest, of both the Eureka and Ulundi synclines. The Eureka Syncline was forced onto Onverwacht rocks in the eastern portion of the Jamestown Schist Belt, while the Ulundi Syncline was thrust against the inner arc of the Eureka Syncline thereby bringing into juxtaposition rocks of the Fig Tree and Moodies groups.

7. The main tectonic elements and strain indicators resulting from the emplacement of the diapiric granite plutons in the areas flanking the Sheba Hills are illustrated schematically in Figure 12.

8. Gold mineralization in the Sheba Hills is largely structurally controlled, the mines being located in or adjacent to faults, fractures, or fissures, in a wide variety of host rocks. Most of the gold, in its present form and setting, is hydrothermal in character. The origin of the gold remains uncertain but it is considered likely that it migrated to its present environment principally from source rocks of volcanogenic or fumarolic exhalative origin. Most of the gold is considered to have been derived from the Onverwacht Group lavas but indications are available suggesting that gold may also have been introduced during the deposition of the banded chert and iron formation units of the Fig Tree assemblage.

9. The possible stratiform origin of much of the gold mineralization requires further investigation. Potential exists for the establishment of large tonnage, low grade, gold deposits in banded iron formations and other, volcanogenically derived (exhalative), sedimentary rocks in Archaean greenstone belts.

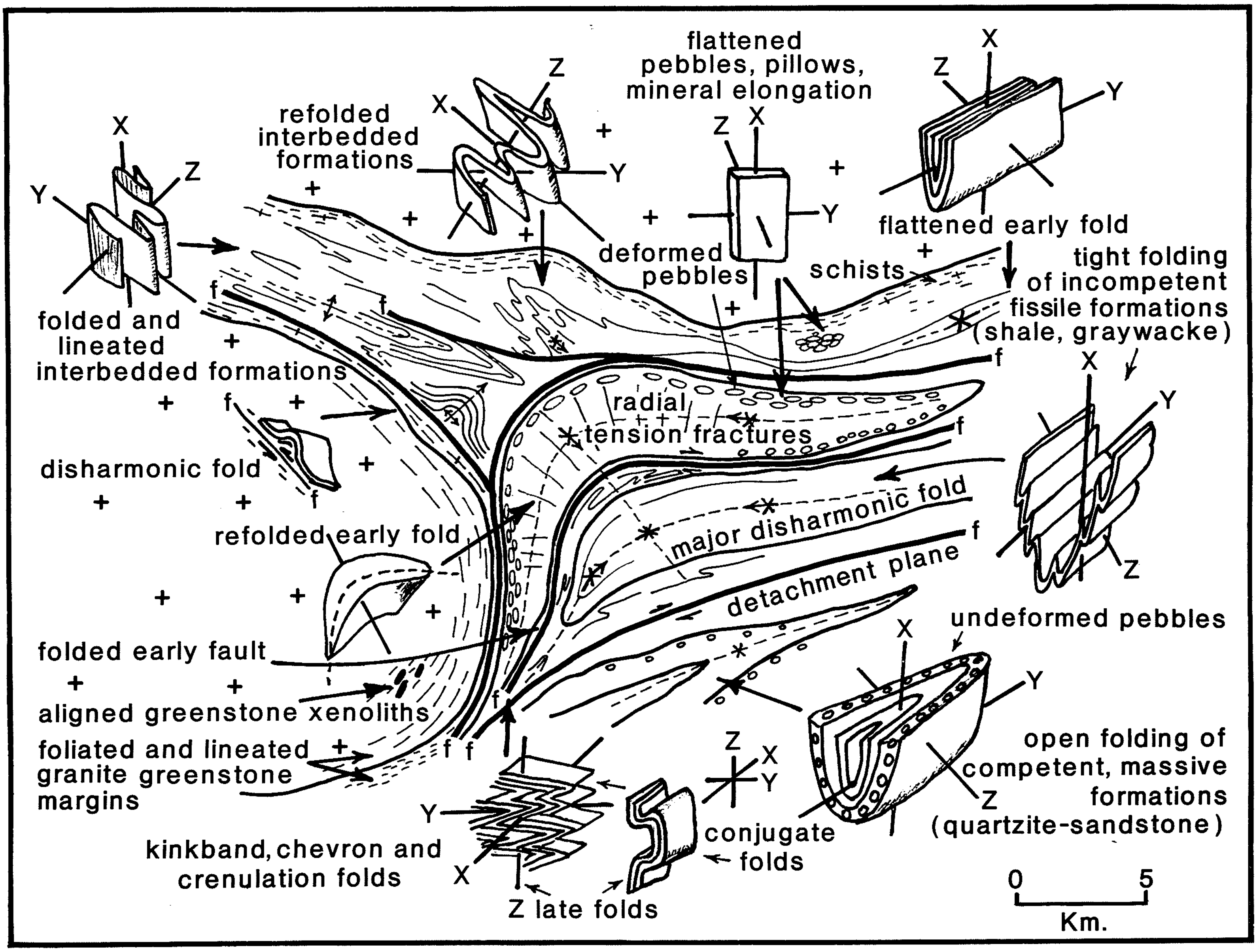


Figure 12 : Schematic diagram illustrating the main tectonic elements and strain indicators on the northwest flank of the Barberton greenstone belt (after Anhaeusser, 1973b).

8. REFERENCES

Allsopp, H.L., Ulrych, J.J. and Nicolaysen, L.O., 1968. Dating some significant events in the history of the Swaziland System by the Rb-Sr method. Can. J. Earth Sci., 5 : 605-619.

Anhaeusser, C.R., 1964. The geology of the Lily Syncline and portion of the Eureka Syncline between Sheba Siding and Louw's Creek Station, Barberton Mountain Land. Unpub. M.Sc. thesis, Univ. Witwatersrand, Johannesburg.

Anhaeusser, C.R., 1965. Wrench faulting and its relationship to gold mineralization in the Barberton Mountain Land. Inform. Circ. No. 24, Econ. Geol. Res. Unit, Univ. Witwatersrand, Johannesburg, 20 pp.

Anhaeusser, C.R., 1966. Facets of the granitic assemblage on the northwest flank of the Barberton Mountain Land. Inform. Circ. No. 32, Econ. Geol. Res. Unit, Unit. Witwatersrand, Johannesburg, 27 pp.

Anhaeusser, C.R., 1969a. The stratigraphy, structure, and gold mineralization of the Jamestown and Sheba Hills areas of the Barberton Mountain Land. Unpub. Ph.D. thesis, Univ. Witwatersrand, Johannesburg, 332 pp.

Anhaeusser, C.R., 1969b. A comparison of pebble and fold deformations in the Nelspruit granite contact aureole, Barberton Mountain Land. Trans. geol. Soc. S. Afr., 72 : 49-60.

Anhaeusser, C.R., 1972. The geology of the Jamestown Hills area of the Barberton Mountain Land, South Africa. Trans. geol. Soc. S. Afr., 75(3) : 225-263.

Anhaeusser, C.R., 1973a. The evolution of the early Precambrian crust of southern Africa. Phil. Trans. R. Soc. Lond. A. 273 : 359-388.

Anhaeusser, C.R., 1973b. Precambrian tectonic environments. Inform. Circ. No. 78, Econ. Geol. Res. Unit, Univ. Witwatersrand, Johannesburg, 19 pp. also : Ann. Rev. Earth Planet. Sci., 3 (in press).

Anhaeusser, C.R. and Viljoen, M.J., 1963. Discussion on paper by J.G. Ramsay entitled : *Structural investigations in the Barberton Mountain Land, Eastern Transvaal.* Trans. geol. Soc. S. Afr., 66 : 399-401.

Anhaeusser, C.R. and Viljoen, M.J., 1965. The base of the Swaziland System in the Barberton-Noordkaap-Louw's Creek area, Barberton Mountain Land. Inform. Circ. No. 25, Econ. Geol. Res. Unit, Univ. Witwatersrand, Johannesburg, 32 pp.

Anhaeusser, C.R., Viljoen, M.J. and Viljoen, R.P., 1966. A correlation of pre-Fig Tree rocks in the northern and southern parts of the Barberton Mountain Land. Inform. Circ. No. 31, Econ. Geol. Res. Unit, Univ. Witwatersrand, Johannesburg, 22 pp.

Anhaeusser, C.R., Roering, C., Viljoen, M.J. and Viljoen, R.P., 1968. The Barberton Mountain Land : a model of the elements and evolution of an Archaean fold belt. Annex. Trans. geol. Soc. S. Afr., 71 : 225-253.

Anhaeusser, C.R., Mason, R., Viljoen, M.J. and Viljoen, R.P., 1969. A reappraisal of some aspects of Precambrian shield geology. Bull. geol. Soc. Amer., 80 : 2175-2200.

Bayley, A.W., 1894. The De Kaap annual yearbook of local information. A.W. Bayley and Co., Barberton.

Bursill, C., Luyt, J.F.M. and Urie, J.G., 1964. The Bomvu Ridge iron ore deposit. in: S.H. Haughton (Ed.), *The geology of some ore deposits in southern Africa.*, Geol. Soc. S. Afr., 2(4) : 405-414.

Condie, K.C., Macke, J.E. and Reimer, T.O., 1970. Petrology and geochemistry of early Precambrian greywackes from the Fig Tree Group, South Africa. Bull. geol. Soc. Amer., 81 : 2759-2776.

De Gasparis, A.A.A., 1967. Rb-Sr isotopic studies relating to problems of geochronology on the Nelspruit and Mpageni granites. Unpub. M.Sc. thesis, Univ. Witwatersrand, Johannesburg.

Gay, N.C., 1968. The composition of gold from the Barberton Mountain Land. Trans. geol. Soc. S. Afr., 71(3) : 273-290.

Gay, N.C., 1969. The analysis of strain in the Barberton Mountain Land, eastern Transvaal, using deformed pebbles. J. Geol., 77(4) : 377-396.

Gribnitz, K.H., 1964. Notes on the Barberton gold field. in: S.H. Haughton (Ed.), *The geology of some ore deposits in southern Africa.*, Geol. Soc. S. Afr., 2(1) : 77-90.

Gribnitz, K.H., Poole, E.J. and Voges, S., 1961. Geological notes on the Swaziland System. Unpub. Rep. Geol. Dept., E.T.C. Mines Ltd., Barberton.

Gross, G.A., 1965. Geology of iron deposits in Canada : Vol. 1. General geology and evaluation of iron deposits. Geol. Surv. Canada, Econ. Geol. Rep. 22, 181 pp.

Hall, A.L., 1918. The geology of the Barberton gold mining district. Mem. geol. Surv. S. Afr., 9 : 347 pp.

Hearn, M.G., 1943. A study of the working properties of the chief gold producer of the Barberton district, eastern Transvaal. Unpub. D.Sc. thesis, Univ. Witwatersrand, Johannesburg.

Hunter, D.R., 1970. The Ancient Gneiss Complex in Swaziland. Trans. geol. Soc. S. Afr., 73 : 107-150.

Koen, G.M., 1947. Die geologie in die omgewing van Sheba, Barbertonse distrik. Unpub. M.Sc. thesis, Univ. Pretoria.

Kuenen, Ph. H., 1963. Turbidites in South Africa. Trans. geol. Soc. S. Afr., 66 : 191-195.

Mathers, E.P., 1887. *Golden South Africa*. Whittingham and Co., London.

Oosthuyzen, E.J., 1970. The geochronology of a suite of rocks from the granitic terrain surrounding the Barberton Mountain Land. Unpub. Ph.D. thesis, Univ. Witwatersrand, Johannesburg.

Ramsay, J.G., 1962a. Interference patterns produced by the superposition of folds of similar type. J. Geol., 70 : 466-481.

Ramsay, J.G., 1962b. The geometry of conjugate fold systems. Inform. Circ. No. 6, Econ. Geol. Res. Unit, Univ. Witwatersrand, Johannesburg, 12 pp.

Ramsay, J.G., 1963. Structural investigations in the Barberton Mountain Land, eastern Transvaal. Trans. geol. Soc. S. Afr., 66 : 353-401.

Reimer, T.O., 1967. Die geologie der Stolzburg Synklinale, Barberton Bergland (Transvaal-Sud äfrika). Diplom-Arbeit, Goethe-Univ., Frankfurt, Germany.

Roering, C., 1965. The tectonics of the main gold producing area of the Barberton Mountain Land. Inform. Circ. No. 23, Econ. Geol. Res. Unit, Univ. Witwatersrand, Johannesburg, 23 pp.

Roering, C., 1967. Non-orogenic granites in the Archean geosyncline of the Barberton Mountain Land. Inform. Circ. No. 35, Econ. Geol. Res. Unit, Univ. Witwatersrand, Johannesburg, 13 pp.

South African Code of Stratigraphic Terminology and Nomenclature, 1971. Trans. geol. Soc. S. Afr., 74 : 111-131.

Steyn, M. v. R., 1965. Basal rocks of the Swaziland System in the Steynsdorp Valley and Fairview areas of the Barberton Mountain Land. Unpub. paper presented at the 8th Ann. Congr. of the Geol. Soc. S. Afr., Johannesburg, 37 pp.

Strauss, C.A., 1948. Geological report on the New Clutha group of gold mines, Barberton. Unpub. Rep. Geol. Surv. South Africa.

Turner, F.J. and Verhoogen, J., 1960. *Igneous and Metamorphic Petrology*. (2nd ed.). McGraw-Hill Book Company, Inc., New York, 694 pp.

van Eeden, O.R., 1941. Die geologie van die Shebarante en omstreke, distrik Barberton. Unpub. D.Sc. thesis, Univ. Stellenbosch.

van Eeden, O.R., 1972. The geology of the Republic of South Africa. An explanation of the 1:1 000 000 map, 1970 edition. Spec. Publ. Geol. Surv. S. Afr., 18, 85 pp.

van Eeden, O.R. and Marshall, C.G.A., 1965. The granitic rocks of the Barberton Mountain Land in the Transvaal. Unpub. paper presented at the 8th Ann. Congr. of the Geol. Soc. S. Afr., Johannesburg, 17 pp.

van Vuuren, C.J.J., 1960. Geological report on the Bonanza Gold Mine, Barberton district. Unpub. Rep. Geol. Surv. South Africa.

van Vuuren, C.J.J., 1964. The geology of portion of the Ulundi Syncline between Hislop's Creek and Fig Tree Creek, Barberton Mountain Land. Unpub. Rep. Econ. Geol. Res. Unit, Univ. Witwatersrand, Johannesburg, 133 pp.

Viljoen, M.J., 1964. The geology of the Lily Syncline and portion of the Eureka Syncline between the Consort Mine and Joe's Luck Siding, Barberton Mountain Land. Unpub. M.Sc. thesis, Univ. Witwatersrand, Johannesburg.

Viljoen, M.J. and Viljoen, R.P., 1967. A reassessment of the Onverwacht Series in the Komati River Valley. Inform. Circ. No. 36, Econ. Geol. Res. Unit, Univ. Witwatersrand, Johannesburg, 35 pp.

Viljoen, M.J. and Viljoen, R.P., 1969a. An introduction to the geology of the Barberton granite-greenstone terrain. Spec. Publ. Geol. Soc. S. Afr., 2 : 9-28.

Viljoen, R.P. and Viljoen, M.J., 1969b. The geological and geochemical significance of the upper formations of the Onverwacht Group. Spec. Publ. geol. Soc. S. Afr., 2 : 113-151.

Viljoen, M.J. and Viljoen, R.P., 1969c. A proposed new classification of the granitic rocks of the Barberton region. Spec. Publ. geol. Soc. S. Afr., 2 : 153-180.

Viljoen, M.J. and Viljoen, R.P., 1969d. The geochemical evolution of the granitic rocks of the Barberton region. Spec. Publ. geol. Soc. S. Afr., 2 : 189-218.

Viljoen, R.P. and Viljoen, M.J., 1971. The geological and geochemical evolution of the Onverwacht volcanic group of the Barberton Mountain Land, South Africa. Spec. Publ. geol. Soc. Aust., 3 : 133-149.

Visser, D.J.L. (compiler), 1956. The geology of the Barberton area. Spec. Publ. geol. Surv. S. Afr., 15 : 253 pp.

Voges, S., 1961. Report on the Bonanza Mine. Unpub. Rep. Geol. Dept. E.T.C. Mines Ltd., Barberton.

* *

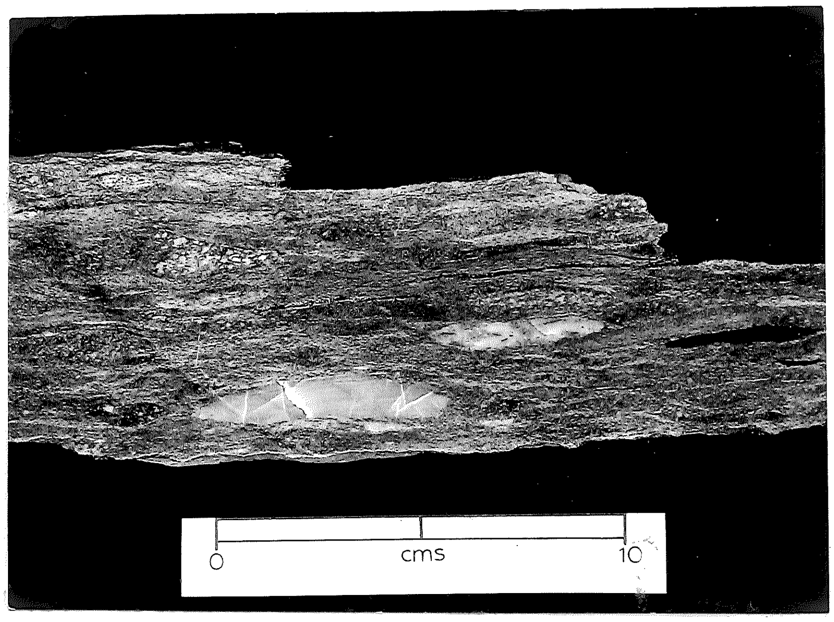
PLATE 1

A

A. Aerial photographic compilation (1966) of portion of the Eureka and Ulundi Synclines situated northeast of Barberton. For detailed geology of this area see Figure 2.

B

C



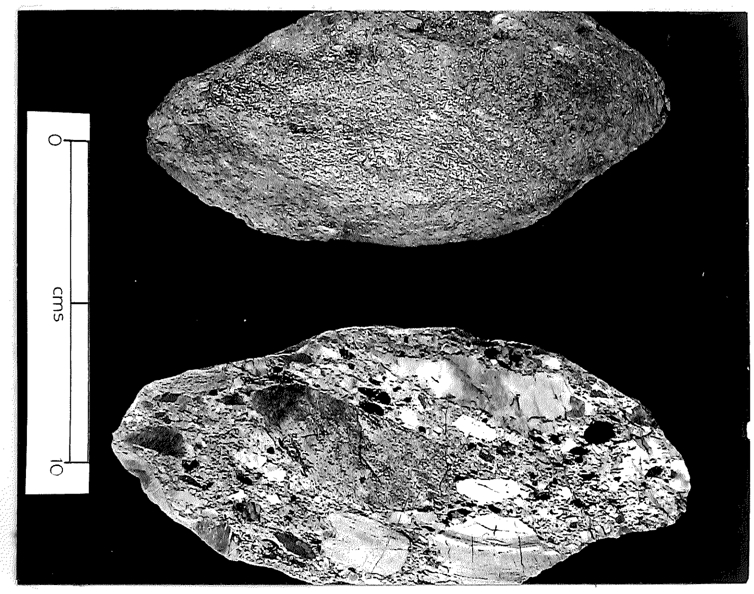
B. Felspathic tuff-agglomerate horizon of the Fig Tree Group conformably underlying Moodies Group basal conglomerates near the New Clutha Gold Mine.

C. Specimen of deformed Fig Tree Group tuffaceous greywacke conglomerate found conformably underlying Moodies Group basal conglomerates near Eureka Siding. Pebbles consist of black and white chert and felspathic greywackes (tuffs and pyroclasts).

PLATE 2

A

B



A. Undeformed remnant of Fig Tree Group volcanogenic (pyroclastic) fragments occurring below the Moodies Group sediments on the farm Hayward 310 JU, near Clutha Siding.

B. Specimen of a pebble of conglomerate from the Moodies basal conglomerate on the southern limb of the Eureka Syncline near the Royal Sheba Gold Mine. The pebble consists mainly of chert fragments, some of which are desilicified and porcellanous.

C

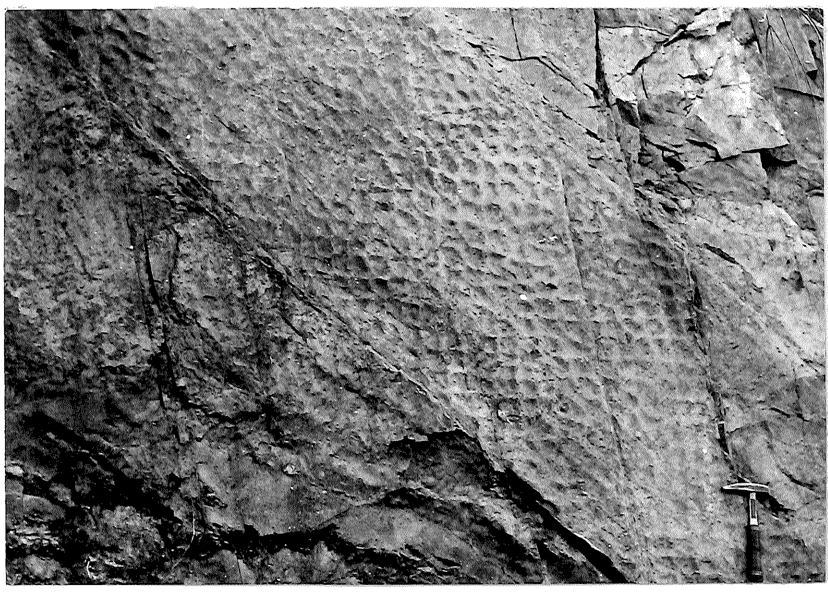
D

C. Rounded pebbles of quartz and felspar porphyry (centre) and quartzite (upper right) in calcareous quartzites immediately above the Moodies basal conglomerate near the Thistle Gold Mine, Joe's Luck Siding area.

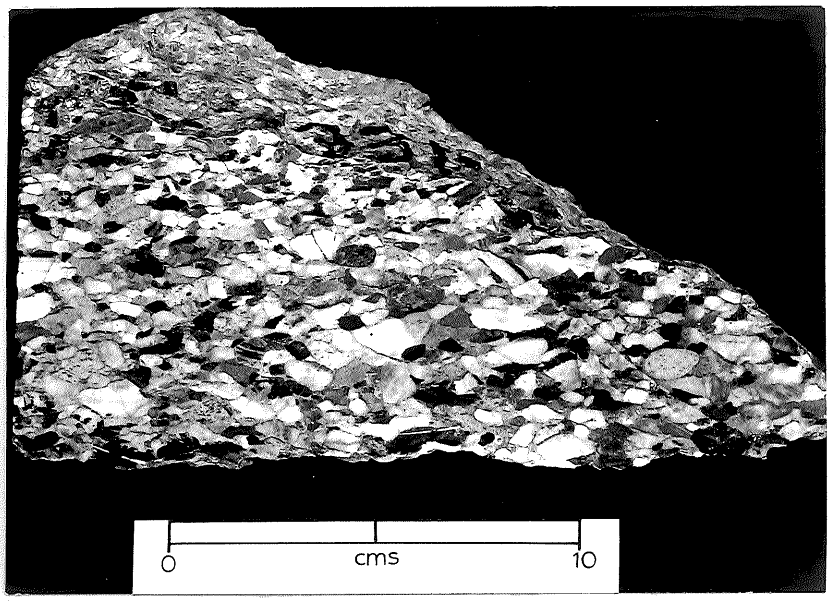
D. Trough cross-bedding in Moodies Group felspathic quartzites exposed in Hollebrand's Pass, Fig Tree Creek. Cross-bedded foresets are accentuated by carbonaceous layers. Way up directions difficult to determine probably because of tectonic flattening of the formations.

PLATE 3

A



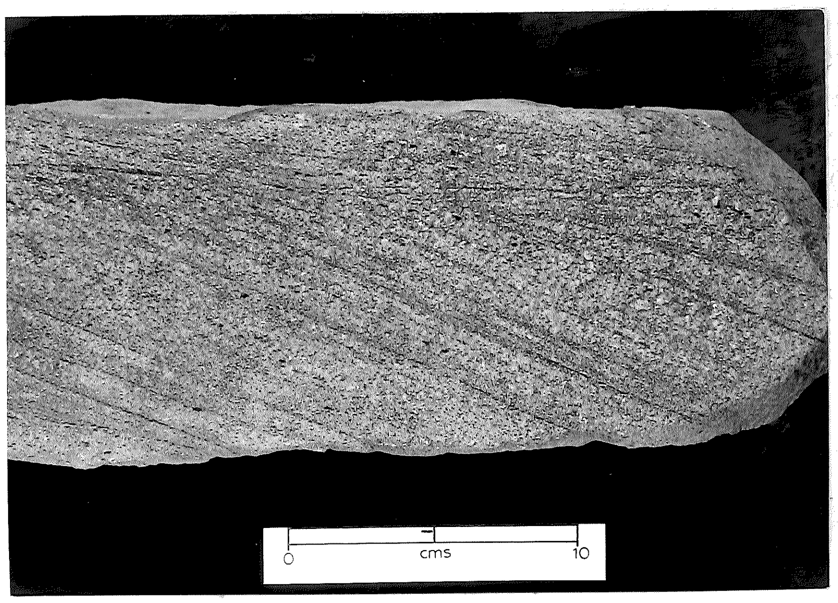
B



A. Interference or cross-ripples in Moodies Group carbonaceous quartzites exposed in Hollebrand's Pass, Fig Tree Creek. Polygonal or rectangular ripple patterns of this type commonly occur in shallow water where deflections of the wave patterns are most prevalent.

B. Specimen of consolidated gravel occurring as a lens in quartzites of the Joe's Luck Formation near the Joe's Luck Gold Mine. There is a remarkable absence of matrix sands between the gravel particles.

C



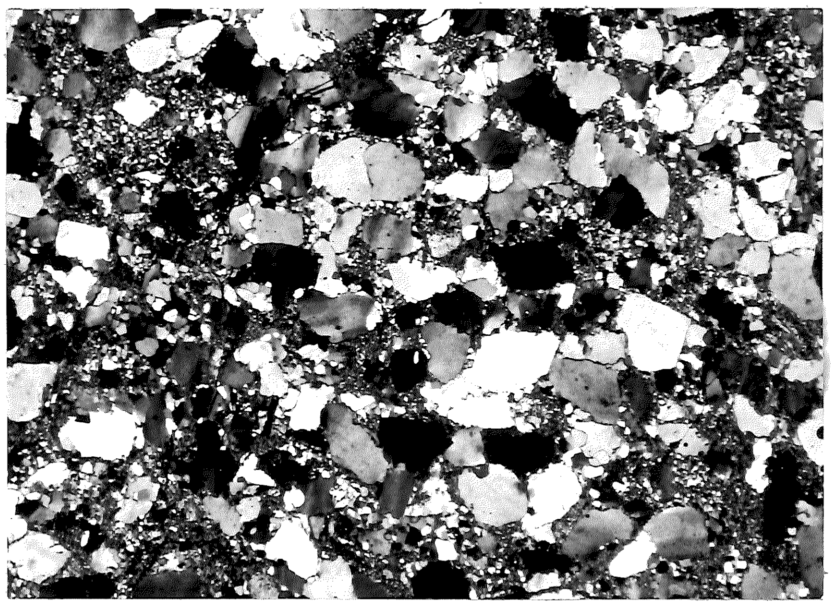
D

C. Planar cross-bedding in quartzites of the Joe's Luck Formation near the Joe's Luck Gold Mine. Coarse-to-fine grading of the sediment occurs within the false-bedded units of the foresets. Cross-bedding of this type yielded reliable way up determinations.

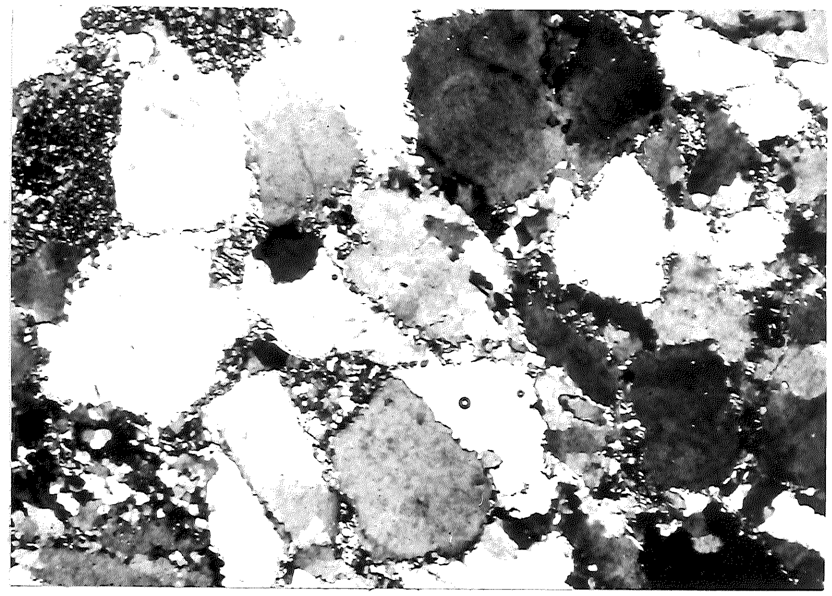
D. Cast of a scour-trough together with linear current markings in quartzitic sandstones of the Baviaanskop Formation west of the upper workings of the Fairview Gold Mine. Current flow direction was probably from base to top of photograph.

PLATE 4

A



B

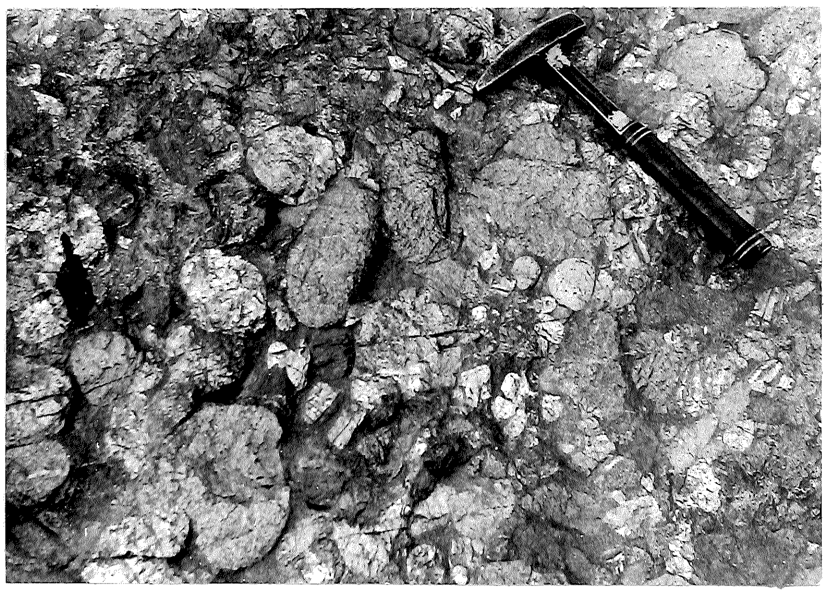


A. Microphotograph of relatively unmetamorphosed quartzites from the Baviaanskop Formation on the eastern limb of the Eureka Syncline near the Victory Hill Gold Mine. The quartzite consists essentially of quartz and chert in a microcrystalline quartz matrix mosaic (crossed nicols X75).

B. Microphotograph of deformed and metamorphosed Baviaanskop Formation quartzite from the western limb of the Eureka Syncline near the Fairview Mine offices. The Kaap Valley Granite contact is approximately 500 m west of the quartzite horizon. Note the sutured grain boundaries of the quartz and chert.

C

D



C. Fig Tree shales and greywackes displaying graded bedding and a pronounced oblique slaty cleavage. Both the bedding and the cleavage are steeply inclined. Locality - New Clutha Gold Mine area.

D. Relatively undeformed pebbles in the basal conglomerate of the Moodies Group exposed in a stream on the southern limb of the Eureka Syncline near the Royal Sheba Gold Mine. There is no preferred alignment or flattening of pebbles in areas removed from the influence of the intrusive granites.

PLATE 5

A

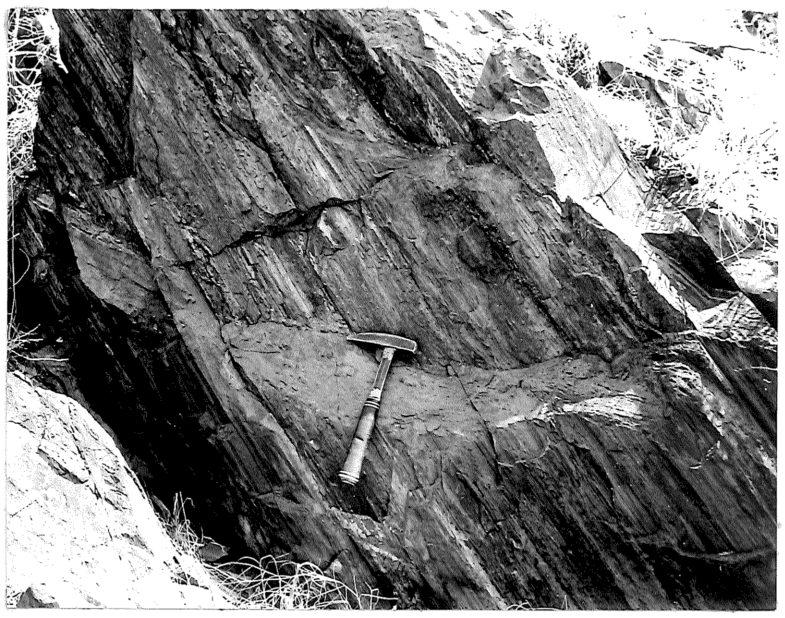
B

A. Crenulation folds (kink-band folds) with horizontal fold axes and axial planes developed in finely laminated brittle shales and sub-greywackes of the Moodies Group. These minor folds are associated with conjugate folds (Plate 7A) in the Eureka Syncline along the Havelock road. The attitude of the minor folds suggests they were developed in a vertical stress field.

B. Flattened pebbles of the Moodies Group basal conglomerate exposed in a road cutting near Joe's Luck Siding. The deformed pebbles display a uniform plunge of pebble long axes parallel to the pick handle.

C

D



C. Steep lineations developed in the marginal portion of the Kaap Valley Granite near Caledonian Siding. The foliation and lineation in the granite was produced by the alignment of hornblende and biotite at the time of emplacement of the diapiric pluton.

D. Steeply plunging lineations in actinolite schists of the Onverwacht Group exposed in the area east of Caledonian Siding. The schistocity and strong mineral alignment was caused by the diapiric emplacement of the Kaap Valley Granite.

PLATE 6

A

B

A. Basin-like structure in Moodies Group shales and sub-greywackes exposed in a road cutting 1 km north of the Fairview Mine offices.

B. Dome-like structure in Moodies Group sub-greywackes 1 km west of the upper workings of the Fairview Gold Mine. Interferring dome and basin structures are produced by the superimposition of two generations of minor folds. Crossing anticlines produce dome-like structures while intersecting synclines form basin structures (Ramsay, 1962a).

C

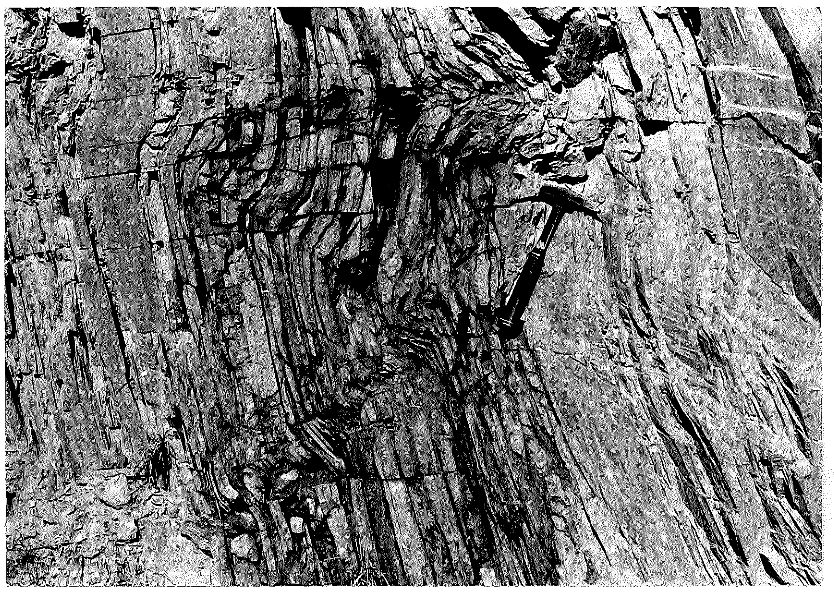
D

C. Chevron folds with horizontal fold axes and axial planes developed in felspathic quartzites of the Clutha Formation in the area east of Eureka City in the Eureka Syncline.

D. Chevron or accordion fold in felspathic quartzites associated with conjugate folds (Plate 7B) displayed on a cliff face east of Eureka City. The chevron and conjugate folds represent late phase deformational structures produced by a near vertical stress field.

PLATE 7

A



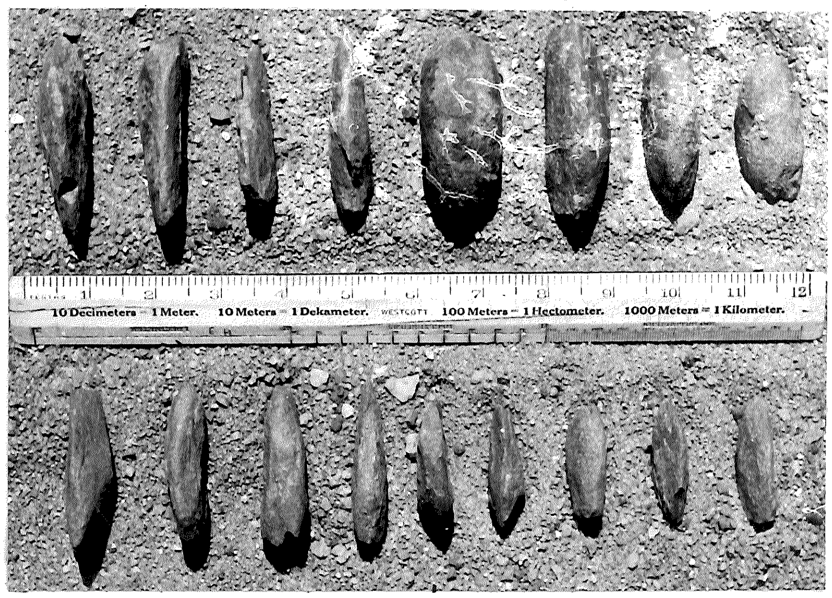
B

A. Conjugate fold in finely laminated brittle shales and sub-greywackes of the Moodies Group. The conjugate fold occurs together with minor crenulation folds (see also Plate 5A) all of which were produced as a result of a late stage vertical stress field. Locality - Eureka Syncline, Havelock Road.

B. Conjugate fold in felspathic quartzites of the Clutha Formation east of Eureka City. The stress field calculated from conjugate and chevron folds (Plate 6C and D) in this area as well as from conjugate folds near the Bonanza Gold Mine also indicates a near vertical pressure maximum for late phase structures developed in the area north of Barberton.

C

D



C. Quartz veins honeycombed throughout a leached surface exposure of the Sheba "Bar" (fault) near the Golden Quarry workings in the Sheba Valley.

D. Flattened chert pebbles from the Moodies basal conglomerate, collected between Eureka Siding and Ezzy's Pass on the northern limb of the Eureka Syncline. The deformed conglomerates are approximately 2 km south of the Nelspruit Granite (photograph shows a/c planes of pebbles).

PLATE 8

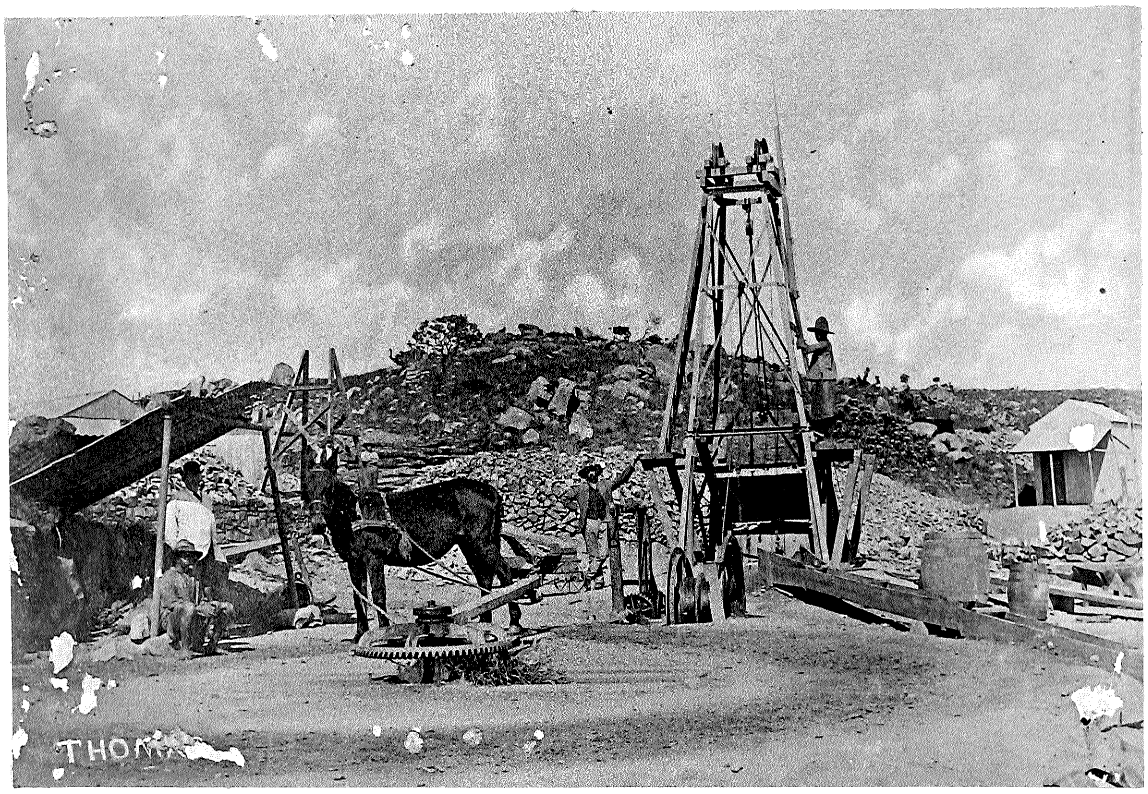
A

B

A. View east down Sheba Valley showing the numerous workings and intensive activity of the Sheba Gold Mining Company - circa 1890.

B. Recent view down the same, yet almost deserted, Sheba Valley. On the left can be seen the famous Golden Quarry workings. In the distance on the right are mine dumps of the Sheba Gold Mine, while in the foreground are cherty rocks forming part of the Sheba Fault.

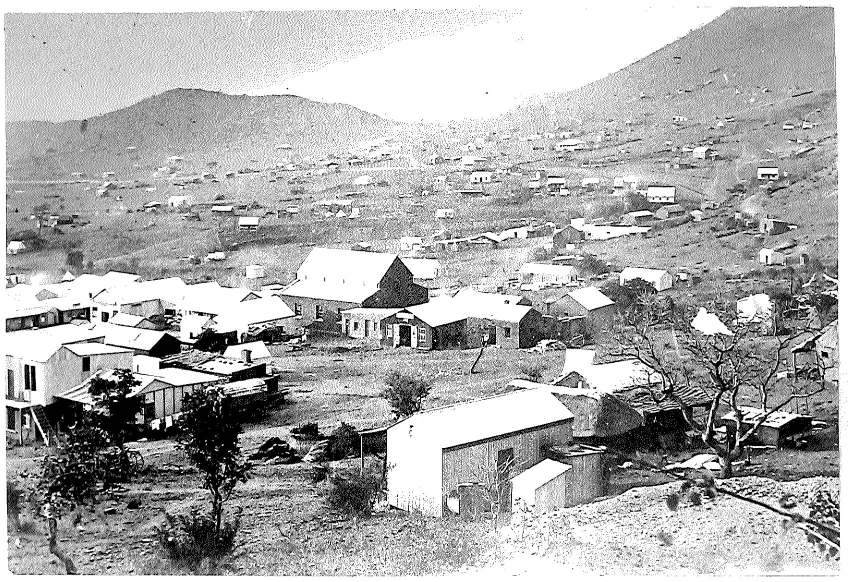
C



C. Historical photograph (circa 1890) of the Thomas Gold Mine situated 1 km north-west of Eureka City in the Eureka Syncline. Gold-quartz veins filling fractures in quartzites of the Joe's Luck Formation were mined in this area.

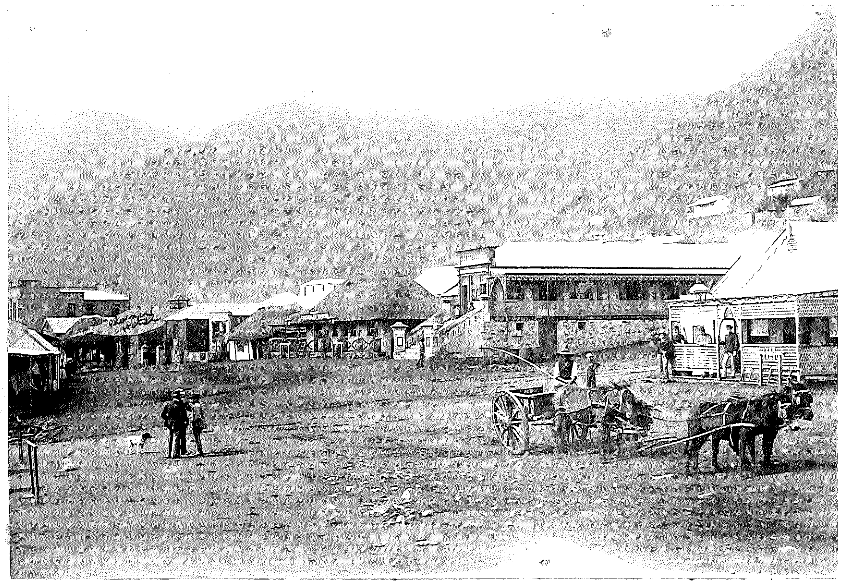
PLATE 9

A



EARLY BARBERTON - CIRCA 1887

B



PILGRIM STREET, BARBERTON -
CIRCA 1887

C

EUREKA CITY NORTH OF SHEBA GOLD MINE -
CIRCA 1885

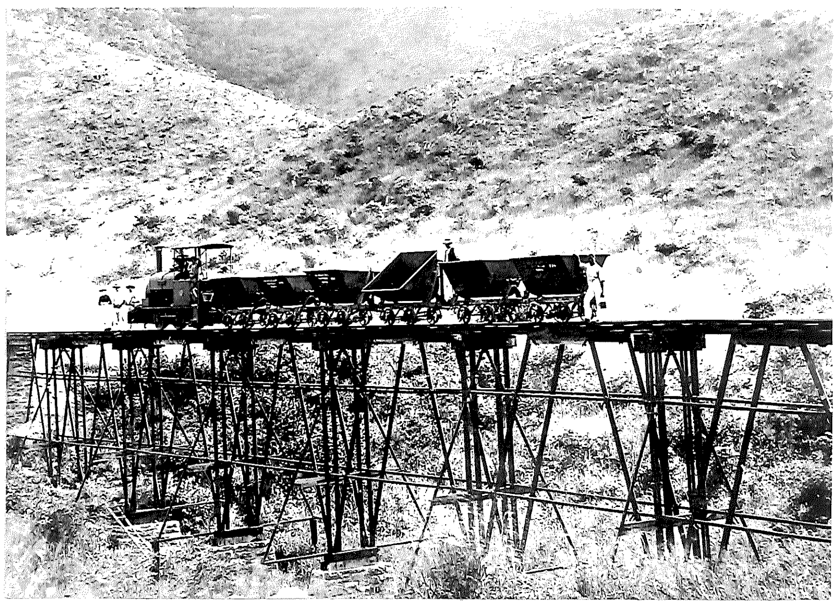
D

THE FIRST STOCK EXCHANGE
IN THE TRANSVAAL
BARBERTON - CIRCA 1885

E

SOME INTREPID AND STALWART DIGGERS -
PIONEERS WHO HELPED "OPEN UP" THE LOWVELD

F



SHEBA TRAMWAY - FIG TREE CREEK,
1887