THE GEOLOGY OF A PORTION OF SOUTH-WESTERN ALBANY

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SYNOPSIS

During 1963 an area was mapped around Sidbury, 23 miles south-west of Grahamstown. The object of the survey was to examine stratigraphic problems, which included the nature of a large occurrence of shale south of Alicedale in a region previously mapped as Witteberg, and the relationship between Silcrete and Calcrete.

During the investigation evidence of the existence of two, possibly three, major thrust-faults and of extensive overfolding to the south was discovered. There is reason to believe, that movement on the Zuurberg Fault was initiated in pre-Cretaceous times, and renewed in the early Cretaceous. The Silcrete is shown to be related to the pattern of present-day drainage. Stone implements found embedded in the Calcrete suggest that it is of Recent age.

INTRODUCTION

1. THE AREA

a) Locality The area investigated and mapped geologically is limited by the degrees of longitude 26°E and 26°20'E, and latitudes 33°20'S and 33°30'S. The east-west boundary is 19.2 miles long, and the north-south boundary 11.4 miles. Altogether 219 square miles were mapped. The area is situated between Grahamstown and Port Elizabeth. The southern boundary is at places less than 15 miles from the coast. The small village of Sidbury, in the Albany Division, is situated near the centre of the area about 5 miles north of the national road which runs from Grahamstown to Port Elizabeth. Approximately 5/6 of the area lies in the Albany Division, the remainder, west and south of the Bushmans River, lies in the Alexandria Division.

b) Communications All parts of the area are easily accessible by road. The national road from Grahamstown to Port Elizabeth traverses the southern and south-eastern parts of the area. In addition there is a good system of divisional and farm roads.

The railway from Grahamstown to Port Elizabeth crosses the north-eastern corner of the area at Highlands, and also runs for about 12 miles in the western part, mostly along the Bushmans River, between Alicedale and Paterson (Sandflats).

c) Settlement There are no large towns in the area. Sidbury is a small village which consists of a few European homes, two churches, a primary school, a hall and a small trading store. Practically the only occupation of the people around Sidbury is farming. Cultivation plays a minor role, and most of the land is under grass. The main income of the farmers is from cattle and sheep. In view of these circumstances the population density is relatively low. Farm produce is taken chiefly to the Port Elizabeth markets either by rail or by road.

d) Vegetation The natural vegetation consists of grass and bush. Forests are absent.

Dense bush is always found on the slopes of steep valleys and on the soft shales and sandstones of the Bokkeveld Series. In some places, and sometimes for considerable distances, the bush is practically impenetrable and mapping is difficult.

The quartzites of the Witteberg Series are covered by Rhenoster bush, or, where this has been removed, by grass.

Windblown sands, which extend over much of the region, are covered by thick bush only in the south and south-west of the area. South of Sidbury, and in the south-eastern part, grass is found on this formation.

Mimosa is confined to the lowest parts of the region, especially the Bushmans River valley.

e) Topography and Drainage Eighty-five percent of the area is drained by the Bushmans River and its tributaries, and 15% by the Kariega River and its tributary, the Assegaai River. The Bushmans River and the Kariega River are the only two streams which reach the sea, all others are tributary to these two. The former does not rise in the area, its source being several miles to the north-west. The Kariega River has its source on the farms Boekenhout and Carlsrust, but leaves the area in an easterly direction on Fabers-kraal. The pattern of drainage can be described as dendritic. The rivers are short and receive many tributaries, which drain small, deeply incised valleys. The drainage is radially outward from a beacon which stands at an altitude of 2,251 feet in the north-western corner of Proctorsfontein. The drainage appears to be superimposed, structure tends to exercise very little control. This is particularly true of the western half of the area. All rivers are seasonal.

No rainfall figures were available for the area. The rainfall curve for Grahamstown shows two maxima, one in November, one in March, with a mean annual rainfall of 27.45".

The highest point in the area is on Carlsrust, where a beacon stands at an altitude of 2,727 feet. Near Rustfontein (part of Roodekop) the ground drops to below 700 feet. The relief of the area thus exceeds 2000 feet. Along the northern boundary of the map much of the ground is above 2000 feet. Most of the area forms part of an old coastal plain, which slopes towards the sea at about

100 feet per mile. The old plain is highly dissected by the modern drainage. In the southern half it is overlain by younger formations, resulting in an undulating landscape. The northern half is exceptionally rugged in places.

2. PREVIOUS WORK

Rogers in 1905 reported on the Zuurberg volcanics (Trans. S.A. Phil. Soc. XVI, 1905 and Ann. Rep. Geol. Comm. for 1905), and together with Haughton (29) described these again in 1924. Schwarz (58) gave an account of the Alexandria Formation in 1908 and in 1913 described the Cretaceous rocks of the Bushmans River area (59). The Tertiary formations of the Eastern Cape were described by Haughton (24) in 1926. Haughton (25) also gave a general account of parts of the area in a description covering the geology between Graha mstown and Port Elizabeth. This was published in 1928. The problems of Eastern Province geology were outlined by Mountain (45) in 1945, in his presidential address to the Geological Society of South Africa. Several descriptions have been published of areas adjoining the one under investigation, but very little has been written which relates directly to the geology of this area. Mountain (46) in 1946 published a report on the area east of Grahamstown, and in 1962 the same author (50) described the geology of the country around Port Alfred. In the same year Engelbrecht, Coertze and Snyman (18) published a description of the geology between Port Elizabeth and Alexandria. Part of the northern boundary of their area forms the southern boundary of the area presently investigated.

3. FIELD WORK

The field work was carried out intermittently during the months March 1963 to September 1963. At the beginning no aerial photographs were available. This, and the unusually wet weather during March and April, initially slowed down progress somewhat. The south-eastern corner of the area on Seven Fountains, Matjes Kraal, Klipheuvel and Roodekop had to be mapped directly onto 1:18,000 topographical survey sheets. The rest of the area was mapped on aerial photographs.

Originally it had been hoped to confine the field work to the area shown on map 1. While mapping the south-western portion of the area, however, it became clear, that the work could not rigidly be confined to these limits. A certain amount of reconnaissance mapping had to be undertaken outside the area. This was necessary to obtain additional information regarding certain structural problems. The reconnaissance mapping took the form of three traverses across the Zuurberg, one along the national road north of Paterson, a second $3\frac{1}{2}$ miles west of Paterson, and a third traverse along the old Zuurberg Pass, eighteen miles to the west of the area. No details were mapped; only the major structural features were examined. Additional mapping was also carried out south of the area on Woodbury, Rokeby Park and Kongas Mond.

Altogether about eighty days were spent in the field, and a little more than 600 miles covered on foot.

4. BRIEF SUMMARY OF THE GEOLOGY

Geologically the area falls wholly within the range of the Cape Fold Belt. All systems from the Cape to Recent are represented. However, not one of the systems is represented by its full succession. The area is of extraordinary interest, not only as a result of the variety of rocks present, but also because of their structural features and interrelationships. In the table below are set out the systems and series present.

Alluvium Silcrete, windblown sands High-level gravels		Tertiary to Recent
Sandstones, conglomerates	Uitenhage Series	Cretaceous System
Tuffs	Stormberg Series (?)	Karroo System
Shales, sandstones Quartzites	Witteberg Series	Cape System
Shales, sandstones	Bokkeveld Series	Cape System

The distribution of the various systems is shown on map 1. The Cape System forms a conformable highly folded sequence. Bokkeveld underlies about 17.5%, Witteberg Quartzite about 47% and Upper Witteberg Shales 3.2% of the area. The base of the Zuurberg Volcanics is not exposed, and their relationship to older rocks is therefore not known. They underlie only about 0.3% of the area. The Wood Beds, found over only 1.5% of the region, overlie the volcanics unconformably, and together with these have been faulted down against rocks of the Cape System. A variety of little disturbed Tertiary to Recent rocks overlie all older formations unconformably. Together these young sediments cover about 30.5% of the area. (Calcrete 2%, Windblown Sand 22%, Alluvium 6.5%).

5. MAPS

A set of aerial photographs, taken in July, 1957, was used for the field work. The photos are all 9" x 9" and have a scale of approximately 2.2" per mile.

In addition to the photographs, topographical survey sheets, on a scale of 1:18,000 and contoured at 50 foot interval, were available for the whole area. These proved indispensable in the preparation of the accompanying geological map and for the determination or estimation of altitudes.

Two publications by the Geological Survey have been most useful. The geology of the area of the present survey is depicted on a scale of 1" = 3.75 miles on Cape Sheet 9, published in 1928, which covers the area between Port Elizabeth and Grahamstown. Many details have been omitted from this map, but a good picture of the regional geology and of the setting of the Sidbury area is nevertheless obtained. Much useful information was also obtained from a geological map and accompanying explanation (18) published by the Geological Survey in 1962. This map covers parts of the districts of Port Elizabeth, Alexandria and Port Alfred, and a small part of its northern boundary forms the southern boundary of the area now investigated. The scale of the map is 1:125,000.

Maps on a scale of 1:62,500, the scale chosen for the final map, were not available, and it was necessary to construct a map on this scale from the 1:18,000 topographical survey sheets by means of a pantograph. The scale of 1:62,500 was chosen to conform with the metric scales presently employed by the Geological Survey.

A perhaps unusual technique was devised to facilitate the transfer of field data from the aerial photographs onto the final map. For this purpose the system of gridlines on the 1:18,000 topographical sheets was also drawn onto a provisional working map on the scale 1:62,500. An aerial photograph showing minimum distortion, as judged by the fact that it showed equal change of scale from the centre outwards in all directions, was then selected. From points of intersections of gridlines determined on the topographical sheets and on the photographs, a grid was constructed for this particular photograph, and drawn onto transparent polythene plastic. The photographs showed varying degrees of distortion, but the grid on the transparent overlay was found to be very near in scale to that of all other photographs. By comparing individual photographs with the 1:18,000 topographical sheets it was always possible to identify sufficient points of intersections of gridlines on the photographs to make it possible to place the grid of the transparent overlay with an adequate degree of accuracy over the photographs. Data could then be transferred directly onto the final map from points and traces marked on the overlap. Depending on the amount of distortion the grid had to be shifted accordingly for the different parts of each photograph. It is considered, that no serious errors have been introduced on the scale of 1:62,500.

6. ACKNOWLEDGEMENTS

Mr. A. Ruddock, Senior Lecturer in the Department of Geology, Rhodes University, undertook to act as supervisor of research. I am indebted to him for his active interest in the work, and for his inexhaustable supply of new ideas, which continually led me to investigate new channels.

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To my parent, who paid all my expenses during the year, and my father, who took the photomicrographs and made all enlargements I am particularly indebted.

Further I wish to thank all the farmers in the area, whose hospitality has been quite overwhelming, and has made the fieldwork an unforgettable pleasure.

Thanks are also due to the Geological Survey for the loan of the aerial photographs, and to Miss Delene Schoeman, who sacrificed part of her vacation, and with infinite care coloured the geological maps.

THE STRATIGRAPHY OF THE REGION

INTRODUCTION

A summary of the geological formations has been given on p.5, and will not be repeated here.

Several papers have recently been published regarding the subdivision of the Cape System. Swart (65), on tectonic grounds, thinks it may be desirable to subdivide the Cape System into only two series: the T.M.S. up to the glacial zone, and a second series to include all the strata between the glacial zone of the T.M.S. and the Dwyka Tillite. On page 477 he writes:

> "To me the Cape System in the Wuppertal Area consists of two parts: the Table Mountain and Bokkeveld Series. The lower Witteberg in this locality is only another phase of the latter series".

Theron (66) on the other hand believes that in the Willowmore district the base of the Witteberg can be fixed on mineralogical grounds,

> "... the lower boundary of the Witteberg Series can be clearly delimitated by means of a sudden brookite affluence".

Furthermore, Theron puts forward palaeontological evidence why the Upper Witteberg Shales should be reclassified as Lower Dwyka Shale.

Fölbich, (22) in a paper as recently as 1962, refers only to Lower Dwyka Shales, not Upper Witteberg Shales.

No work was done on this problem in south-western Albany, and the writer adhered to the subdivision presently employed by the Geological Survey (17; p 259).

THE CAPE SYSTEM

Table Mountain Sandstone and Dwyka Tillite are nowhere exposed in the area, neither the Witteberg nor the Bokkeveld is therefore fully represented.

THE BOKKEVELD SERIES

The Bokkeveld Series is exposed in the core of four complex anticlines. One exposure is in the north-east of the area south of the Highlands railway station. Eastwards this outcrop can be traced to beyond Howieson's Poort, where the contact between Bokkeveld and Witteberg is well exposed in the national road cutting. The largest exposure is in the north-western part of the map, where the Bokkeveld is exposed in an anticlinorium which is nearly six miles wide. A third exposure is found along the southern margin of the map on Grootfontein, Rokeby Park and Kommas Mond. A small occurrence is found on

Fig.1

Fig.2

Schietkop. Bokkeveld may crop out in the core of an overfolded anticline on Doornkloof and Retreat (p.44), and possibly also on the Greenvale - Grootfontein boundary. The outcrops are small, and it is not possible to say whether the shales and sandstones are interbedded in the Witteberg Quartzite, or are part of the Bokkeveld.

Outcrops are poor, and frequently continuous for only a few feet. Where well exposed, the Bokkeveld is seen to be highly folded. The direction of dip may alter rapidly and the beds are frequently contorted. Overfolding on a small scale is common. Intraformational folding, normal faults and thrust-faults with a throw of a few inches to a few feet are well exposed along the railway line south of Eagles Crag (Fig.1). It is not possible to say how much of the series is actually exposed. Below the Witteberg quartzite on the western side of the farm River Bend (part of Roodekrantz) more than 400 feet of horizontal Bokkeveld must be present Unfortunately there is a near vertical drop down to the river.

The contact with the Witteberg is not difficult to establish. In south-western Albany it is conformable, and was taken at a point where massive bluish quartzites of the Witteberg Series give way to the first massive reddish shales and micaceous sandstone of the underlying Bokkeveld. The Bokkeveld is usually covered by thick bush, but the Witteberg quartzites mainly by grass. The contact can clearly be seen on aerial photographs simply by the change in vegetation.

The Bokkeveld consists of yellowish argillaceous micaceous sandstone, dark blue shale, which weathers to a reddish and then to a khaki coloured shale, quartzitic sandstone and rare quartzites. Notable is the absence of any great thickness of fissile shale. This makes the Bokkeveld easily distinguishable from the Upper Witteberg Shales.

The best exposure is found along the railway line south of Eagles Crag, where the series lies nearly horizontal; the exposed rocks are estimated to be about 400 feet below the Witteberg Quartzite. The sandstones are well bedded, and are rarely massive for more than one foot vertically. Cross bedding is well developed in bands only two or three inches thick. This suggests that the Bokkeveld is of shallow water origin. Spirophytons are abundantly present in a purple coloured shale. Plant fossils were not found.

On Sweetkloof, and possibly also on Grootfontein a 60 - 80 foot band of quartzite is present about 100 feet below the Bokkeveld - Witteberg contact. Another 50 - 60 foot horizon of quartzite is present in the valley on Sweetkloof, but its stratigraphic position is not known. In thin section the Bokkeveld sandstones show a recyrstallised mosaic of quartz and an abundance of sericite.

The Bokkeveld weathers to a reddish-brown loamy soil. On slopes, where erosion has nearly stripped off the soil cover, the surface may be covered with numerous red, iron oxide stained fragments of shale, irregular shaped, and frequently jagged. These fragments are distinctly different from the paper-thin khaki coloured flakes of shale produced on weathering by the Upper Witteberg Shale.

THE WITTEBERG SERIES

The Witteberg Series, the uppermost portion of the Cape System, is devided into the Witteberg Quartzite and the Upper Witteberg Shale. The full sequence of the quartzites is present in the area, but only a portion of unknown thickness of the upper shales is still preserved. The Witteberg is dominant in the area. Almost exactly one-half of the area is underlain by rocks belonging to this series.

a) The Witteberg Quartzite. The Witteberg Quartzite consists predominantly of bluish, glassy quartzite with interbedded bands of micaceous sandstone and thin bands of black shale. The thickness of the Witteberg Quartzite could be determined with a fair degree of accuracy. The full succession is present on the farms Carlsrust and Faberskraal, where the quartzites dip continually south at angles of 15 - 25 degrees. If the average angle of dip is taken to be 20 degrees, then 2800 feet of quartzite are developed between the Bokkeveld and Upper Witteberg Shales. This figure agrees well with thicknesses determined elsewhere in the Cape Fold Belt (p.48).

The Witteberg quartzites form, besides silcrete, the formation most resistant to weathering, with the result that it is found on elevated ground. It forms an old plain which is deeply incised by rivers. Witteberg outcrops are fairly continuous in the north and central parts of the region, while younger formations cover much of the series in the southern half. The quartzites are strongly folded, but probably not as contorted as the underlying Bokkeveld shales. Anticlines and synclines are well defined, and major structural features are easily recognised. Folding is

Fig.3

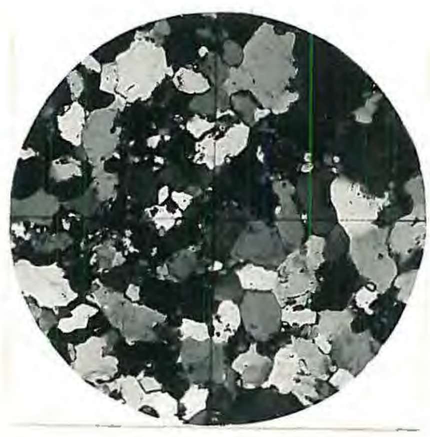


Fig.4

Fig.5

almost universal, and horizontally disposed quartzites are virtually absent. They can be seen only in the north-western corner of Sidbury Park. The quartzites dip at all angles, from the near horizontal to the vertical. Overfolding to the north and south is frequently seen.

The Witteberg Quartzites are highly recrystallized (Fig.5). In thin section it can be seen that they are constituted of an equigranular mosaic of quartz grains with an average diameter of 0.4 mm. Recrystallization is complete. The crystal boundaries are highly irregular, and traces of an original texture are altogether absent. Sericite is almost always present, as are smaller amounts of ilmenite, zircon and pleochroic tourmaline. Felspar is absent. Rutile needles are found in large numbers in many grains, but may be wholly absent in others.

In the field the Witteberg quartzites frequently have a white or yellowish colour, which is produced by a thin layer of lichens which grow on the rock. On the surface the Witteberg quartzites normally protrude through the soil in slabs parallel to the bedding. Cross bedding is well developed. Rarely are bedding planes separated by more than one foot of massive quartzite. The bedding planes show well defined slickensiding, indicating that movement has taken place on these during folding. Cross bedding was not measured systematically, but was observed, and indicated a source of the Witteberg quartzites in a south-easterly direction.

An unusual type of outcrop can be observed in several places. Here the Witteberg has taken on a glassy, highly polished surface. Sedimentary features such as bedding and cross bedding planes can not be observed. The surface may also be highly pitted and show signs of differential weathering. The general appearance of the Witteberg is very similar to that of silcrete found elsewhere in the area. A freshly broken hand-specimen, and the texture as seen under the microscope, unmistakebly show, however, that the rock is Witteberg quartzite, and not a silcrete (Fig.4). It is possible, that it is a transitional phase between Witteberg quartzite and silcrete. Outcrops of this nature are found on the floor of a donga in the southern most corner of Springfield, the south-western corner of Sidbury Park and near the homestead of Nazaar Annex (part of Matjes Kraal). It is of interest, that all the three occurrences are closely associated with eolian sand of Recent origin (p.32). Any person studying

Fig.6

the problem of the origin of silcrete might find it rewarding to examine the mentioned sites.

Conglomerates do not occur in the Witterberg, but near the top of the quartzites, as seen in the road cutting leading down to the Nazaar River, numerous small ellipsoidal cavities are found (Fig.6). The long axes of these trend roughly parallel to the bedding. The cavities appear to have been filled with shale pebbles, long since weathered out. A similar occurrence can be seen near the western boundary of Hillside, but here the stratigraphical position is not known.

Interbedded shales and micaceous sandstones are common. Where these interbedded horizons can positively be identified as belonging to the Witteberg Quartzite, they rarely exceed 40 feet in thickness. Greater thickness of micaceous sandstones and shales is present in the Komga River valley, and also south of Mountain View (part of Klip heuvel). Because of their synclinal or anticlinal attitude either no base of no top is exposed, and consequently some difficulty is experienced in deciding whether these bands are interbedded with the Witteberg quartzites or not. A good section of the upper 410 feet is exposed in the Nazaar road cutting. A summary of this is given in table 1. The upper 410 feet thus consist of 81% quartzite, 8% micaceous sandstone and 11% shale. The series is overwhelmingly arenaceous while argillaceous rocks are very subordinate.

Fossils are rare in Witteberg quartzites. The imprint of a plant stem, probably Haplostigma irregulare, near the northern boundary of Matjes Kraal, is the only fossil which was recorded.

The contact with the Upper Witteberg Shales is sharp. In the Nazaar River road cutting the top of the quartzite is characterized by a massive 40 foot band of quartzite, which, without any transition zone gives way to the fissile shales of the upper Witteberg. This condition is also found elsewhere in the area.

The Witteberg quartzites weather to a grey soil. This soil is not easily distinguishable for the unaided eye from the grey windblown sand , especially around Sidbury. In the early stages of disintegration the Witteberg quartzites take on a sugary texture which has a reddish appearence due to the chemical disintegration of iron oxides. Iron oxides are, however, never present in sufficient quantities to form a red soil. The

Fig.7

soil cover is never very thick, and rarely exceeds one to two feet, after which it passes into broken and unbroken rock.

b) The Upper Witteberg Shale Upper Witteberg Shales are preserved in a number of tight synclines, the outcrops of which are characterized by being long and relatively narrow. On Hoffmanskloof and Springvale the shales crop out over a strike length of 6 miles, but do not exceed 500 yards in width. A similar, but overfolded syncline is found north of the Zuurberg Fault . Two narrow synclines, filled with Witteberg shales, ~~are filled with Witteberg shales,~~ are found on Matjes Kraal and Klipheuvel, and one on Klipfontein. The widest outcrop occurs on the farms Assegaai Bush, Lathams Farm and Melville Park. Partially covered by silcrete, it attains a width of nearly 1.5 miles. Four and one half miles beyond the eastern boundary these shales attain their fullest development, and are overlain by Dwyka Tillite.

In each one of the narrow synclines only shales are present, sandstones are absent. Micaceous sandstones do occur in the Upper Witteberg Shales, but the succession immediately above the Witteberg Quartzites consists of massive dark blue shales. A sandstone band of unknown thickness is exposed in a quarry approximately 75 feet above the base of the shales. Topographically this sandstone band forms a low ridge parallel to the valley on Assegaai Bush. The absence of sandstones in the narrow synclinal valleys suggests that no great thickness of the Upper Witteberg Shales is present. The shales are highly folded, crumpled and cleaved. Bedding planes are difficult to recognise. The iron content of the shales gives the soil derived from them a deep red colour. Freshly weathered shale breaks up into small khaki and reddish coloured paper-thin flakes. This is characteristic of the lower portion of the Upper Witteberg Shales, and is quite distinct from anything seen in the Bokkeveld (p. 10)

THE KARROO SYSTEM

THE ZUURBERG VOLCANICS

A narrow belt of volcanic rocks is found on the farms Witteclayrug, Retreat and Doornrug. The Zuurberg Fault, described in detail on pages 49 to 54 , forms their northern boundary. The outcrop of volcanic rocks is from 130 to

Fig.8

300 yard wide and the belt can be traced from Boesmanspoort for 3 miles in a south-easterly direction before it disappears under surface sand on Doornrug. In the Bushmans River valley the volcanic rocks are covered by alluvium. Near the western boundary of Doornrug they are bound on their southern side by alluvium, but further east they are overlain unconformably by the Wood Beds of the Cretaceous System. Two sections of the Zuurberg Fault, which on Doornrug and Stilgenoegen is offset by two wrench-faults, do not have volcanic rocks exposed on their southern side.

Outside the area of the present survey, volcanic rocks form a long and narrow belt which can be traced south of the Zuurberg Fault for 80 miles beyond the region in a westerly direction. West of the region volcanic rocks consist of basalts and tuffs which are underlain by breccias, conglomerates, marls and sandstones. Sediments are also interbedded with the tuffs and basalts (29).

East of the Bushmans River no basalts are exposed, the volcanic rocks in the area consist entirely of tuffs. On the farm Woodbury, a little beyond the southern boundary of the area, the most southerly volcanic rocks of the Uitenhage Basin are found. These also form a narrow belt of tuffs, bound on their northern side by a section of the Zuurberg Fault. The belt on Woodbury is very similar to that found on Witteclayrug, Retreat and Doornrug.

The tuffs do not form any pronounced topographical features. On Doornrug, however, the tuffs do form an interrupted ridge between the Witteberg Quartzite to the north and the Wood Beds to the south. At their highest point the tuffs are just over 100 feet above the floor of the valley to the north and south of it.

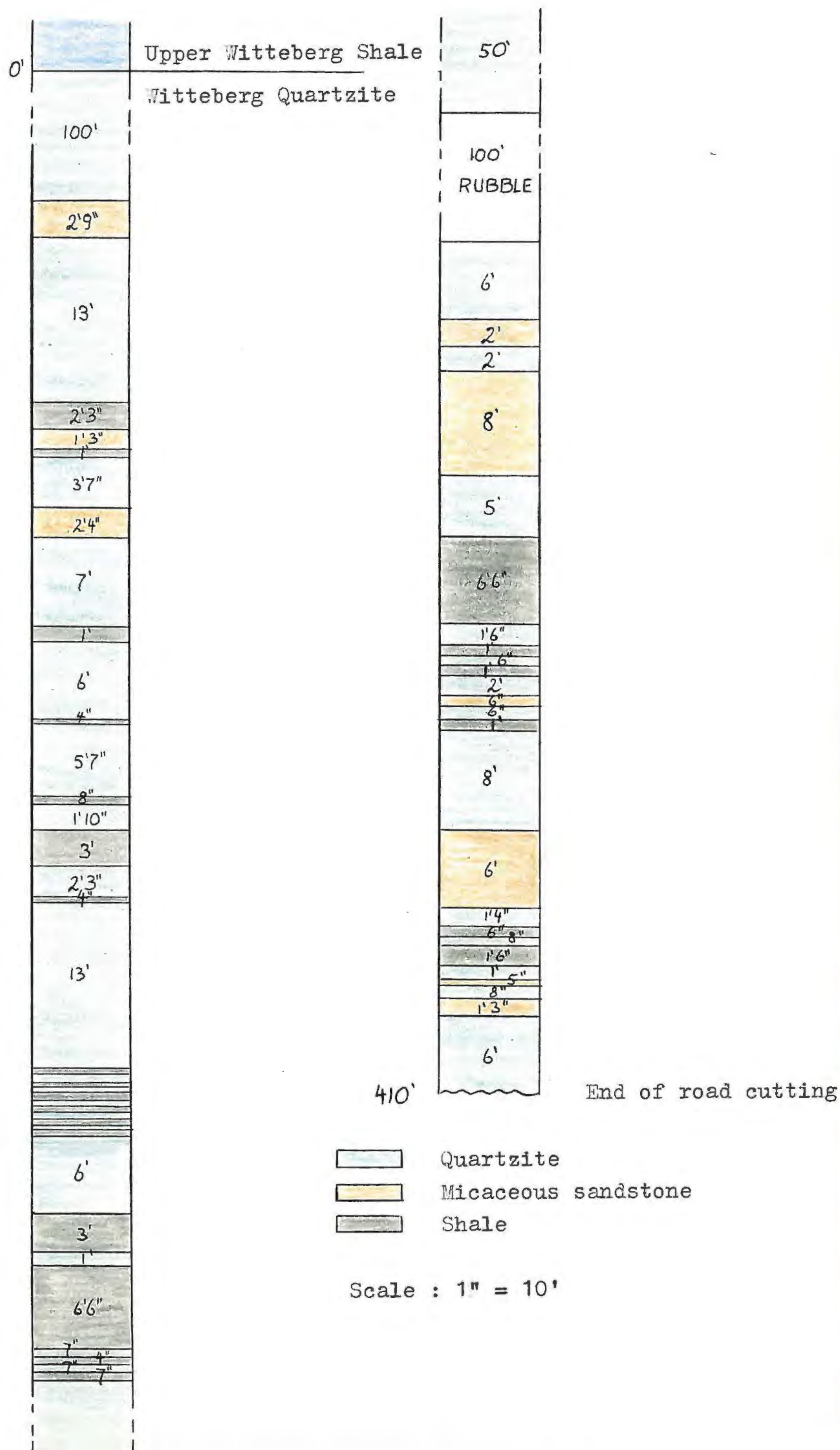
The volcanic rocks are well exposed in a cutting prepared for a new railway siding at Boesmanspoort. On its northern side, where the tuffs rest against the fault, artificial dumpings obscure the contact. The southern limit is well exposed, the tuffs are covered by alluvial sands which contain several pebble beds. The outcrop is about 130 yards wide and approximately 30 feet high. Petrologically there is not much variation in the exposure. The tuffs consist of a white to light grey soft rock, which becomes claylike when moistened. The rock is so friable that no thin sections could be prepared. Near the southern limit of the exposure three parallel bands of hard tuff are found. These bands appear to be a little disjointed and fragmentary. The dip of these bands is

Fig.9

TABLE I

SECTION THROUGH THE UPPER 410 FEET OF THE WITTEBERG QUARTZITE.

(National road cutting immediately west of the Nazaar River.)



20^{o} in a southerly direction. The hard layers are about one foot thick. Two occur very close together. The upper one is overlain by claylike white tuff and this by irregularly shaped blocks of purple and light grey quartzite. A few feet above the quartzite there is a third layer of hard tuff. Under the microscope a thin section of the quartzites shows that they consist of equigranular highly recrystallized quartz grains and occasional muscovite flakes between the grains. The quartzites in the tuff resemble Witteberg quartzite, and microscopically they can not be distinguished from it. The quartzite inclusions dip in the same direction as the hard tuff bands. The hard tuff layers do not show up clearly against the light grey soft tuffs. They are most easily traced by hitting the face of the cutting at short intervals with a hammer. Fresh specimens of hard tuff do, however, differ markedly from the soft tuff. . They do not have the uniform light grey appearance of the latter. One specimen showed a distinctly nodular appearance, light pink nodules set in a matrix of light grey tuff. The colours may vary considerably. One small specimen showed a range of colours which included black, brown, pink, yellow, green and light grey. Under the microscope it can be seen that the hard tuffs consist of extremely small angular grains of quartz set in a glassy matrix. The rock is porous, but it appears that the tuffs consist of more than 90% glass. Tiny flakes of muscovite and strongly pleochroic biotite can be recognised under high magnification. The presence of felspar could not be confirmed. A rare constituent is zircon.

A good exposure of tuff is found in a small quarry on Retreat. Here the tuffs are light pinkish in colour, hard and texturally very uniform.

Half a mile further east the tuffs are light grey in colour and oolitic. The small concretions are very numerous, pink in colour and have a maximum diameter not exceeding 2mm. The oolites give the rock a spotted appearance. Thin section study reveals that the oolites are formed by secondary calcite. A concentric arrangement is very common. The centre consists of angular quartz grains, glass and calcite. This is surrounded by a ring of quartz grains and glass which is free from calcite. This ring is in turn surrounded by quartz grains, glass and calcite (Fig.8). The outer ring shows a greater concentration of calcite towards the core. Calcite is frequently absent in the centre, but when it is present, it is normally in optical continuity with the calcite of the outer ring, although in no way physically connected with the latter. A complete ring normally shows optical continuity; this also in spite of the fact that the calcite consists of a vast number of tiny grains which do not appear to be in physical continuity.

A few yards from the locality where the oolitic tuffs were found, pink tuffs occur which show "pipe" structure. These are not parallel to one another, but run in any direction. Their diameter is up to 5mm. The "pipes" are filled with the same material as the surrounding tuff. No suggestion as to the origin of the "pipes" can be offered.

One hundred yards west of the point on Doornrug, where the volcanics pass under the surface sand , a pisolitic variety of tuff crops out which contains inclusions of angular quartzite up to several inches across. Similar in appearance to the inclusions at Boesmanspoort, these pieces appear to be Witteberg quartzite. Their presence in the tuff suggests that the source of the volcanic rocks can not have been any great distance from the place of deposition.

Tuffs on Woodbury are characterized by a larger number and a greater grain size of quartz as compared with the tuffs at Boesmanspoort and Doornrug. Zircon is also more common, and occurs as irregularly shaped grains with rounded corners.

The fact that the character of the tuffs varies so much laterally, indicates that no one section across the entire outcrop, such as at Boesmanspoort, is representative of the whole belt.

The base of the Zuurberg Volcanics is not exposed, and their relationship to older rocks is not known. At Boesmanspoort about 130 feet are present. West of the area, in the Coerney River, 470 to 500 feet of basalt and tuff are developed. Haughton and Rogers (29) think that the Zuurberg Volcanics closely resemble the Stormberg Volcanics, and are probably the equivalent of these.

THE CRETACEOUS SYSTEM

THE WOOD BEDS

This is the only stage of the Cretaceous System present in the area. Enon Conglomerates and Sundays River beds are absent.

The Wood Beds are confined to irregular narrow outcrops on the northern side of the Bushmans River south of the Zuurberg Fault, in the south-eastern corner of the region. A cover of calcrete obscures much, but good exposures are found on the steep slopes and krantzes along the Bushmans River.

The Wood Beds consist of a thick succession of rapidly alternating calcareous sandstones and conglomerates. Fragments of fossilised wood are present in large numbers. This great regularity of sandstones and conglomerates is only broken in the south-west corner of Bushmans River Outspan where thick bands of unfossiliferous purple and light grey clay are interbedded. The clay , for some distance downstream, is said to form an impervious layer in the river bed, which prevents seepage from farm dams.

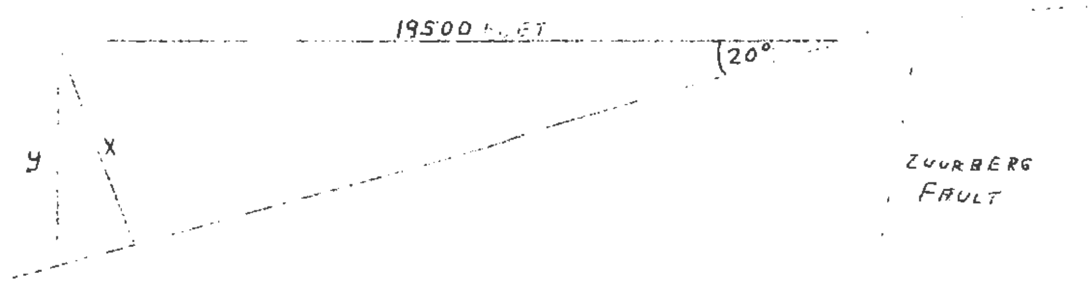
The conglomerates consist almost invariably of small pebbles. Characteristic is the rarity of well-sorted closely packed thick conglomerates. The conglomerates occur in large numbers as thin bands of pebbles, frequently less than 1 inch thick, separated by calcareous sandstone. "Pebble bands" would probably be a better term than "conglomerate". The pebbles rarely exceed an inch in diameter and consist of abundant rounded pebbles of Karroo shale (25;p.24), quartzite pebbles, fragments of chert, jasper, amygdaloidal lava and agate.

A thin section cut from a sandstone shows loosely packed equigranular grains of up to 0.4mm. in diameter, set in a matrix of calcite. Calcite constitutes approximately 30% of the rock. The grains consist chiefly of quartz, occasional fresh plagioclase felspar, zircon and ilmenite. Grains of fine grained, highly altered glassy lava are common. Quartz and felspar grains are always angular, and show virtually no signs of rounding.

Fossilised wood is characteristic of the Wood Beds, and is found everywhere where these are well exposed. The fossil wood has a deep brown colour and occurs as pieces up to several feet in length. The original cell-structure is well preserved. Schwarz (59) calls the fossil wood Araucaria and Pandanus. Atherstone in 1857 described dinosaur bones from the Bushmans River Cretaceous beds. Schwarz found fragments of bone on the farm Woodbury, and concluded that they must have belonged to an animal 50 - 60 feet long.

The dip of the Wood Beds, where this can be measured, is everywhere 20 degrees towards the south, i.e. away from the Zuurberg Fault. The precise direction of dip and strike could not be determined, nowhere was a bedding plane seen in three dimensions. Haughton (25) gives the dip as slightly west of south.

Much of the stratification of the Wood Beds appears to be initial dip. This could, however, not be proved by direct observation. The width of outcrop of Wood Beds between Doornrug and Papenkuilsfontein is 19,500 feet. A simple calculation shows that on Papenkuilsfontein a true thickness (x) of nearly 6,700 feet of Wood Beds must be present, if the bedding planes were originally horizontal planes of deposition. The vertical thickness (y) will then be



about 7,100 feet (slide rule calculations). A thickness of such a magnitude seems unlikely. Du Toit (17;p.378) states that where most fully developed the Wood Beds are perhaps 3,000 feet thick. A deep borehole (49) sunk at Swartkops in 1909 reached the floor of the Uitenhage basin and just intersected the Bokkeveld Shale at a depth of 3,020 feet. Haughton (25; p.28) states:

> "The general conditions of deposition must have been those of a subsiding delta, and the estuarine deposits of Zwartkops and Port Elizabeth may consequently be looked upon as the bottom-set deposits laid down at the same time as the Variegated Marls and Wood Beds (foreset beds) and at least part of the subaerial conglomerates".

The large amounts of fossilised wood, the abundance of shale pebbles, the absence of well sorted conglomerates, the angularity of grains, all point to rapid deposition under torrential conditions and fully support Haughtons idea of foreset beds in a subsiding delta (see p.63).

TERTIARY TO RECENT FORMATIONS

HIGH-LEVEL GRAVELS

Scattered throughout the southern half of the region are small isolated patches where water-worn pebbles are found in abundance. The pebbles are found as:-

a) Loose pebbles and boulders. This is the most common type. The majority of pebbles varies in size from that of a pea to several inches in diameter. Exceptionally boulders up to a foot or two were encountered. The shape of the pebbles varies considerably, they may be nearly spherical, egg-shaped or flat.

b) Ferruginous conglomerate. In several places pebbles are set in a hard, ferruginous matrix. The conglomerates are so hard, that fresh specimens break across matrix and pebble with equal ease. However, the matrix weathers much faster than the pebbles.

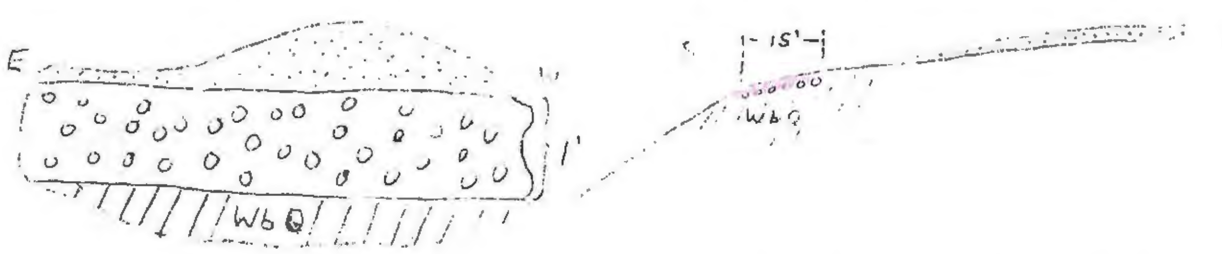
Fig.10

Fig.11

c) Calcareous conglomerate. This has been found at only one point.

The High-Level gravels are closely associated with the Windblown Sand (p.32). The Windblown Sand overlies the pebbles and conglomerates on an apparently slightly uneven surface which slopes towards the sea. Where the overlying sands are eroded away, the gravels are exposed, most commonly along the upper convex slopes of valleys.

Two small occurrences are found on Klipheuvel . Overlooking the Nazaar River small pebbles are found at an altitude of 1200 feet. The pebbles here consist exclusively of Witteberg quartzite and vein quartz. No silcrete pebbles were found. A short distance from the exposure of the pebbles, angular fragments of Witteberg quartzite are set in a ferruginous matrix. The pebbles and the ferruginous breccia are slightly below the level of the nearest silcrete, but it can not be stated with certainty whether the silcrete overlies them or not. The second occurrence on Klipheuvel is found one mile west-south-west of the first, also at an altitude of 1200 feet. Here a one foot layer of ferruginous conglomerate lies directly on unweathered Witteberg quartzite. The conglomerate is overlain by a fine grained ferruginous sandstone. The conglom-



erate and ferruginous sandstone rest slightly below the upper slope of the valley. Witteberg quartzites crop out only five yards uphill from the section, but are themselves overlain by windblown sand only a few yards further north. Silcrete is not found near the conglomerate.

On Matjes Kraal ferruginous conglomerates are found at 1200 feet and near the southern boundary of Klipfontein pebbles are found at the same altitude. The pebbles lie loosely on Witteberg quartzite. They are not very numerous and are widely scattered. Silcrete occurs in the vicinity, but no silcrete pebbles were seen. Haughton (25;p.31) described an occurrence near the eastern boundary of Klipfontein where brecciated Witteberg quartzite is cemented by a ferruginous cement. A large number of pebbles (Fig.11) are exposed at 1200 feet near Thorneycroft (part of Klipfontein).

On Komgas Mond Witteberg quartzite pebbles are exposed on both sides of a valley at 1025 feet. On the western side of the valley the pebbles are set in a matrix of calcareous sandstone derived from the overlying sand .

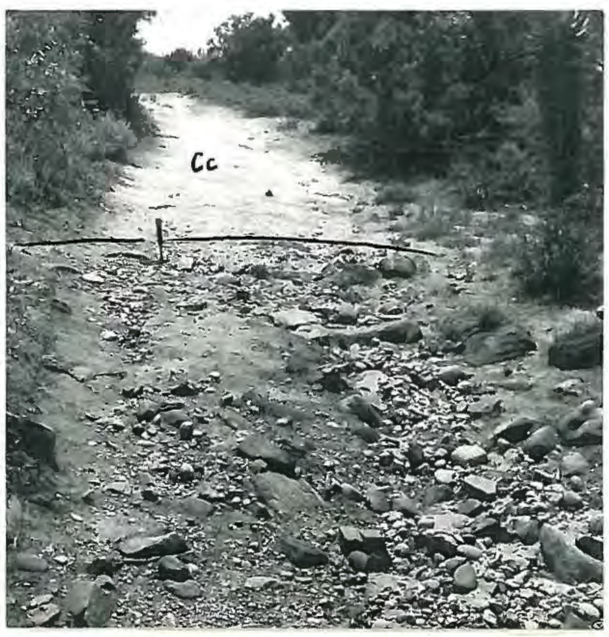


Fig.12

Near the northern boundary of Rokeby Park, 15 feet of unconsolidated calcareous sand are exposed in a national road cutting. The sand overlies Bokkeveld shales at an altitude of 1,025 feet. Four feet above the base there is a 12 inch thick conglomerate. This is overlain by 2 - 3 feet of sand and this in turn is overlain by a band, 12 inches thick, consisting of about 95% ilmenite. Higher up in the sands several more conglomerates are found. (Fig. 10)

Further west loose pebbles are found in abundance on Schietkop at 1200 feet. Two agates and pieces of green jasper were found among the pebbles. Ferruginous conglomerate occurs on Sidbury Park at 1300 feet.

Abundant pebbles are exposed in an erosion pit at the extreme southern tip of Springfield. Erosion has cut through the Windblown Sand and exposed the underlying pebbles, and the Witteberg Quartzite, at an altitude of 1300 feet. This occurrence proves that the pebbles are not confined to the upper slopes of valleys, but do underlie the Windblown Sand over extensive parts of the area. More pebbles, at 1250 feet, occur one mile north-west of the erosion pit.

On Doornrug pebbles are found at several points. Loose pebbles occur abundantly at 1200 feet on either side of the Upper Witteberg Shale band. Agate and pieces of jasper are interspersed with the pebbles. South of these pebbles, gravel overlies Witteberg quartzites and volcanic tuffs. The gravels transgress over the outcrop of the Zuurberg Fault. The pebbles are consolidated by a ferruginous matrix. Massive slabs have a thickness of 2 - 3 feet. Much of the matrix has weathered away, and loose pebbles are abundant. The pebbles and conglomerate are overlain by calcrete. In the south-eastern corner of Doornrug pebbles weather out from under calcrete at 950 feet. Agate, jasper and pebbles of amygdaloidal lava are common.

High-Level gravels emerge from under calcrete on Witteclayrug at at elevation of 1275 feet. Witteberg quartzite pebbles are abundantly found near the homestead Heaton Part (part of Witteclayrug). A boulder of ferruginous conglomerate was found near the homestead, but the material was not seen in place.

Outside the region gravel was seen at 950 feet on Rokeby Park, a few hundred yards to the south of the area (Fig.12).

The gravels underlie the Windblown Sand apparently over a considerable part of the area. Not everywhere around the margin of the Windblown Sand are gravels found, but the converse does generally hold true, where gravels and conglomerates are found, one does not have to look far to find windblown sands. There is, however, at least one exception to this rule; an isolated patch of gravel at 1300 feet on Retreat is nowhere near windblown sand .

The High-Level gravels are older than silcrete. No silcrete pebbles were seen amongst the gravels. The gravels are always at an altitude a little below that of the nearest silcrete, and pebbles were not seen any-where to weather out from under the windblown sand where the latter overlies silcrete. This indicates that pebbles were not deposited on silcrete. This can satisfactorily be explained. Silcrete and Windblown Sand are not confined to remnants of the old coastal plain (p.30), but are related to the present day topography. High-Level gravels are only exposed where windblown sands overlie the former on such remnants. The High-Level gravels may originally have been far more extensive but are today found only where they have been preserved under a protective cover of windblown sand. It is impossible to say whether silcrete overlies gravel at any point in the area.

The origin of the gravels is not known with certainty. They are either the product of marine erosion, or were deposited by a meandering river or rivers. It is significant that volcanic inclusions, such as agate and jasper are found in the gravels north of the Zuurberg Fault. Mountain (48) precludes the Dwyka Tillite as a possible source of agate. The agate and jasper could only have been derived from either the basalt several miles to the west of the area, or from the Wood Beds. Both formations are confined to the area south of the Zuurberg Fault. Whatever their source, some agent has carried them north of the fault. An advancing sea or a meandering river could equally well have accomplished this. The distribution of the gravels, however, suggests a marine origin. They are most common at 1200 feet, and were not seen above 1300 feet. A line drawn through all occurrences at 1200 feet is virtually parallel to the present coast. The peculiar concentration of pebbles at this elevation is more easily attributable to shoreline action than to a meandering river. A more erratic distribution of gravels over the whole area could be expected, if the gravels had been deposited by meandering rivers (p.60).

THE SILCRETE

Introduction Silcrete, or Surface Quartzite, in South Africa is of two types, the coastal and the inland variety. Much doubt seems to exist as to their origin and time of formation. Frankel and Kent (19) have shown that the silcrete at Grahamstown is derived from the underlying rock, and thus represents a silicified soil or subsoil. Mountain (47) has demonstrated that at Grahamstown the silica of silcrete is derived through the leaching of the underlying rock. Frankel (20) came to similar conclusions at Albertinia. Fossil plants in silicified deposits at Fort Grey, East London, were described by Adamson (1) who deduced a Tertiary age but admits that "all (fossils) are types that might be in existence at the present time". Dixey (12) describes silicified surface deposits in central Africa, which originally did not form in situ. He deduces an end-Tertiary age. Du Toit (17) states that some of the Kalahari silcrete has been formed by the replacement of part or the whole of calcium carbonate by silica.

No detailed laboratory study of silcrete was undertaken during the present survey, but the field relationship alone suggests that the character of the silcrete in S.W. Albany is highly variable. Some is clearly derived in situ from the underlying rock, and represents a silicified soil or rubble, other can only have been derived through the silicification of eolian sand. In places silcrete is overlain by calcrete, and it is quite possible that the former is derived from the latter through the replacement of calcium carbonate.

Occurrence and Field Relationships Silcrete is common in south-western Albany, and the area described in this survey is no exception. Silcrete is, however, virtually confined to the south-eastern portion of the map. Small outliers do occur along the northern boundary of the area.

The silcrete is characterised by its patchiness and irregular outlines of outcrop, as seen in places. It overlies unconformably all older formations, but is more commonly found on the Witteberg Quartzite than on either the Bokkeveld or the Upper Witteberg Shales. The reason for this preference is not known. Silcrete is in places overlain by windblown sand and also by calcrete. Haughton (25) thought that silcrete and limestone occurred side by side, and that the silcrete on Komga Mouth, Roodekop and other farms on the northern side of the Bushmans River, seem to grade into the limestone . The writer could find no evidence to substantiate this, but did see many localities where the limestones (calcrete) overlie the silcrete. Nowhere is silcrete in contact with Alexandria limestone.

The mode of occurrence of silcrete is highly variable. Most commonly it occurs as long narrow scarps near the top of a hill. Other forms are as thin

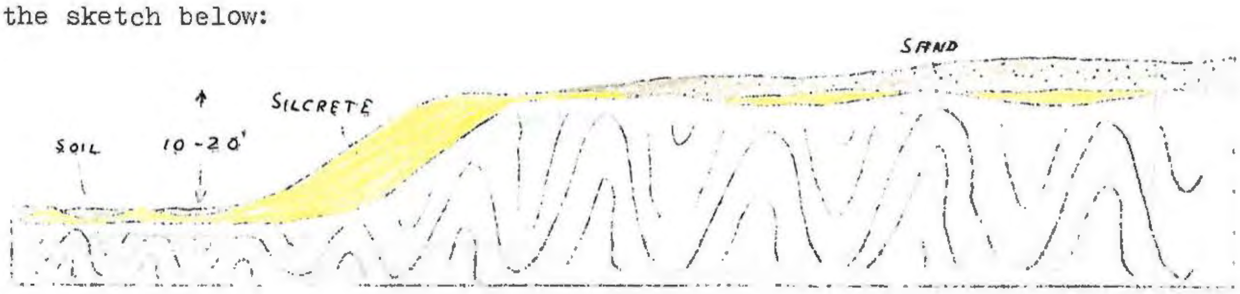
Fig.13

sheets or crusts on Witteberg quartzites, or they may occur as small, fairly thick outliers. The height of a scarp rarely exceeds 20 feet, the most frequent height being only 10 - 15 feet. An exceptionally high scarp, 45 feet, is found on Grootfontein. The base of silcrete is rarely seen exposed. At the foot of a scarp a soil cover obscures this. Although large tracts of silcrete are overlain by eolian sand a little more is known about their top. On Welcome Wood, and also on Klipheuvel, Witteberg quartzites crop out a short distance above the scarp. This suggests that silcrete does not form a continuous sheet as thick as the scarp is high. Frankel (20) found this to be the case near Albertinia, and Mountain (47) has found the same near Grahamstown. He writes:

> "Furthermore, a section through the edge of the silcrete platform in the pipe-line trench, leading from the service reservoir to the treatment plant showed conclusively that the silcrete thickened from nothing at all in the neighbourhood of the Leander beacon to about 25 feet at the edge of the platform".

Where silcrete does form sheets it tends to be patchy and thin, frequently not exceeding a few inches. The two patches on Boekenhout are no more than a thin crust on Witteberg quartzite. The discontinuity of silcrete was also proved in a borehole drilled near the point where the boundary fences of Birchwood Park, Klipfontein and Matjes Kraal meet. The borehole was drilled to a depth of 140 feet at an altitude of 1,480 feet. The nearest silcrete, only one quarter mile to the north, rests at an altitude of 1,380 feet. The borehole drilled passed this depth and stayed all the way in unconsolidated sand.

Conspicuous is the absence of silcrete scarps in the neck of valleys. A scarp may be prominent all along the side of a valley, but a little short of the steep river course the scarp disappears. The many outcrops seen in the field suggest that the most likely section across a scarp of silcrete appears as shown in the sketch below:



Near the southern boundary of Assegaai Bush, on Klipfontein, and also on Roodekop, two distinct levels of silcrete are present, taking the form of two scarps. Each scarp is about 10 feet high, and the one is about 15 feet above the other. Between the two scarps the slope is soil covered, so that the relationship between the two is not known.

Fig.14

Fig.15

Silcrete in south-western Albany is of two types, the massive and the nodular varieties. Frankel (20) has found the same two types near Albertinia, although in south-western Albany the relationship between the two appears to be different from that at Albertinia. Frankel states that at Albertinia the nodular variety is found at or near the surface, and the massive variety forms layers at varying depth. In the area of the present survey the inverse is the case. Good sections of silcrete are exposed in two pits, one in the north-east corner of Sidbury Commonage, and one on Klipfontein. The succession on Sidbury Commonage is as follows (Fig.14).

Soil	1'
Massive silcrete	1' – 1½'
Nodular silcrete	2' – 2½'
Highly leached Witteberg quartzite	?

On Klipfontein nodular silcrete is even interbedded with and found in cracks of massive silcrete. The bulk of the nodular silcrete, however, underlies the massive variety . (Fig.15).

The matrix of silcrete is either siliceous or ferruginous. Frequently it can be observed that over a distance of only a few feet laterally the matrix of silcrete changes from a predominantly siliceous one, to a predominantly ferruginous matrix. This can clearly be seen on Matjes Kraal and south of Sidbury.

<u>Microscopic study of the silcretes</u> The texture and mineral composition of silcrete varies considerably, and it is not easy to give a general description which can be applied to all silcrete present in the area. Broadly speaking silcrete consists of small quartz grains set in a siliceous matrix of smaller quartz grains. The matrix frequently has a brown pasty appearance, may be isotropic, and individual grains may be so small, that they cannot be distinguished under the microscope. The quartz grains are usually angular, and may show replacement texture. Not all the grains are angular, and almost every slide shows at least a few well rounded grains. The maximum size of a single grain which was measured was 1mm. Normally all grain sizes from the size where they can just be recognised under the microscope, to 1mm. may be present. Not always are the quartz grains single crystals, grains of vein quartz consisting of several crystals are quite common. Heavy minerals are almost always present, ilmenite, highly pleochroic tourmaline and rounded grains of zircon being common.

The silcrete on Carlsrust forms a thin layer, which covers the surface of

Fig.16

huge quartzite boulders. A thin section of the contact between the quartzite and silcrete shows that the texture of the quartzite forms a mosaic of equigranular grains, which have been forced apart, or are being replaced by silcrete. Cracks have developed in the quartzite parallel to the contact, and silcrete has infiltrated into these cracks. The cracks do not necessarily follow grain boundaries, but may split grains and force these apart (Fig.16). Recrystallization is incomplete, the texture of the quartzite can still be recognised in the silcrete. Several grains of quartz still form a mosaic which is identical to the texture of the quartzite.

No original texture can be recognised in the silcrete near the eastern boundary of Boekenhout. A mass of isolated angular quartz grains is set in a silcrete matrix. A few of the grains are well rounded. The matrix itself is variable, in places it consists almost entirely of tiny quartz grains, but in the same slide it may also consist almost entirely of a brown, pasty isotropic matrix.

The patch of silcrete between Springvale and Hoffmanskloof shows very little matrix. The grains are angular, and closely packed together. Rounded grains are absent. A few larger grains of vein quartz are present. The silcrete in the south-western corner of Hoffmanskloof consists of disintegrated Witteberg quartzite which has been recemented by a brown pasty matrix. The matrix shows strong crescent-shaped streakiness. The texture of the Witteberg quartzite is still clearly discernible, large numbers of grains are still coherent and form a mosaic.

The silcrete which overlies Bokkeveld shale on Sweetkloof and Welcome Wood is completely recrystallized. No original texture can be detected. The quartz grains are highly angular, but a few rounded grains are also present.

A thin section prepared from silcrete in the north-eastern corner of Sidbury Commonage has a matrix which consists almost entirely of tiny quartz grains, a pasty matrix is almost wholly absent. Many larger quartz grains are well rounded, and there appears to be a rough alignment of long axes of quartz grains. Unfortunately the orientation of the section is not known. Larger quartz grains show cracks which are filled with a thin film of pasty matrix.

The silcrete between Greenvale and Hillside forms a composite sheet. It slopes down the southern side of a hill. Near its northern limit coarse fragments of Witteberg quartzite are cemented together. Southwards the silcrete

Fig.17

Fig.18

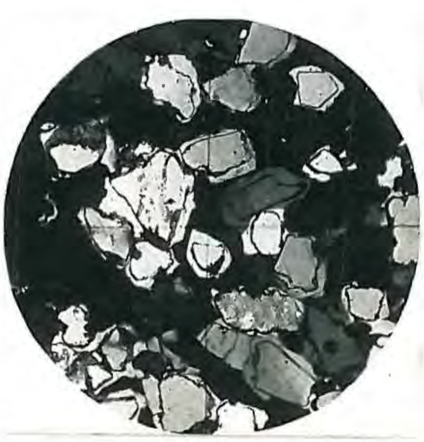
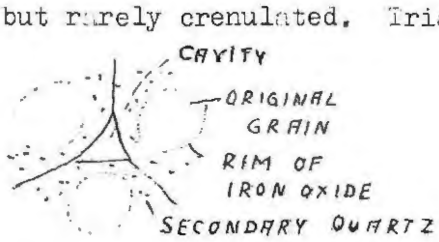


Fig.19

becomes finer, the inclusions of Witteberg quartzite become smaller and smaller. The homestead on Hillside stands on silcrete which has a predominantly ferruginous matrix. South of the homestead this ferruginous silcrete overlies yellow unconsolidated sand. The base of this is not exposed. Figure 17 shows recrystallized Witteberg rubble with a large grain of vein quartz from the northern end of the sheet.

North-east of Midhurst (part of Seven Fountains) silcrete is strongly banded. The bands are steeply dipping, and strike E 7°S. The regional strike of the Witteberg Quartzite is E 30° S. This and the texture exclude the possibility that the banded silcrete is an altered Witteberg quartzite. The quartz grains of the silcrete are angular to subrounded. The matrix consists of extremely fine grained quartz and pasty matrix (Fig.18). The only heavy minerals present are a few grains of ilmenite. The banding of the silcrete is due to a local increase in the proportion of dark pasty matrix. The silcrete has a pale olive grey colour, and the bands are clay coloured. South-east of Midhurst, silcrete crops out from under the sands. This has a normal silcrete texture, but is characterized by a larger proportion of heavy minerals. Zircon , ilmenite and rutile are common. The matrix consists of tiny grains of quartz, brown pasty matrix is concentrated only in a few small spots. A large number of the quartz grains are well rounded.

On Klipheuvel a completely different type of silcrete is found. The narrow scarp on this farm, which continues beyond the eastern boundary of the area, shows in thin section, that it silicified without any matrix (Fig.19). Each quartz grain is surrounded by a thin film of reddish iron oxide. Onto this film of iron oxide secondary quartz has been deposited, which is in optical continuity with the grain. The film of iron oxide clearly shows the nature of the original grains. The original grains are angular to highly rounded. The contact between secondary quartz grains is almost always straight or slightly wavy, but rarely crenulated. Triangular cavities between three grains are



quite common, but they may be filled with quartz, which is not in optical continuity with any one of the three grains. The silcrete is rich in heavy minerals, a greater proportion of tourmaline is present than elsewhere in the area. Other heavy minerals are zircon, ilmenite and (rare) rutile. Where the scarp leaves the area the texture has again changed.

Highly angular to well rounded quartz grains are surrounded by a film of iron oxide. The matrix between grains consists of finely devided brown quartz, some pasty matrix and deep red translucent iron oxide. The rock is very porous. Grains of vein quartz are present. The matrix encroaches on the grains, so that the contact between grains and iron oxide is frequently very indistinct. No secondary quartz in optical continuity with the original grains is deposited. Heavy minerals are tourmaline, zircon and ilmenite. A few of the ilmenite grains are unusually long, with the long axis about 6 times the short axis.

The texture as seen in thin section, and also the field relationship, suggests that the silcrete in the area is of two types, the one is a silicified soil or rubble, and the other appears to be a silicified eolian sand. The presence of well-rounded grains in the former is a little puzzling. A line running roughly from Melville Park to Beacon Hill (part of Schietkop) separates the two types. North of this line silicified soils and rubble are dominant, and south of this line, especially south of the national road, silicified sands appear to predominate.

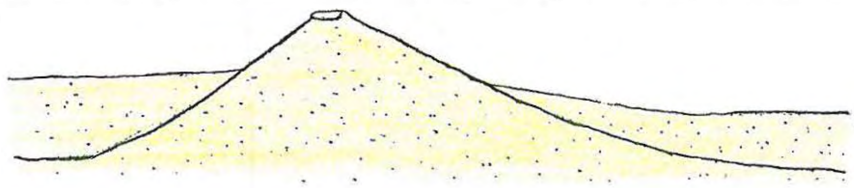
Conical Structures in Silcrete Near Sidbury and on Proctorsfontein unusual conical structures were found in the silcrete. No reference could be found in the literature to any similar structures, and it is thought that the description presented here is the first of its kind. It is for this reason, that silcrete cones are treated at somewhat greater length than their size and frequency might warrant.

Silcrete cones are found along the western boundary of Greenvale, where about one dozen were seen, and an isolated one was found a few yards south of the Sidbury - Grahamstown road on Proctorsfontein. Nowhere else were silcrete cones seen in the area, and Professor Mountain and Mr. Ruddock of the Geology Department, Rhodes University, have assured the writer, that they have nowhere come across similar structures during their extensive field work in the Albany district. The cone from Proctorsfontein, and a small fragmentary one from Greenvale are in the Rhodes University Geology Department collection.

The cones on Greenvale are found on a scarp of silcrete which faces in a north-easterly direction. The length of the scarp is about 0.5 miles. Cones are found on top of the scarp, where the silcrete outcrop is about 30 yards wide, and also on the slope below the top of the scarp. In almost all cases the cones are inbedded in hard silcrete, and it is almost impossible to extract

Fig.20

a good specimen. Several of the cones are not fully exposed, they are partially covered by silcrete, and exposed only where the covering silcrete has been removed by weathering. Frequently it is possible to expose a greater part



of the cone by chipping with a hammer and chisel. The texture of the silcrete of a cone is identical to that of the surrounding silcrete.

All cones have a roughly circular base. The base of cones on top of the scarp is in most cases horizontal, but below the top several cones have a base with a definite slope in the same direction as the scarp. The diameter of the base may be anything from a few tenth of an inch to two inches. The largest diameter measured was 2.25 inches. The cones vary in height, but $\frac{1}{4} - \frac{1}{3}$ of the diameter of the base is a good average. This, however, depends on the apical angle, which also varies. Measurements of the apical angles varied between 105° and 127° (one apical angle is only 80°). 110° is the most common angle. Relative to the horizontal all cones (with one exception) are asymmetrical, one side has a steep angle of dip, and the opposite side has a considerably smaller angle. The cone axis is therefore inclined to the horizontal. The apical angles were measured in a vertical plane between the steep and the small angle of dip, and the compass point of the trace of this plane in the direction of the steep face was noted. This is also the compass direction in which the axis is inclined, but not its direction in space.

A few of the cones show a marginal depression, but in the majority of cases this marginal depression is only partially developed, in a few it is altogether absent.

An interesting feature is displayed by the apex. This was seen to come to a perfect point in only one specimen, in all others the apex has either been bevelled off, or shows a small circular depression(Fig.20) resembling the crater of a volcano. A bevelled apex is very irregular and splintery, almost as if it had received a hard blow with a hammer. The cone from Proctorsfontein (Fig.21) apparently has a cone-in-cone structure. A small section of an inner cone is exposed. The inner cone appears to have a smaller apical angle, but this could not be substantiated by measurements.

The slopes of cones in most cases are gently curved convex upwards and may show weak striation. There is a silcrete cone in the Rhodes University Geology

Fig.21

Department collection, which is said to have been produced artificially during blasting operations in a quarry near Albertinia (Fig.21). This percussion cone is perfectly symmetrical. The apex forms a point, the apical angle is 110^{o}, the base is circular and has a diameter of 2.7 inches. The sides are smooth, and curve gently convex upwards.

The Table below summarises the measurements which could be taken.

TABLE 2

CONE	STEEP ANGLE	SMALL ANGLE	DIAMETER OF BASE	APICAL ANGLE	DIRECTION OF AXIS	REMARKS
1	40^{o}	22^{o}	0.85"	118^{o}	N 60^{o} E	Core poorly exposed. Marginal depression only in N.E.
2	-	-	-	-	W 10^{o} N(?)	A sector of only 90^{o} is exposed.
3	42^{o}	11^{o}	2.25"	127^{o}	W 2^{o} N	Very well exposed Marg.depression all around. Perfect apex.
4a	45^{o}	30^{o}	-	105^{o}	S 60^{o} W	
b	40^{o}	30^{o}	2"	110^{o}	S 30^{o} W	
5	50^{o}	50^{o}	2"	80^{o}	N 15^{o} E	The only symmetrical cone.
6	45^{o}	25^{o}	1"	110^{o}	S 50^{o} W	
7	40^{o}	30^{o}	2"	110^{o}	W 30^{o} N	
Proctors-fontein	-	-	-	115^{o}	-	No field measurements.
Albertinia	-	-	2.7"	110^{o}	-	Artificial cone.

Conical structures in sedimentary rocks have been discussed by several authors. Tarr (69) describes conical structures in calcareous rocks, he states that cones are most common in shales and marls. R. Dietz (1959, 1960, 1961) discusses shatter cones from various localities. He associates conical structure with forceful explosions, and thinks that they are characteristic of meteorite-impact (T.G.S.S.A. 1961). Hargraves (23) describes conical structures in the Vredefort ring, all of which before folding, pointed towards the centre of the structure. Hargraves concludes that the cones were formed by an explosion at the centre of the present ring structure. Brink and Knight (discussion contributed to Hargraves paper) point out, that in experimental work apical angles of less than 90 degrees are produced, if the vertical pressure exceeds the horizontal pressure, and apical angles greater than 90 degrees are produced, if the horizontal pressure exceeds the vertical pressure.

This suggests that the silcrete cones formed essentially under horizontal pressure.

It is highly unlikely that the silcrete cones have been formed by meteorite impact. The cone axes display random orientation, and it would be too much coincidence if a large number of meteorites had struck the silcrete from many directions.

The writer can think of no mechanism which could possibly have set up shock waves sufficiently strong to produce cone structures in silcrete. The cones are, in all probability, not percussion cones, and a simpler, less violent origin has to be postulated. The difficulty is that the cones are apparently confined to the Sidbury area. It is possible, that they are related to some unknown feature, which is peculiar to the Sidbury silcrete. The only logical explanation at this stage seems that the cones were formed through internal stresses set up during the formation of the silcrete.

The Height of Silcrete above Sea Level The elevation of silcrete above sea level varies much from point to point, but generally speaking it is lowest along the southern boundary of the region and from there rises progressively northwards.

The most southerly silcrete in the area on Roodekop, 17 miles from the sea, is found at an altitude of 1110 feet. Two outliers on this farm occur at appreciably lower levels. One is found at an altitude of 1070 feet, and the more westerly of the two at approximately 980 feet. The most elevated silcrete is found along the southern boundary of Boekenhout at 2035 feet. Silcrete is, except for one break, found at all elevations between these two extremes, i.e. over a range of 1055 feet. Careful mapping of silcrete shows that in the region they are rarely flat-lying sheets, are not necessarily found capping hills, but are also found resting on the side slopes of valleys.

In the north-east corner of Komgas Mond the silcrete drops 90 feet in one mile in a south-westerly direction. The silcrete along the boundary between Greenvale and Hillside drops as much as 120 feet in three-quarters of a mile. The sheet north-east of Sidbury varies in altitude between 1650 feet at its western end and just over 1800 feet at its eastern end. A small outlier of silcrete on Sydneys Hope rests against the slope of a ridge 200 feet below its summit, and a similar outlier on Proctorsfontein rests more than 300 feet down the slope from the same ridge. Four small outliers along the northern boundary of Welcome Wood overlie Bokkeveld shales in a valley at an average altitude of

1790 feet. Immediately to the south the Witteberg quartzites rise to 1866 feet, and to the north the ground rises to above 2200 feet in a little over one mile. Along the southern boundary of Assegaai Bush the silcrete lies at an altitude of just over 1700 feet. On Melville Park, where the silcrete leaves the area, it has dropped to an altitude of 1425 feet.

Map 4 shows the variation of the elevation of the silcrete in the form of generalised contours. The map was constructed by determining spot heights on the surface of the various silcrete outcrops. The spot heights were estimated from contours on the topographical sheets, and spot heights, given on these contour maps, were used wherever possible. Contours were then drawn on the assumption that no generalised contour can be extrapolated into a region where the present altitude of rocks older than the Silcrete exceeds that of the generalised contours being drawn.

The contour plan shows some interesting features. The 1100, 1200, 1300(?) 1400 feet contours are fairly evenly spaced lines running roughly east-west, parallel or sub-parallel to the present coast. The 1500 foot contour also runs roughly east-west, but before it leaves the area, it swings sharply to the north and then to the east again. This swing is even more pronounced in the 1600-2000 foot contours. The generalised contours show that the silcrete on Proctorsfontein, Assegaai Bush, Birchwood Park, Lathams Farm, Melville Park and Seven Fountains conforms to the shape of a distinct ridge and a depression parallel to it. This ridge corresponds to a present day ridge which forms the watershed between the Assegaai River to the north-east and the Kazaar River, Komga River and the system of rivers which flows in a south-westerly direction to Boesmanspoort. The valley in the pattern of generalised contours, coincides in position with a present day valley carved by the Assegaai River out of the soft upper Witteberg shales on Assegaai Bush, Lathams Farm and Melville Park.

Between Komgas Mond and Sydneys Hope the silcrete rises gradually from 1100 to 1820 feet over a distance of seven miles, i.e. a gradient of about 100 feet per mile. Between Sydneys Hope and Boekenhout, no silcrete is found between 1820 and 2035 feet. This may be connected with the abrupt steepening of the slope on Sydneys Hope and Proctorsfontein.

The highest occurrence of silcrete at 2035 feet on Boekenhout is almost at the same elevation as the silcrete around Grahamstown (2050 - 2200 feet). North of the highest occurrence silcrete again occurs at lower levels. On Carlsrust it lies at an elevation of 1936 feet. The most northerly patch of silcrete, on

Hoffmans Kloof and Springvale, is 1860 feet above sea level.

The investigation has shown that in south-western Albany district, silcrete of different origins is present. Some silcrete forms a silicified soil or sub-soil, other has been derived from a sediment.

The study of the elevation above sea level of silcrete, clearly shows that the silcrete corresponds to an undulating surface, and not to a simple plain sloping continually seawards. The relationship between silcrete and the Tertiary coastal peneplain may be one of the following:

a) Silcrete formed on an undulating coastal peneplain, which determined the later drainage pattern.

b) The modern drainage carved up the coastal peneplain, and silcrete only formed after this pattern had been established.

c) Silcrete of different ages is present. Successively younger silcrete formed at increasingly lower levels, as the rivers incised deeper into the coastal plain.

It is not possible to say, at this stage, which is correct.

WINDBLOWN SAND

Fully 22% of the area in the southern half is underlain by a fine grained sand, which obscures much of the structure of the underlying Cape rocks. Except for river alluvium the surface sands form the youngest formation in the region. They are found to overlie all other rocks. Haughton (25) described the limestones north of the Bushmans River and included them as part of the continental type of deposit of the Alexandria Formation. The writer is in agreement with Haughton, that the deposit does not have a marine origin.

The sands are extraordinarily uniform. They are very fine grained, and even the smallest grains are well rounded and polished. This, and the complete lack of any fossils or shell fragments, the absence of conglomerates within the sands and the presence of an abundance of stone implements, seems to preclude a marine origin.

The Geological Survey also regards the sand as being of eolian origin. Engelbrecht, Coertze and Snyman (18; p 27) state:

"Op die noorde grens van die gebied lê eoliese sand van Tersiêre tot Resente ouderdom bo-op die ferrikreet en silkreet".

Haughton apparently did not recognise that the limestones, which he mapped

Fig.22

Fig.23

as calcrete (Cc) on Cape Sheet 9 - Port Elizabeth, are only part of a deposit which is much more extensively developed north of the Bushmans River than is shown on that map. The windblown sand can be divided into three types:

a) Calcareous sand (calcrete). This forms a hard white surface crust, but below the surface it consist mainly of unconsolidated or semiconsolidated sand, coloured white or creamy by finely divided calcium carbonate. The calcareous sand is very fine grained, consists entirely of well rounded quartz grains and a calcareous matrix. The occurrences of calcareous sand are very erratic, and cannot be mapped as a continuous deposit. On the map the calcareous sand has been marked Cc.

b) Red sand. Much of the windblown sand is not calcareous, but rich in iron oxide. It gives the deposit a deep brown-red colour. Except for the matrix the red sand is similar to calcareous sand. It is marked RS.

c) Grey sand. Over much of the area no matrix is present, but only a fine grained grey sand. Whether a calcareous or ferruginous matrix was ever present is not known. Grey sand grades into Witteberg soil at its northern limit near Sidbury. It is marked GS on the map.

Grey sand overlies silcrete on Seven Fountains. The deposit appears nowhere to be very thick. A little west of Midhurst (part of Seven Fountains) silcrete protrudes through the sand cover. Where the national road cuts through the silcrete scarp at the entrance to the Nazaar River valley (Fig.23) the deposit of windblown sand is from 1 to 5 feet thick, and overlies ferricrete. Several stone implements were extracted from the windblown sand immediately above the contact with ferricrete. On Matjes Kraal, where only a little silcrete is found, much is covered by grey sand, and it is not known whether silcrete does underlie the deposit.

A borehole sunk near the point where the boundaries of Matjes Kraal, Klipfontein and Birchwood Park meet, has pierced through 140 feet of unconsolidated sand before striking solid rock. The south-western corner of Birchwood Park, and almost the entire eastern half of Klipfontein are covered by windblown sand.

150 feet of unconsolidated material was encountered on Roodekop in a borehole about 50 yards south of the point where the road crosses the Roodekop-Komgas Mond boundary. The borehole was sunk at an altitude of about 1330 feet. The farm Roodekop takes its name from a hill of the same name, which is covered by red sand. The Roodekop beacon stands at an altitude of 1425 feet. The surrounding silcrete rests at an elevation of 1200 feet. More than 200 feet of

sand may therefore be present. 600 yards east of the beacon, calcareous tufa and calcareous sand are exposed in a small quarry.

In the north eastern corner of Komgas Mond a large number of broken bones was found embedded in calcrete. The bones are exposed in a quarry which is about eight feet deep.

South of Thorneycroft (part of Klipfontein) red sand covers a hill which rises to 1406 feet. Numerous nodules of calcareous tufa are present in the soil. A hard calcareous tufa is found on the southern slope of the hill. The thickness of the deposit on this hill also appears to be about 200 feet.

Between Thorneycroft and Komgas Mond grey sand is exposed in road cuttings. Nodular ferricrete has formed in abundance on the freshly exposed surfaces, but underneath the ferricrete uniform grey sand is found. Stone implements are common in the grey sand. In the south-western corner of Klipfontein, the national road passes through a cutting in a hill, which is cut entirely in calcareous sand. Here the deposit appears to have a thickness of 130 feet. An interesting borehole has been drilled near the homestead on Komgas Mond at an elevation of 1270 feet. The borehole passed through 235 feet of unconsolidated material, striking solid rock at 1035 feet. The nearest rock outcrop, 400 yards to the north, is at an elevation of 1250 feet. The surface under the windblown sand has thus dropped 215 feet in 400 yards. The borehole may be situated above an old valley, completely filled with sand.

Near the western boundary of Grootfontein, the national road cuts through a thin layer of calcareous sand and exposes steeply dipping Bokkeveld shales. The base here is at an altitude of 1000 feet, and the overlying sand is only about 12 feet thick. In the thick bush on Grootfontein and the southern part of Schietkop it is virtually impossible to map the limits of the Windblown Sand accurately. Facing the Komga River on its western side, the sand is mainly in the form of surface tufa, but further west on Schietkop this passes into grey and red sand. All along the national road on Schietkop there seems to be no great thickness of sand present.

South of Brentwood (a part of Schietkop) the base is exposed at 930 feet in a quarry. Only a few feet of red sand overlie Witteberg quartzites. Northwards however, the sand thickens considerably. West of Beacon Hill (part of Schietkop) the base is exposed at 1170 feet. The beacon on Sidbury Hill stands at an elevation of 1543 feet. Theoretically about 370 feet of sand could be present.

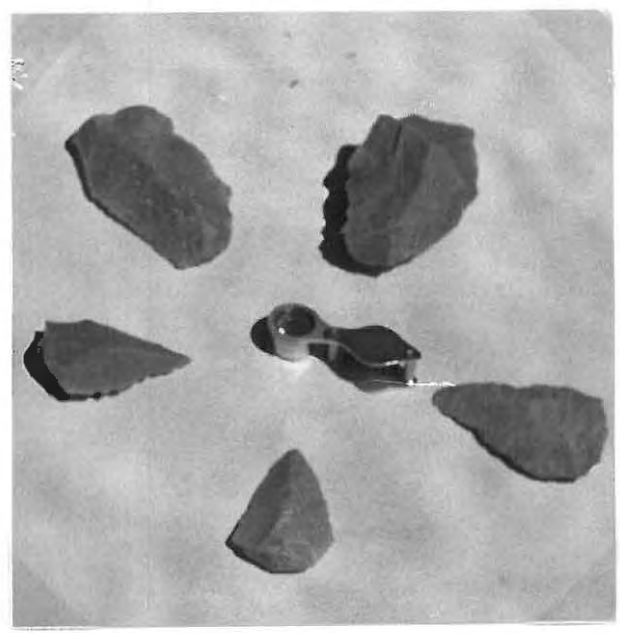


Fig.24

This may, however, be far from the truth, and evidence from Springfield suggests that the base may have the same direction of slope as the surface of the overlying sand. Near Beacon Hill, on the west side of Sidbury Hill, calcareous sand is exposed in a quarry. The floor of the quarry is about 1350 feet above sea level. On the eastern side of the same hill, and at the same elevation, there is no trace of any calcareous sand in a deep donga. The vertical exposure is about 50 feet high and consists entirely of red sand, which is absolutely uniform in character. No sedimentary features such as bedding or cross-bedding, could be detected. A well shaped Middle Stone Age implement was found embedded in the sand about 6 feet above the floor of the donga. Halfway between Beacon Hill and Brentwood, a donga exposes the windblown sand to a depth of about 30 feet. Here again a Middle Stond Age implement was found embedded in the side. Nodular ferricrete forms thin bands. The floor of the donga shows streaks of ilmenite.

In an erosion pit in the extreme southern corner of Springfield, the base of the Windblown Sand is exposed at 1300 feet. The deposit is about 20 feet thick and consists entirely of red sand. Masses of water-worn pebbles are exposed on the floor of the donga. Many of the pebbles show distinct signs of chipping. The natural exposure of the donga has unfortunately been interfered with in an attempt to stem the erosion. Large boulders have apparently been thrown into the donga, and it is not possible to say what is in place and what has been dumped. Nevertheless isolated pebbles and stone implements can be dug out of the steep or even vertical sides of the donga. The upper ten feet are very uniform, pieces of quartzite, pebbles and stone implements occur below that level. Besides Witteberg quartzite pebbles, abundant ferricrete is found on the floor and lumps of nodular calcareous tufa are common. The floor of the donga consists of a partly recrystallised Witteberg quartzite (p.11) which has lost all signs of bedding planes. Its surface has a polished appearance and is highly pitted. The floor is not horizontal, it slopes uphill in the same direction as the top of the overlying sand, but at a smaller angle. This suggests that the surface under some of the sand is not horizontal, but slopes in the same direction as the surface of the overlying windblown sand. In this donga on Springfield the drop of the base is about 100 feet in 400 yards. Above the donga there is a small quarry, in which one foot below the surface three water-worn pebbles were found. Isolated pebbles were also seen on the surface in the vicinity. The presence of pebbles in the windblown sand is a little puzzling, but in the same way as the stone implements they may have been dropped by pre-historic man.

Along the boundary between Schietkop and Doornrug, lumps of calcareous tufa, over one foot in diameter, are ploughed up in the red sand. On Doornrug, Bushmans River Outspan and on Papenkuilsfontein, calcrete overlies the Wood Beds of the Cretaceous System. No estimate of the thickness can be given here. Near the western boundary of Doornrug, calcareous sand is exposed in a quarry, where the deposit is strongly cross-bedded. This is the only occurrence in the region where any sedimentary features have been observed. The base is not exposed. North of the Zuurberg Fault, on Doornrug, calcareous sand covers a ridge of Witteberg quartzite. A second ridge further north is capped by red sand. Immediately north of the fault, and just below the calcareous sand a single crystal of calcite, the size of a tennis ball, was found. Its origin is obscure.

On Sidbury Park the Windblown Sand grades into the soils derived from Witteberg quartzite, and the two can only be distinguished with the aid of a hand lens or a microscope.

West of the Bushmans River, some difficulty was experienced in mapping the Windblown Sand. Much sand has been washed into the shallow valleys of tributaries to the Bushmans River. The northern limit can be fixed with little difficulty. Calcareous tufa overlies Witteberg quartzites on Doornkloof, Retreat and Witteclayrug. Here it covers the Zuurberg Fault for three miles. South of Boesmanspoort, the sands are not found east of the railwayline. The railway cuttings show boulder beds which appear to be riverworn and part of recent alluvium. Near the western boundary of Brakfontein the base is exposed at 960 feet in a quarry, where the sand overlies Wood Beds. This is the only exposure of Wood Beds which was seen west of the Bushmans River.

The three varieties of windblown sand form fairly distinct belts. Calcrete is confined to the area south of a line drawn from Doornkloof to Klipheuvel. Grey sand is predominantly found north of a line drawn from Amberley (part of Sidbury Park) to Klipheuvel. Red sand forms a wedge between calcrete and the grey sand belts. The deposits do grade into one another. It is especially common for calcrete and red sand to occur side by side. The lines cannot be regarded as sharp lines of demarkation. The reason for the zoning is not known.

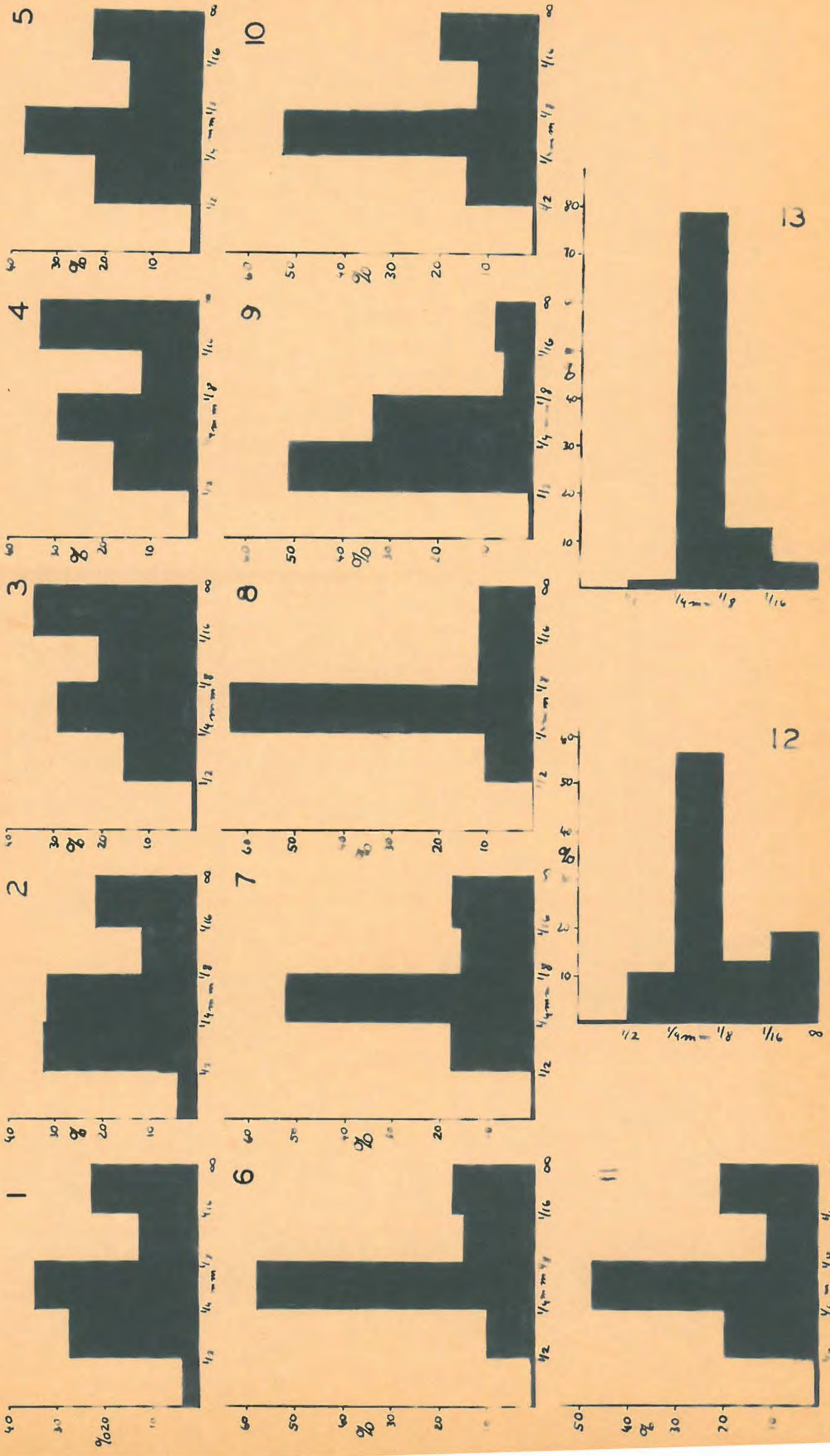
Some difficulty was experienced in demarkating the northern limit of the

TABLE 3

Grade \ Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13
+30	3.61	3.81	0.87	1.13	1.89	0.25	0.24	0.14	0.02	0.04	0.52	0.16	0.02
30 - 44	9.83	14.60	4.37	6.06	6.02	2.02	2.91	1.99	9.18	2.29	4.66	1.85	0.02
44 - 60	17.46	17.80	10.90	11.66	16.54	8.09	14.45	7.96	43.10	12.20	15.54	8.41	1.80
60 - 85	22.41	20.15	16.10	16.72	23.41	28.95	28.10	33.90	24.68	33.00	30.55	29.48	2[illegible].40
85 - 120	11.88	11.35	13.04	13.05	13.63	28.78	24.00	30.43	9.15	19.71	17.06	27.61	[illegible]1.75
120 - 200	12.51	11.11	20.45	11.70	15.21	14.78	15.61	11.29	5.81	12.43	11.09	13.02	12.79
- 200	22.40	21.25	34.23	33.81	23.02	17.18	17.50	11.48	8.15	20.25	20.59	19.44	5.97
	99.90	100.07	99.96	100.13	99.72	100.05	99.81	100.19	100.09	99.92	100.01	99.97	99.93

SAMPLES: 1. Witteberg soil, Faberskraal. 2. Witteberg soil, Boekenhout. 3. Witteberg soil, Springvale. 4. Witteberg soil, Proctorsfontein. 5. Witteberg soil, Assegaai Bush. 6 - 8. Windblown sand, Sidbury Park. 9. Windblown sand, Schietkop. 10. Windblown sand, Klipfontein. 11. Windblown sand, Matjes Kraal. 12. Windblown sand, Matjes Kraal (above ferricrete). 13. Sand, Matjes Kraal, (sand locality as 12, but underlying ferricrete).

HISTOGRAMS TO ACCOMPANY TABLE 3



windblown sand around Sidbury. Here grey sand and Witteberg quartzite soil of similar appearance grade into one another.

In order to find some distinguishing features, grade analyses were carried out on five samples of known Witteberg quartzite soil, and seven samples of known windblown sand (see Table 3 and the accompanying histograms.) The Witteberg quartzite soils all show a fairly even distribution of all grain sizes. Six out of the seven windblown sand samples show a marked peak in the $\frac{1}{4}$ to $\frac{1}{8}$ mm range.

Visual roundness and sphericity tests on grains were carried out on three Witteberg quartzite soil samples and on three windblown sand samples. In each case 100 grains in the -30 to +44 range were compared visually with a roundness and sphericity chart (37; p 81). The results were averaged and are summarised in the table below. The sample numbers are the same as in Table 3.

TABLE 4

SAMPLE NO.	ROUNDNESS	SPHERICITY	TYPE OF SAMPLE
1	0.335	0.705	Witteberg quartzite soil
4	0.373	0.705	" " "
5	0.367	0.700	" " "
7	0.748	0.741	Windblown sand
9	0.746	0.694	" "
10	0.716	0.728	" "

The table shows that the sphericity of grains of Witteberg quartzite soil and of windblown sand is very much the same, but there is a marked difference in the rounding of the grains.

The histograms of six of the seven windblown sand samples are very similar, indicating that the Windblown Sand is very uniform in character over the whole area.

There is, however, a marked difference in samples 12 and 13. Sample 12 is a windblown sand overlying ferricrete on Katjes Kraal. Sample 13 is a yellow sand a few feet below sample 12, and separated from this by a layer of ferricrete. As would be expected, the grade analyses strongly suggest that the Windblown Sand is a deposit different from the uniform sand underlying the ferricrete.

No practical application was made of the results. With experience it was soon possible in the field to tell a Witteberg quartzite soil apart from a windblown sand with the aid of a handlens.

The number of stone implements found embedded at various depths in the Windblown Sand indicates that it is a very young geological formation. It dates to a period when Man already walked on the surface of the earth.

Deposition of the Windblown Sand must have taken place during a hot and dry period of the South African Pleistocene. The material was probably derived from the Alexandria Formation, to the south and south-west of the area, and carried inland by strong onshore winds.

ALLUVIUM

Unconsolidated sand and conglomerates are found on the flood plain of the Bushmans River and on several terraces up to 130 feet above present river level.

The alluvial deposits and river terraces were not studied in detail.

THE STRUCTURE OF THE AREA

INTRODUCTION

The structure of the area is complex and for the purpose of description may be considered in three parts:

A) The structure of the Cape System. This system lies at or near the surface over seven-eighths of the region. The rocks have been intensely deformed and folded into a series of parallel anticlines and synclines, which trend from 23 to 28 degrees S of E.

B) (I) The structure of the Stormberg Volcanics and of the Cretaceous System and their relationship to the Witteberg Quartzite against which they lie in the south-western corner of the area.

(II) The structure of Tertiary to Recent sediments and their relationship to older rocks.

C) The area of the present survey seen in its regional setting.

The principal fault separating the Cape System of the Zuurberg from the Uitenhage Series and Stormberg Volcanics, generally known as the Zuurberg Fault, will also come up for consideration. Post-Cretaceous movement on this fault has been claimed by Haughton, who states (25;p. 8),

> "At the end of this (Cretaceous) deposition the region suffered faulting. The largest fault is that known as the Zuurberg fault which now forms the northern boundary of the Uitenhage Basin. This cut athwart the strike of the folded rocks and let down the beds on its southern side. The fault plane is not straight, but is bowed at its eastern end, with concave side facing the south, and is broken near the Bushmans River by a series of step faults which throw it to the south on the eastern side".

The age of this fault will be reviewed in later pages in the light of associated structural phenomena on either side of it.

(A) THE STRUCTURE OF THE CAPE SYSTEM

THE NORTH-EASTERN ANTICLINORIUM

The north-eastern corner of the region on Boekenhout, Carlsrust, Faberskraal and neighbouring farms is structurally dominanted by an upward movement. The Bokkeveld Series is exposed in a long and broad anticlinal strike vale, which can be traced for nearly twenty miles beyond the eastern boundary of the area. At its western end, on Boekenhout and on Carlsrust, the Bokkeveld pitches under the Witteberg quartzite in a direction W 17° N. Near the Carlsrust beacon the angle of pitch can be measured at 4 to 5^{o}.

Due to poor outcrops it was not possible to obtain structural data from the Bokkeveld shales, but details of the structure of the anticline were obtained from points in the Witteberg quartzites immediately above the Bokkeveld shales.

South-west of Highlands, on Carlsrust and on Boekenhout, the Bokkeveld and Witteberg in plan send a number of short tongues into one another. Detailed measurements of angles of dip show that each tongue of Bokkeveld shale extending into the Witteberg quartzites corresponds to a small anticline, and each tongue of Witteberg quartzite extending into the Bokkeveld corresponds to a small syncline. The structure is therefore an anticlinorium.

Between Highlands station and Milburn (part of Carlsrust), a distanceof three miles, the anticlinorium is folded into six smaller anticlines separated by five synclines (Section 3). Along the eastern boundary of Carlsrust the Bokkeveld outcrop is 2$\frac{3}{4}$ miles wide but despite such a wide outcrop, the western termination of the Bokkeveld Series is fairly abrupt, and takes place over a distance along strike of only 2$\frac{1}{4}$ miles. This sudden termination is brought about by the small angles of dip in the minor structures of the anticlinorium, and the pitch of the strata.

The angles of dip of the smaller anticlines and synclines rarely exceed 10 to 20 degrees. South of Carlsrust beacon one fold limb does exceed this value, where the Bokkeveld-Witteberg contact dips north at 45 to 65 degrees.

The southern limb of the anticlinorium is very simple; it dips at a uniform angle of 15 - 25^{o} in a southerly direction. There is no reversal of dip, and the complete Witteberg Quartzite succession is continuously traversed, until the Upper Witteberg Shales are reached on Melville Park, Lathams Farm and Assegaai Bush. At the Highlands railway station, and for some distance towards Alicedale, the Bokkeveld-Witteberg contact is locally overfolded to the north, and dips 50^{o} in a southerly direction. 850 yards west of Highlands station the dip becomes normal again, measuring 50^{o} in a northerly direction and still further west it flattens to 25^{o}.

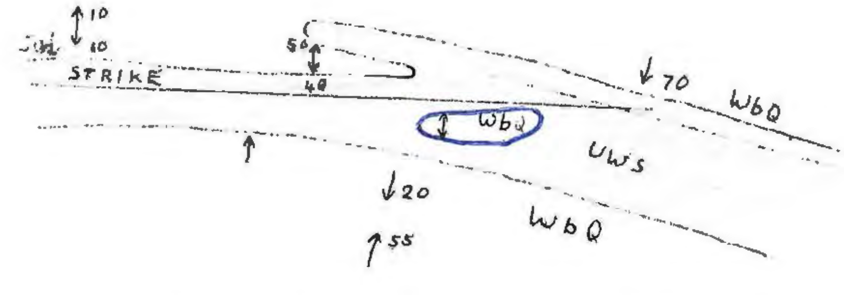
In a westerly direction, on Boekenhout and Springvale, the Witteberg Quartzite continues to pitch in the direction W 17^{o} N, but the structure becomes simpler. The large number of smaller anticlines and synclines present at the base of the Witteberg Quartzite, is not present higher up in the sequence. North of the Upper Witteberg Shales on Springvale, only one anticline and one syncline are observed, where over a comparable distance across strike on Boekenhout three anticlines and two synclines are present.

THE STRUCTURE ON HOFFMANS KLOOF AND SPRINGVALE

Proceeding in the direction of strike from the area previously described, pronounced changes can be observed. The Witteberg succession, which between Carlsrust and Lathams farm, dips continuously southwards, takes on a different structure to the west and north-west, where it is folded into a series of narrow anticlines and synclines. Ultimately, on the western part of Hoffmans Kloof the succession dips almost continuously northwards. The Upper Witteberg Shales are found on Hoffmans Kloof and Springvale in a narrow, steeply dipping syncline.

Topographically this syncline forms a most pronounced feature which can be traced for six miles. In cross section it forms a U-shaped valley, resembling a glacial trough. The shales on the floor of the valley are flanked on either side by quartzites which rise from 50 to 350 feet above the valley floor. The northern limb of the syncline dips for most of its length 70° in a southerly direction, and only towards the western boundary of Hoffmans Kloof does the dip flatten to 30°. The dip of the southern limb is normal in direction on Springvale, i.e. 70° towards the north, but on Hoffmans Kloof the Witteberg Quartzite locally overlies the Upper Witteberg Shales. This overfolding is nowhere very extensive, and at only short distances south of the contact the dip is everywhere to the north again.

The axis of the syncline trends W 21°30' N on Springvale. It changes abruptly midway across Hoffmans Kloof to W 9°30' N. i.e. through an angle of 12°. Where this change of strike takes place, the structure is seen to be more complex



than that of a simple syncline. Two small anticlines are superimposed upon the main syncline, a phenomenon reflected in the outcrop pattern of the quartzite-shale contact as well as by local dips.

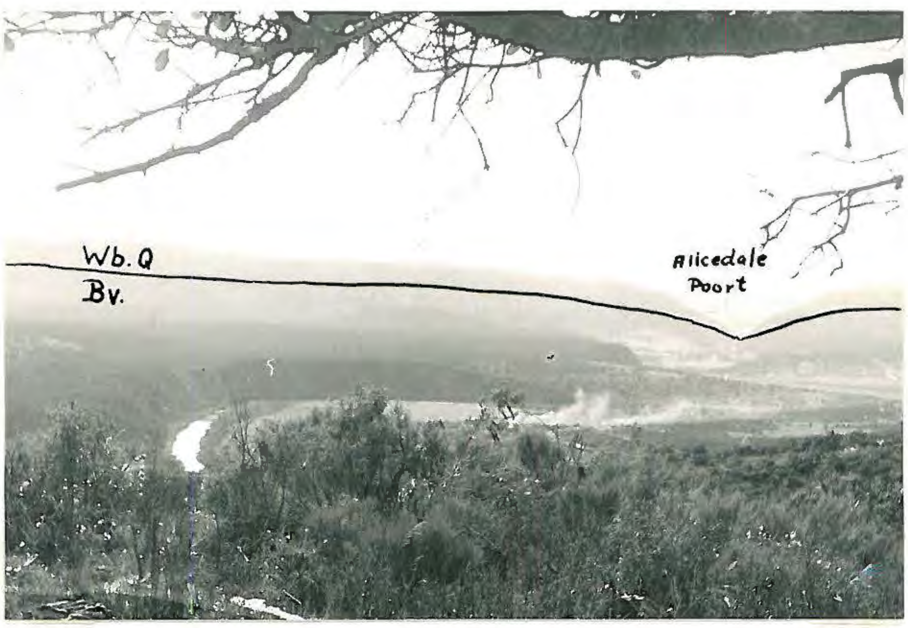


Fig.25

THE NORTH-WESTERN ANTICLINORIUM

As in the north-eastern so in the north-western part of the region an anticlinorium dominates the structure, also with Bokkeveld exposed in the core. The main northern limb has a normal dip direction to the north, but the southern part of this anticlinorium is complicated by two strike faults. As a result of the anticlinorial structure and a pitch of the folds in an east-south-easterly direction the Witteberg Quartzites and the Bokkeveld Shales constitute, in plan, long interlocking tongues, corresponding to minor synclines and anticlines.

The Bokkeveld-Witteberg contact, from Groot Tootobie to Sweetkloof, dips almost continuously northwards at angles of 30 -40°. At the entrance to Alicedale Poort, however, the contact is abnormal. The Witteberg quartzites are intensely contorted, thrust-faulting can be observed and the dip is towards the Bokkeveld shales. Evidence from current bedding is inconclusive, and it is not possible to state whether there is overfolding to the north. The contact at Alicedale Poort may be bounded by a fault.

Bokkeveld shales are exposed in the core of an anticline on Sweetkloof and Welcome Wood. The outcrop of the shales is 1½ miles wide on Roodekrantz, but becomes narrower in an easterly direction. The shales disappear from view on Welcome Wood, where they pitch under Witteberg quartzites in the direction E 24° S. The exact nature of the termination is not known, as the outcrops are poor. The direction of the pitch of the anticline on Welcome Wood is opposite to the direction found on Boekenhout. On Welcome Wood the flanks of the anticline become steeper towards the apex. Quartzites of the northern limb dip 40° N at the contact between the Bokkeveld and the Witteberg, flattening northwards to 20°. The southern limb dips 45° in a southerly direction at the contact, and here also the quartzites flatten to 20° one half mile further south. The limbs of the anticline on Welcome Wood are consequently concave upwards. Progressively westwards, on Sweetkloof, the southern limb of the anticline becomes steeper, and south of Excelsior (part of Sweetkloof) the Bokkeveld-Witteberg contact dips north at 75°. It is inferred that either the strata are overfolded to the south, or a fault separates the two series locally.

Bokkeveld shales are exposed in the core of a second minor anticline on Sidbury Park and on Springfield. Near the eastern boundary of Roodekrantz the width of outcrop of the Bokkeveld is 1½ miles, but in the same way as the anticline on Sweetkloof and on Welcome Wood, it tapers considerably in an easterly direction and forms only a narrow strip where it passes under surface sands. The shales pitch under the quartzites in the same direction as on Welcome Wood. A wrench-fault dislocates the anticline east of Highfield (part of Sidbury Park). This fault trends N 32° E. It is dextral, its eastern side being displaced to the south. The northern limb of the anticline shows a displacement of approximately 250 yards, but the southern limb appears to be displaced by only about 140 yards. (This differential displacement is not clearly shown on Map 1.)

The structure of the Witteberg quartzites between the two anticlines is not that of a single syncline. The trace of the contact and dips of the quartzite suggest that at least three minor synclines separated by two anticlines should be present. Two small synclines are observed in the north-eastern corner of Sidbury Park and on Welcome Wood. Nevertheless the predominantly northerly dip between Excelsior and Highfield does appear to be somewhat anomalous. It has probably been brought about by local overfolding.

South of Highfield the quartzites of the southern limb of the anticline dip in a southerly direction at 25° - 50°. North-east of Carn Ingley (part of Springfield) a dip to the north has been observed. This minor syncline, on the flanks of the anticline, does not appear to assume any magnitude; north-west of Carn Ingley it is not observed and the quartzites dip continuously in a southerly direction. The road between Sidbury and Eagles Crag runs in a strike valley on Bokkeveld shales, west of Sidbury Park. To the north of these shales the Witteberg quartzites, as noted above, dip towards the south, and therefore towards the Bokkeveld in this valley. The trend of this Bokkeveld-Witteberg contact is E 32° S., whereas the strike of the folded quartzites around Carn Ingley is E 22° - 25° S. These observations suggest that the contact between the quartzites and shales is a fault trending about 10° from the strike of the Witteberg. The fault has a downthrown side to the north. On Sidbury Park it throws Witteberg against Witteberg and disappears under surface sand. South of the road from Sidbury to Eagles Crag the Bokkeveld everywhere dips south towards, and therefore under, the Witteberg quartzites, which from Sidbury Park westwards to as far as the railwayline also dip in a southerly direction (Section 1).

THE STRUCTURE ON LOCHNKLOOF, RETREAT AND LOCHNRUG

The interpretation of the structure of the northern portion of the area presented no problems on any large scale. The first problem of any magnitude, stratigraphic and structural in character, was encountered south of Eagles Crag, where it was anticipated that quartzites on Doornkloof and Retreat would dip south and form the southern limb of the north-western anticlinorium. A traverse along the railwayline from Eagles Crag to Boesmanspoort revealed that this was not the case. The quartzites on Doornkloof and Retreat do not dip in a southerly direction, but have a continuous northerly dip of 35° towards the Bokkeveld shales, which crop out in the core of the anticlinorium. The problem became more complex with the discovery of two prominent shale bands, apparently interbedded with the quartzites. No similar shales are interbedded in the Witteberg quartzites of the northern limb of the anticlinorium.

One shale band is found a little north of Boesmanspoort. It enters the area on Doornkloof. On Retreat the bed of the Bushmans River follows it for a distance of nearly 1½ miles. On Doornrug the band becomes considerably narrower and disappears under a cover of superficial sand. It was not seen in the kloof north of the eastern extremity of the volcanic rocks. This shale band will, from now on, be referred to as the "southern shales".

The second shale band, which will subsequently be called the "middle shales" crosses the railwayline a little north of the Bushmans River railway bridge. The identity of the "middle shales" was not established with certainty, and for this reason they have not been drawn separately onto the accompanying map, but have been included with the Witteberg.

Lithologically there are marked differences between the "southern" and the "middle shales". The "southern shales" are highly fissile and break into paper thin flakes. The fresh rock is dark blue, but the weathered shale changes to a khaki-grey colour. Mica is present, but the flakes are almost invisible to the unaided eye. The general appearance of the "southern shales" is very similar to that of the upper Witteberg shales exposed in the road cuttings near the Nazaar River. The "middle shales" consist chiefly of micaceous sandstone, with in places well developed small scale cross-bedding, and interbedded shales. Lithologically the "middle shales" are similar to Bokkeveld shales exposed in the north-western anticlinorium.

During the subsequent investigation, three alternative interpretations were kept in mind:

a) The beds represent a phase of the Bokkeveld, since they appear to dip under shales which occur beneath known Witteberg. This appeared to be

Fig.26

highly improbable from the outset, however, as it was possible to trace the quartzites laterally into known Witteberg quartzites.

b) The beds belong entirely to the Witteberg Series with locally thick interbedded shales and an anomalous northern contact with the Bokkeveld.

c) The quartzites are the Witteberg Quartzite, and the shales belong either to the Upper Witteberg Shales, the Bokkeveld Series or to both.

It appeared, that, on the evidence found along the railwayline, no attempt could be made to identify the succession or interpret the structure. For this reason it was thought that structural features beyond the confines of the region should be examined. Little assistance could be gained from the structure to the south-east, which, as will be shown, is disturbed by transverse faulting, and has much hidden by overlying sand. Selected areas to the west were chosen instead.

Five miles west of the Bushmans River, along the new national road which crosses the Zuurberg north of Paterson, the succession is very similar to that along the railwayline. The "southern shales" are very prominent, and quartzites south of these dip in a northly direction. The "middle shales" were not seen, instead a single quartzite band is found which dips continually northwards until the Bokkeveld shales of the north-western anticlinorium are reached. In places the Bokkeveld is well exposed in road cuttings. For a considerable distance north of the contact the shales dip in a southerly direction at 50°, i.e. towards the quartzites.

Four miles north-west of Paterson an anticline was discovered in a kloof in the quartzites south of the "southern shales". This anticline was not seen along the new national road north of Paterson. It is reasonable to assume, that its axis has been intersected by the Zuurberg Fault somewhere between Paterson and the kloof. The quartzites north of the "southern shales" dip in a northerly direction at 55°, but outcrops beyond the contact are obscured by soil and thick vegetation.

An inspection of aerial photographs revealed that the "southern shales" can be traced from Doornrug for more than twenty miles beyond the western boundary. In the old Zuurberg Pass (Map 3), 15 miles west of the area, the "southern shales" overlie a thick succession of northerly dipping quartzites, which 1500 yards south of the contact turn over into an asymmetrical anticline

Fig.27

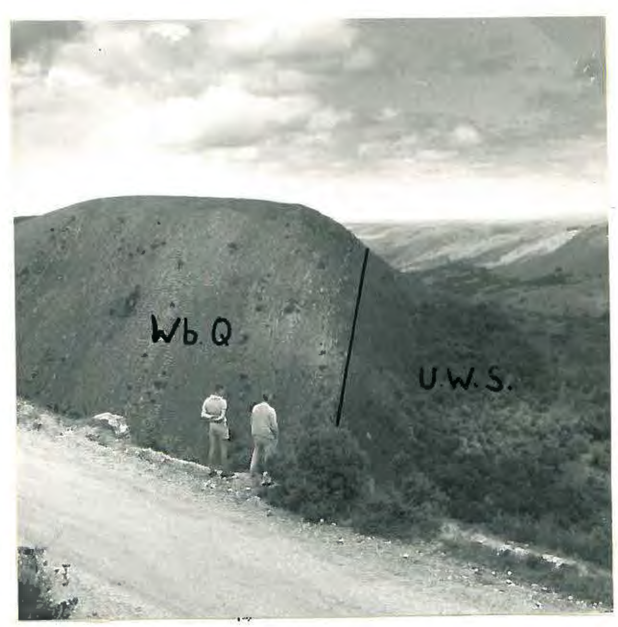


Fig.28

(Fig.27), the same anticline which is seen in the kloof north-west of Paterson, and which is intersected by the Zuurberg Fault near the new national road. The steeper limb of the anticline dips towards the south. 1700 yards south of the axis of the anticline the quartzites are overlain by shales, which are the same shales as the "southern shales" of the northern limb. These shales of the southern limb are in turn overlain by Dwyka Tillite.

This relationship established beyond doubt that the shales underlying the tillite are the Upper Witteberg Shales. The "southern shales" are consequently also the Upper Witteberg Shales. Their identity, suspected on lithological grounds, was thus confirmed on structural evidence.

Once the identity of the "southern shales" had been established, the remaining problem, that of the relationship between the "southern shales" and the quartzites to the north, became comparatively simple. The quartzites had to be Witteberg, they resemble the Witteberg quartzites in every respect. Moreover, no similar quartzites are known to occur in the lower portion of the Karroo System. The apparent overlying position of the Witteberg Quartzites relative to the Upper Witteberg Shales (the "southern shales") could only be explained by one of two structural features, either by a fault or by overfolding. (Later arguments will be presented, which suggest, that, at least on Doornkloof and Retreat, both may be present).

The Witteberg quartzites to the north of the upper Witteberg shales ("southern shales") dip in a northerly direction at 70°. The contact appears to be perfectly normal, a fault does not seem to be present (Fig.28). A careful study of truncated cross bedding revealed, that the quartzites are in fact inverted to the south, and that the upper Witteberg shales rest in an overfolded syncline. Overfolded quartzites crop out over a width of about 1500 yards, which is equivalent to a vertical thickness of about 4,200 feet. This figure is far in excess of the thickness of 2,500 feet (p.48) generally accepted for the Witteberg Quartzite. Drag folding in the overfolded quartzites appears to be responsible for this increase in thickness.

The inverted quartzites give way to upright quartzites very abruptly, as indicated by truncated current bedding. A change in dip is not immediately noticeable and consequently an isoclinally inverted anticline is present. Towards the Bokkeveld the structure of the Witteberg becomes somewhat more complex, and it is not possible to say with certainty, whether a fault separates the two

Fig.29

series at this point as it does further to the east. It is interesting to note, that the Witteberg quartzites north of the Bokkeveld shales are inverted gently to the north, with dips of about 80° in a southerly direction (See Map 3).

When the structure between Eagles Crag and Boesmanspoort was re-investigated, it was discovered that the same cross-bedding relationship exists as in the old Zuurberg Pass, and that the isoclinally overfolded syncline and anticline are also present on Doornkloof, The Retreat and Doornrug.

The exact position of the anticlinal axis was not determinable. The approximate position is one quarter of a mile north of the railway bridge which crosses the Bushmans River on Retreat.

The quartzites north of the "middle shales" are not inverted, truncated current bedding shows that for the greater part the quartzites are in normal sequence, dipping in a northerly direction at 30°. Immediately south of their northern contact with shale, however, there exists, in a railway cutting, a sharp, almost isoclinal anticline, overfolded to the south. It has not proved possible to assign any special significance to this localised feature, but it is perhaps associated with faulting which is presumed to have taken place here.

Examination of cross bedding indicated that the quartzites between the "middle" and "southern shales" are in an inverted position (Fig. 29 - 30), and it appears therefore, that an anticlinal axis is located between the two quartzite outcrops over the "middle shales". South of the railway bridge the overturned quartzites dip in a northerly direction at 15° - 40°. The rocks have therefore been rotated through 140° - 165°. Approximately 100 yards from the bridge the strata can, over a distance of a few feet, be seen to dip in a southerly direction at 5 - 10°. At this point, though veryloc alised, the rocks have been rotated through 185 - 190°. Along the railway line the width of outcrop of the inverted strata is approximately 1300 yards, but since neither of the two flanking axis can be located exactly, the figure indicates no more than the order of magnitude of the phenomenon.

The overfolding becomes less intense in a westerly direction. Whereas the dip of inverted strata between Eagles Crag and Boesmanspoort is 15 - 40°, it is 55° north-west of Paterson and 70° in the old Zuurberg Pass. One mile west of the Pass the strata are vertical, and one mile further the quartzites dip in a southerly direction at 70°. The isoclinally overfolded syncline and anticline can thus be traced for about 20 miles, overfolding becoming less intense, until just west of the old Zuurberg Pass normal, uninverted folding is found.

Along the northern boundary of Doornkloof and Retreat, the Witteberg and Bokkeveld are in all probability separated by a fault. The Witteberg quartzites, as stated, are in normal sequence and dip towards the Bokkeveld, and north of Paterson the Bokkeveld shales dip in a southerly direction towards the northerly dipping quartzites. The side south of the fault is downthrown, since it faults Witteberg down against Bokkeveld. For the same reason the fault on Sidbury Park and Springfield (p.43) has a downthrown northern side. The narrow block between the two faults is therefore uplifted relative to the blocks on either side of it. The possible nature of these faults will be discussed at a later stage (p.59).

The stratigraphic position of the "middle shales" could not be determined with certainty. These shales are either the uppermost portion of the Bokkeveld Series or are an unusually thick band of shale interbedded in the Witteberg Quartzite. No evidence was found to decide in favour of the one or the other. The problem became significant when it was discovered that only 800 - 1000 feet of inverted quartzite are present between the "middle shales" and the "southern shales" (Upper Witteberg Shales).

du Toit (17) quotes a figure of 2,500 feet for the Witteberg Quartzites; de Villiers, Jansen and Mulder (10) determined a thickness of 2,550 feet in the Worcester area; Mountain (46) calculated the thickness to be 2,400 feet in the Grahamstown area. In the region under investigation a thickness of 2,800 feet was determined on Lathams Farm and Fabers Kraal (p.10). It appears that the thickness of the Witteberg Quartzites is fairly constant throughout the length of the Cape Fold Belt. It is unlikely therefore, that the Witteberg Quartzites are locally less than 1,000 feet thick.

If the "middle shales" do belong to the Bokkeveld Series, then there is every reason to believe that more than 1,500 feet of Witteberg quartzite have been eliminated by faulting. Elimination of strata in this particular case could have been brought about only by thrust-faulting; normal faulting would have caused duplication of strata (Section 1A). The base of the "middle shales" is nowhere exposed, and the thickness of outcrop was estimated to be 100 - 150 feet. Nowhere else in the area were shales of such dimension seen to be interbedded in the Witteberg Quartzites. They are certainly not present in the quartzites of the northern limb of the anticlinorium near Alicedale, and no equivalent shales were seen on Lathams Farm and Fabers Kraal, where the whole sequence of the Witteberg Quartzites is exposed. Lithologically, as already stated, the "middle shales" are very similar to the Bokkeveld shales in the core of the anticlinorium. In all probability they do belong to this series.

THE ZUURBERG FAULT AND RELATED TRANSVERSE FAULTS

(a) The Zuurberg Fault This is one of a system of faults which, it is claimed, in mid-Cretaceous time ruptured the coastal region from Natal to the Western Cape. To this system belong the Worcester Fault, Zwartberg fault, faults in the Gamtoos valley, the Baviaans Kloof Fault and others. All these faults have the downthrown side to the south. Several of these faults have been mapped and described in detail. Söhnge (62) has described the Worcester Fault. He calculates that the displacement of this fault is nearly two miles. de Villiers (7), describing the Baviaans Kloof area, is of the opinion that the Baviaans Kloof Fault extends westwards and joins up with the Zwartberg Fault and also continues eastward to form the Coega Fault near Uitenhage. de Villiers desoribes huge fault scarps, and half mile wide breccia zones.

In the area under investigation there are very poor exposures. Nearly half of the length of the Zuurberg Fault and its associated transverse faults is covered by surface sand and the rest is covered by soil or vegetation. It appears, that the contact between tuff or Wood Beds and Witteberg Quartzite is sharp everywhere. Nowhere was a fault breccia seen, and a well defined fault scarp is only present on the farm Woodbury and Bushmans River, south of the area (Fig.31).

Haughton and Rogers (29) have described parts of the Zuurberg Fault in their description of the volcanic rocks south of the Zuurberg. On page 237 they write:

> "In a kloof on the eastern side of Slagboom (20 miles west of the area) the rock south of the Dwyka tillite and nearest it is a breccia-gravel, apparently the result of the weathering in place of a breccia; ....,"

and on page 239:

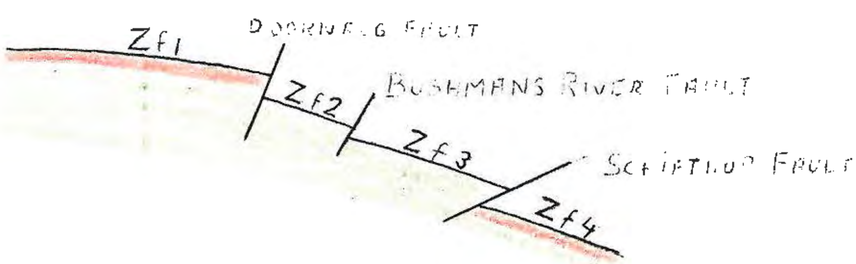
> "The evidence near Enon points to the conclusion that a fault separates the tillite from the volcanic rocks, and that the latter dip south under the Enon conglomerate, ..."

Haughton and Rogers do not discuss the evidence for a fault. On page 244 they write:

"A few yards to the east (of a quarry on Woodbury) is a cliff of tuffs; and at the bend of the river the tuff - Witteberg junction can be seen along a little footpath just below the top of the cliff. Here highly dipping reddish sandy tuffs rest against brecciated quartzites, the fault plane being almost vertical."

Sufficient evidence to suggest the presence of a fault seems to be present outside the area. The writer did not see the spots described by Haughton and Rogers, and despite the fact that direct evidence of a fault is lacking in the area, accepts the view that where tuffs or Wood Beds rest against the Witteberg Quartzite, a fault does separate the younger formation from the older.

The Zuurberg Fault can be traced from Steytlerville, 100 miles west of the area, to the farm Bushmans River, two miles south of Rokeby Park. About nine miles of the fault falls within the area described. Near its eastern end the continuity of the Zuurberg Fault is interrupted by three transverse faults. For the purpose of facilitating discussion, it is proposed to designate the separate displaced portions of the Zuurberg Fault by symbols, and the transverse faults by appropriate geographic names, as indicated below.



The Zuurberg Fault enters the area from the west on Doornkloof, Retreat and Witteclayrug. Here it is wholly obscured, and its position on the map has been inferred from its known position at Boesmanspoort and further west near Paterson. Cape Sheet 9 - P.E. depicts the fault as branching on Witteclayrug and Retreat. No evidence of this could be found in the field, and on the accompanying map this bifurcation is not shown. The position of the fault can be fixed accurately at Boesmanspoort, where it is intersected in the cutting of a railway siding. The actual contact between tuffs and Witteberg quartzites is unfortunately obscured by rubble dumped during construction work. From Boesmanspoort the fault can be traced for three miles in a direction E 25° S, before it disappears under a cover of surface sand on Doornrug.

Under the sand on Doornrug the Zuurberg Fault is displaced by a transverse fault, here called the Doornrug Fault. The Zuurberg Fault appears again near the southern boundary of Doornrug in a valley. The hills to the north of this valley are composed of Witteberg quartzites and to the south of Wood Beds. The floor of the valley is covered by a thick deposit of valley fill from the hills surrounding it on three sides. Zuurberg volcanics are not exposed. This portion

Fig.31

of the fault, Zf2, is approximately 1,400 yards long.

North of the U-bend in the Bushmans River on the boundary between Doornrug and Stilgenoegen, the Zuurberg Fault is displaced by a further transverse fault, which displaces the trace of the fault plane 250 yards to the south on its eastern side.

On Stilgenoegen the fault trace has been designated Zf3. It is flanked on its northern side by Witteberg quartzites and on its southern side by alluvium and Wood Beds. Near the eastern boundary of Schietkop, Zf3 disappears under surface sand. On Schietkop, a third transverse fault, the Schietkop Fault, displaces the trace of the Zuurberg Fault a further 1,700 yards to the south.

South of the area, the Zuurberg Fault is met again on Woodbury. Here tuffs rest against a prominent fault scarp (Fig.31). The eastern extremity of the fault was not seen.

The strike of the Zuurberg Fault is not always parallel to the strike of the Cape fold axes. Twenty-five miles west of the area, the fault intersects a synclinal axis at an angle of nearly 20°. The synclinal axis meets the fault plane in an easterly direction. The anticline, which is intersected by the Zuurberg Fault near Paterson, meets this at an angle of 6°. Under the sand on Doornkloof, Retreat and Witteclayrug, the fault appears to be parallel to the strike of the Cape folds, which is E 20° S. On Doornrug the strike of the fault trace becomes E 25 - 30° S, so that fold axes meet the fault plane at small angles in a westerly direction. Zf2 strikes E 40° S. On Stilgenoegen the strike reverts to E 20 - 25° S, a direction which is also maintained on Woodbury just beyond the southern margin of the map.

(b) <u>The Transverse Faults</u> Haughton (25;p 8) apparently was the first person to realise that the plane of the Zuurberg Fault is not continuous, but

> "...is broken near the Bushmans River by a series of step-faults which throw it to the south on the eastern side."

The existence of the Doornrug Fault is inferred from the relationship of the Zf1 and Zf2 portions of the trace of the Zuurberg Fault. Nothing is known of its nature other than that the displacement along the fault must be approximately 1,000 yards.

The Bushmans River Fault trends approximately N 32° E, and displaces the trace of the Zuurberg Fault by 200 yards. It is of interest to note that the direction of the Bushman River Fault is the same as that of the wrench-fault which displaces an anticline on Sidbury Park.

A little more is known about the Schietkop Fault. Its trace can be fixed with a fair degree of accuracy on Woodbury and Schietkop. On Woodbury tuffs flank the Zuurberg Fault on its southern side. The Witteberg quartzites to the north form a very prominent fault scarp (Fig.31), which ends abruptly at the national road. On Schietkop two quarries are found; in the one Witteberg quartzites and in the other Wood Beds are quarried for road metal. A straight line can be drawn from the termination of the fault-scarp on Woodbury to between the two quarries; so that each quarry just touches this line. The Schietkop Fault trends N 55° E. The displacement along it amounts to about 2,000 yards. The northward extension of the Schietkop Fault is buried beneath sandy deposits. If it is extrapolated, it should appear again on Grootfontein, four miles to the north-east. No evidence of its existence can be found in the Komga River valley, where prominent steeply dipping quartzite layers and interbedded shale bands of the Witteberg Quartzite are not displaced. The inference is therefore, that the Schietkop Fault, despite a displacement of more than one mile, dies out beneath the cover of sand in under four miles.

A detailed study of the structure and lithology north of each section of the Zuurberg Fault, reveals some startling similarities, which can hardly be coincidental, and which have led the writer to believe that the transverse faults are wrench-faults with predominantly horizontal movement. Witteberg quartzites immediately north of Zf4 on Woodbury dip steeply towards the north at 60 - 70°. A short distance farther north a shale band is found. The shales are exposed at only a few places, but can, nevertheless, be traced for more than 2½ miles. Lithologically they closely resemble the upper Witteberg shales found elsewhere in the area. The nature of the Witteberg quartzites north of the shales is not known in detail, but on Rokeby Park, the contact between Witteberg Quartzite and Bokkeveld Shales is inverted to the south, the dip being 60° to the north.

North of Zf3 the dip of Witteberg quartzites is from 40 - 60 degrees in a northerly direction. A short distance north of Zf3, on Schietkop, shales are found, which again resemble upper Witteberg shales, but which could not positively be identified. Upvalley from Zf3 Bokkeveld shales are exposed in an anticline. The southern contact between Bokkeveld and Witteberg is again overfolded to the south, the dip being 60° to the north. The fold axis of the anticline is found in the trough of a minor syncline (see section 2), which preserves the lower portions of the Witteberg in the crest of the overfolded anticline.

It appears, from the general sequence north of Zf4 and Zf3, that the anticline which exposes Bokkeveld in its core on Schietkop is the same as the anticline exposing Bokkeveld on the southern portion of Grootfontein and Rokeby Park. The anticline on Schietkop is clearly displaced to the north along the Schietkop Fault.

The sequence north of Zf2 on Doornrug is a little obscure, no shales were seen, only quartzites protrude through the thick cover of soil and vegetation on the hill slopes. Overfolding could not be established with certainty, but dips are generally high and towards the north, being 80° near the fault (Zf2) and 60° three quarters of a mile north of it. North of this point the outcrops in the valley floor are completely obscured by sand. It is noteworthy, that at this point Witteberg quartzites are found, and not Bokkeveld shales as in the valley on Schietkop, less than one mile along strike in an easterly direction. This suggests strongly a northwards displacement along the Bushmans River Fault north of Zf2.

The structure and lithology north of Zf1, on Doornkloof and Retreat has already been described, and will not be repeated here. Only north of the eastern end of Zf1 in a kloof on Doornrug, does the structure become intricate. The upper Witteberg shales are not exposed, overfolding appears to be present a short distance north of Zf1, and the presence of a fault-breccia suggests a somewhat more complex structure.

The evidence points strongly to the fact that the transverse faults are wrench-faults with considerable horizontal displacement. Not only is the Zuurberg Fault plane itself displaced, but the sequences north of at least three sections of the Zuurberg Fault are so similar that the conclusion is drawn that the various parts were once continuous. If Haughton's observation (29) that the fault-plane is vertical is correct, then the shortest way to achieve a two mile displacement for Zf1 relative to Zf4, is simply by lateral movement. Apparent lateral displacement can, of course, also be obtained by vertically displacing an inclined fault-plane. Any inclination of the Zuurberg fault-plane would be expected to be at high angles to the south i.e. towards the downthrown side. On the assumption that the fault-plane dips 70 degrees in a southerly direction, Zf1 would have to be down faulted 5.5 miles relative to Zf4, to obtain its northward displacement of two miles. There is no evidence to support this.

Vertical displacement would, moreover, not explain the northward displacement of an asymmetric anticline overfolded to the south. A subordinate vertical component may be present, but the horizontal component must be the dominant one.

Overfolding, wrench-faulting and thrust-faulting must all be closely associated. There is every reason to believe that the overfolds, wrench-faults and thrust-faults are inter-related and of the same age. Overfolding is most intense on Retreat and Doornkloof, i.e. north of Zf1, that section of the Zuurberg Fault which is displaced farthest to the north. Overfolding and thrusting will also explain the absence of any signs of the Schietkop Fault on Grootfontein. The displacement of the Zf4 section of the Zuurberg Fault relative to Zf1 has been achieved by wrench-faulting, overfolding and thrust-faulting, and not by the movement of rigid blocks.

An origin of the structure similar to the one advanced to Trevisan (5;p 167-8) to explain the Brenta wrench-faults in the Lombardy Alps, is suggested.

THE STRUCTURE OF THE EAST-CENTRAL REGION

Upper Witteberg shales are contained in a broad syncline east of Sydneys Hope. The southern contact between Witteberg quartzite and upper Witteberg shale is largely covered by silcrete, it is, however, well exposed on the western part of Assegaai Bush. Here the contact is overfolded in a north-easterly direction, the dip being 45 - 55° in a south-westerly direction. The syncline narrows considerably westwards and pitches out on Sydneys Hope.

On Sydneys Hope the Witteberg quartzites and the southern contact between quartzite and shale strike E 20° S, but on Assegaai Bush this changes abruptly and swings southwards to trend E 57° S. This trend continues for two miles before swinging back to the regional direction of strike under the silcrete. The northern contact and the Witteberg quartzites north of it strike E 15° S. On Assegaai Bush the contact trends E 40° S for about one mile, and then turns due East. On Lathams Farm the contact is again parallel to the regional strike.

Outside the area the Upper Witteberg Shales can be traced for nineteen more miles in a south-easterly direction (see Map 2).

THE STRUCTURE IN THE SOUTH-EASTERN PART OF THE REGION

South of Assegaai Bush Witteberg quartzites are folded into a series of anticlines and synclines which strike E 27° S. On Matjes Kraal upper Witteberg shales are found in two narrow synclines separated by an anticline. The more northerly of the two shale outcrops is nearly two miles long. The more southerly outcrop maintains a persistent width of 200 - 250 yards for nearly four miles, before it leaves the region on Klipheuvel. A little to the east of the region, on Glendye, it widens considerably. Six miles outside the area is probably joins up with the upper Witteberg shales exposed in the syncline east of Sydneys Hope (see Map 2)

THE STRUCTURE SOUTH-EAST OF SILBURY

Tight folding characterises the Witteberg Quartzite in the Komga valley, and for some distance south of Hillside dips of 60 to 90 degrees are common. Still farther south the rocks dip at less steep angles. Southward from a point a short distance north of Komga (part of Grootfontein) Bokkeveld shales crop out from under the quartzites. The Bokkeveld - Witteberg contact dips 60 degrees in a northerly direction. The contact can be traced to the south-eastern corner of Grootfontein, where it disappears under surface sand.

On Komgas Mond the structure becomes a little obscure. Witteberg quartzites along the southern boundary of the region on Komgas Mond form a steep syncline. Bokkeveld shales crop out in the northern limb of this syncline. In the river bed, south-east of the homestead on Komgas Mond, there is no sign of the Bokkeveld - Witteberg contact, which is found on Grootfontein. Sandstones and quartzites dip south under the Witteberg quartzites. East-north-east of the homestead the dip is towards the north. The structure in the river course therefore consists of one anticline. One mile farther east along strike in a river bed, a totally different structure **is** found. Bokkeveld shales crop out in a narrow anticline north of the syncline just before the river leaves the area. North of this anticline sandstones and quartzites are folded into a large number of anticlines and synclines.

(B) THE STRUCTURE OF POST-CAPE FORMATIONS

(1) STRUCTURE OF ZUURBERG VOLCANICS AND WOOD BEDS

At Boesmanspoort, where tuffs are well exposed, they dip in a southerly direction at 20°. Dips of equal magnitude were measured by Haughton and Rogers (29) on Mimosa and Slagboom, and 15 degrees on Woodbury. The northern limit of the tuffs is defined by the Zuurberg Fault. On the southern side they are overlain by sandstones of the Wood Beds. The Wood Beds display a similar dip of

15 - 20 degrees in a southerly direction, but for reasons set out on page 18 the writer does not believe that this is true dip, but rather that it is false bedding on a large scale. The apparent conformity between the two series is therefore non existent. An unconformable relationship was proved by Haughton and Rogers (29) when they found tuff and basalt pebbles in a conglomerate of the Uitenhage series. Pebbles of volcanic origin, such as agate and chert, are quite common in the Wood Beds.

(II) THE STRUCTURE OF TERTIARY TO RECENT SEDIMENTS

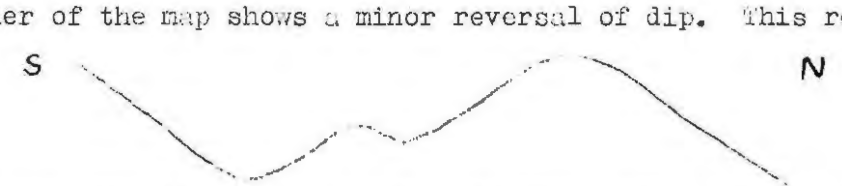
A variety of Tertiary to Recent sediments unconformably overlies the older rocks. The deposits lie on an old plain which slopes gently towards the sea. Except for post-Tertiary uplift none of the sediments has been involved in folding so that all lie essentially in an undisturbed position.

(C) THE REGIONAL GEOLOGICAL SETTING OF THE AREA

An interesting feature of the structure of the Cape System is that major synclinal structures, when viewed along strike, appear to be aligned with major anticlinal structures. An example of this is the syncline on Assegaai Bush and Lathams Farm, which is found aligned with the north-western anticlinorium. A study of the regional map (Map 2) shows that this is not an isolated occurrence, but that it is characteristic of a much larger portion of the structure of the Cape Fold Belt in the Eastern Cape Province. An attempt has been made on the regional map to draw in the major fold axes, and to show the relationship between the various synclinal and anticlinal structures.

Along the northern margin of the map an anticlinorium appears to pass laterally into the syncline on which Grahamstown is situated, and the major syncline north-west of Alicedale appears to have been placed opposite the north-eastern anticlinorium.

The south dipping limb between the anticline and the syncline in the north-west corner of the map shows a minor reversal of dip. This results in a small



anticline and syncline on this limb. Westward these two small structures are not reflected in the outcrop pattern. The small syncline pitches in an easterly direction and becomes more and more prominent. At Grahamstown this syncline, measured between the crests of the anticlines to the north and south of the city, is seven miles wide. The small anticline apparently pitches in a westerly direction; south of Grahamstown it exposes Bokkeveld shales.

The Dwyka Series and some Ecca are preserved in the major syncline north-west of Alicedale. This syncline trends E 16° S near the western boundary of the map, north of Alicedale the trend is E 6° S, but west of Grahamstown it swings sharply to strike E 22° S. South of Grahamstown the syncline is still clearly recognisable, but has dwindled considerably in magnitude. The pitch is in a north-westerly direction, and exposes successively higher strata in that direction.

The structure, which has been described as the north-eastern anticlinorium, becomes less important in a westerly direction. North-east of Alicedale it is still prominent, but north-east of the same village it is no more than a small anticline on the southern limb of the major syncline.

The syncline which preserves upper Witteberg shales on Assegaai Bush and Lathams Farm, can be traced westwards to an insignificantly small syncline on the northern limb of the north-west anticlinorium south-east of Alicedale. Conversely the main axis of the north-west anticlinorium can be traced to a small anticline on the southern limb of the syncline.

In general it can be said that the major synclines have their origin in minor reversals of dip on the limbs of major anticlines and vice versa. Pitching of the folds in one direction or another, either increases or decreases the magnitude of the folds along strike.

The folds appear to be more tightly compressed in the western half of the map than in the eastern half. In the eastern half, folds appear to be more numerous, several die out in a westerly direction. The distance between the crests of two anticlines along the western margin of the map is 10 miles. Along the eastern margin the same two folds are 19 miles apart.

A CRITICAL REVIEW OF THE STRUCTURE

The description of the structure raises several interesting problems, to which at present no definite answer one way or the other can be given.

The most unusual observation is that a syncline and an anticline have isoclinally been overfolded to the south. Overfolding is common in the Cape Fold Belt and frequent reference is made to it in the literature, but this is, with one exception, everywhere to the north. de Villiers (7; p 154) mentions strong overfolding to the north in the Baviaans Kloof area, and Haughton (25, 27, 28) mentions asymmetric anticlinal folds with steeper limbs to the north. du Toit (8; p 196) in a contribution to de Villiers (7) paper writes,

> "Overturning is far from uniform in the foldbelt, though invariably to the north, when present on any scale. West of a line drawn from Karroo Poort to Mossel Bay it is rare. From Prince Albert eastward it is quite frequent".

Mountain mentions overfolding to the south near Port Alfred (50; p.15)

> "A peculiar feature of these rocks (Witteberg quartzites) in the neighbourhood of Salt Vlei and Kowie Points is the continuous tendency of the rocks to dip at high angles to the north-east. This represents an approximation to isoclinal folding, but is unusual, in being thus overfolded to the south-west".

Mountain thinks that a few hundred feet may be involved, but was unable to make accurate measurements. This overfolding may genetically be connected with the overfolded portions north of the Zuurberg Fault. It may be worth while to investigate whether the overfolded rocks at Port Alfred are associated with a major fault in a south-westerly direction.

Overfolding to the south is unusual, and is apparently limited to restricted parts of the eastern Cape Province.

It has been shown that the trace of the Zuurberg Fault has been displaced by three wrench-faults. Total displacement on these faults has been $\pm$3000 yards. The Zuurberg Fault is generally thought to be of mid-Cretaceous age. If this is correct, than the three wrench-faults must be younger. This implies a period of severe compression during a post mid-Cretaceous period. Opinion on a renewal of compression after the mid-Cretaceous period of tension faulting is divided, although the protagonists, at present, appear to defend the weaker case. Haughton, Frommurze and Visser (30; p 27) find evidence near Mossel Bay that Enon has been thrusted from the south over the pre-Cape rocks. Potgieter (52; p 410) however, disputes the presence of a thrust, and believes that the fault is more likely of the normal gravity type. Söhnge (62; p 261) states,

> "The final phase of the faulting movement was evidently accompanied by exceptional crustal compression, by which the inclusions of the Enon conglomerate underwent marked fracturing and distortion".

Du Toit (8; p. 195, Contribution to de Villiers paper) believes in a post-lower but pre-upper Cretaceous phase of compression:

> "... the intensity of which is probably far greater than generally supposed, as shown by local dips in the Enon up to 60°, etc. The overturning of some of the Cape strata may just have been due to this renewal of compression, which, superimposed on the older foldings, is naturally arcuate with concavity to the south".

de Villiers disputes this (8; p 201),

> "Such dips, however, are invariably directed towards the north, i.e., towards the fault, and otherwise no plications attributable to folding were noticed. All departures from the horizontal in the Enon beds may, therefore be explained by the faulting with its resulting northwards tilting of the downthrown strata ...., These high dips in the Enon could have been produced by faulting alone, and no post-Enon period of folding need be supposed, the more so since no true folds were encountered in the Cretaceous beds."

South of the Zuurberg Fault the situation is somewhat different. Here the Cretaceous rocks dip 15 - 20^{o} in a southerly direction, i.e., away from the fault. Obviously de Villiers explanation of faulting and tilting towards the fault can not be applied south of Zuurberg in the same sense as elsewhere in the Fold Belt. If tilting has taken place in the Wood Beds, it is away from the fault, and not towards it. As pointed out, however, the writer does not believe in any post mid-Cretaceous folding or drag, but thinks that the Wood Beds rest essentially in a horizontal position (p.18).

Two, possibly three, faults were inferred on Springfield (p.43), Doornkloof and Retreat (p.48). Although no direct evidence of these faults was seen in the field, the conclusion is drawn that they are thrust-faults. The accompanying sections (Sections 1 and 1A) clearly show that a narrow block is upthrown relative to the two blocks on either side of it. Normal tensional faults would imply that a big block to the north and a big block to the south were downthrown. If the two faults are thrust-faults, this difficulty falls away. The narrow horst is a block wedged out between the big blocks on either side of it. On page 48 it was pointed out that 1,500 feet of Witteberg quartzite are missing if the "middle shales" are Bokkeveld. Under the prevailing circumstances only a low-angle thrust-fault could have eliminated the quartzites.

The evidence is convincing proof of a period of strong compression. The wrench-faults appear to date this to a period later than mid-Cretaceous. The compression has resulted in severe folding in the rigid Cape rocks, to the extent that these were overfolded appreciably to the south, wrench-faulted and thrust-faulted. Yet despite a supposed post mid-Cretaceous movement of 3,000 yards on these wrench-faults this compression has had no effect on the Wood Beds. This is somewhat paradoxical, and for this reason it is unlikely that the compression post-dates the mid-Cretaceous, but must be pre-Cretaceous in age.

Considering this, it is concluded that the Zuurberg Fault was initiated in pre-Cretaceous times, and that it was displaced by wrench-faults before the deposition of the Wood Beds.

THE COASTAL PENEPLAIN

The rise of ground level from the southern boundary of the area northwards is a gradual one up to about the 1,800 foot contour, which runs approximately from Lathams Farm to Sweetkloof. The slope is on an average 100 feet per mile, or 1 degree. This plain, which covers more than ¼ of the whole area forms part of an extensive coastal plain, which can be traced all along the Cape coast and into Natal. On this plain rest Tertiary limestone and a variety of deposits including gravels, silcrete and eolian sand. The surface forms part of King's (35) African cycle. Bullen - Newton classified the Alexandria Formation as mid-Pliocene. du Toit (17; p 439) thinks that formations dating from the late Eocene to Miocene are present. Mrs. C.G. Rümke (18) of the Geological Survey has identified foraminifera as belonging to the Upper Oligocene to Miocene.

The relationship between the surface on which the Alexandria limestones and that on which the silcrete rests, is a little obscure. Haughton in "Handbuch der Regionalen Geologie" states that:

> "In the areas where the silcrete and Tertiary limestones occur close together, there is an abrupt step from the one to the other, but where, as in Humansdorp, no limestones occur, the silcrete covered peneplain slopes evenly to the present coast".

Haughton (25), however, also stated that:

> "The peneplain on which the limestones and surface deposits rest is a continuous one from Sandflats to the sea in the middle of the area".

Mountain (45) sees the problem of the coastal plain as being twofold: (a) how the surface was formed, by river or by the sea, (b) the subsequent history of the peneplain. Haughton (25) thinks that the surface under the limestones was formed by the sea, and the surface on which the silcrete rests as subaerial in origin.

Alexandria limestones do not occur in the area of the present survey, but they are found to the west at Paterson and south on Aluinkrantz. The occurrence at Paterson is at an elevation of 1,150 feet, and on Aluinkrantz at 650 feet. Near East London, at Needs Camp, Alexandria limestones are found in a small depression at 1,205 feet. This proves, that the sea during Tertiary time stood at least at the present 1,200 foot contour. de Villiers (7) found evidence in the Baviaans Kloof that the land since the Tertiary has risen at least 1,400 feet and Visser (70) states:

> "At the beginning of the Tertiary the South African continent must have stood nearly 1500 feet lower than at present and a broad continental shelf was cut by the sea, with an equally extensive coastal plain, stretching

> inland from the shore.. . Towards the end of this epoch of planation, while the land started to rise coarse conglomerate with a highly siliceous matrix, only a few feet thick, was deposited on the coastal plain by the meandering rivers, which had cut it".

There is sufficient evidence to suggest that the sea did rise to levels higher than that on which today some silcrete is found.

Besides the two outliers on Roodekop, the lowest silcrete in the area, near the homestead of Rustfontein (on the boundary between Kongas Pond and Roodekop), is found at an elevation of 1,110 feet. How far inland the sea did advance is impossible to say, but it is suggested that at least the lower parts of the plain, on which silcrete rests, has a marine origin. If the high-level gravels have a marine origin, then the sea must have stood at least at the present 1,300 foot contour.

No work was done on the elevation of the surface on which Alexandria limestones rest. It is therefore not possible to say whether there is a break in the slope of the surfaces on which silcrete and Alexandria limestone rest.

THE GEOLOGICAL HISTORY

During the Silurian, when Southern Africa was part of the super continent Gondwanaland, a peneplain developed over the southern half of what is now the Cape Province. This plain also extended over land which at that time, lay beyond the limits of the present continent.

Towards the end of the Silurian, the peneplain slowly subsided forming an east-west trough, the Cape Geosyncline. A long period of sedimentation set in , which only terminated during the Jurassic. The material which filled the geosyncline was chiefly derived from the north. Sediments of the Cape System were deposited until the Lower Carboniferous. During part of the Carboniferous Gondwanaland was covered by a thick ice sheet. Glacial till was deposited in the geosyncline from floating ice. Sediments of the Ecca and Beaufort Series, which followed after the glacial period, were deposited conformably in the Cape Geosyncline on the Dwyka Tillite. During this period (Permian) the centre of deposition slowly shifted northwards to form the Karroo Geosyncline.

Folding of the Cape Geosyncline began during the Lower Beaufort (upper Permian) and culminated during the Triassic. The sediments were highly compressed, uplifted and eroded. Coarse waste material was swept northwards and largely supplied the debris for the Molteno Beds. The long period of sedimentation, erosion and re-sedimentation ended during the Jurassic with the eruption of the Stormberg lavas.

From the Jurassic to the present day, the inland regions of Southern Africa have been relatively stable. Marine transgressions took place along the margins of the present coast during the Cretaceous and Tertiary. During the Cretaceous tensional faulting, probably connected with the rupture of Gondwanaland, effected parts of the Cape Fold Belt.

This brief description gives a summary of the history of the Cape and Karroo geosynclines as it is presently accepted. (17; p 559 - 576). It is in the light of this, that the geological history of the area of the present survey must be viewed. The writer envisages the following events. These are somewhat speculative; but do appear to be in harmony with field evidence.

The Bokkeveld and Witteberg Series were highly folded during the main phase of compression of the Cape Geosyncline (Permian to Triassic). This compression cannot have been continuous, but must have alternated with short periods of tension. It is during one of these tensional phases, that the Zuurberg Fault was initiated in already highly folded strata. A final, severe phase of compression followed, which resulted in wrench-faulting, overfolding and thrust-faulting in the rocks north of the Zuurberg Fault.

The folding of the Cape System was followed by a period of erosion. Eventually everything was blanketed by the Stormberg lavas.

In the early-Cretaceous a period of tension set in when Gondwanaland ruptured. Movement on the Zuurberg Fault was renewed, and vertical movement now also took place south of the Zuurberg Fault on the planes of the three wrench-faults. South of the Zuurberg progressive faulting produced a basin which subsided rapidly. The nature of the sediments which were deposited south of the Zuurberg Fault indicate that they were deposited under torrential conditions. As fast as the basin subsided, it was being filled with debris derived from the rocks to the north of the fault.

The deposition of the Cretaceous beds was followed by the formation of a coastal peneplain, on which in Tertiary to Recent times Alexandria limestones, gravels, silcrete and eolian sand were deposited.

Since the deposition of the Alexandria limestone, the coastal margin has been uplifted between 1,200 to 1,500 feet.

The events as described above eliminate large scale compression in post-mid-Cretaceous times. It is suggested that the Cretaceous faulting, at least south of Zuurberg, has been contemperaneous with the deposition of the Wood Beds, and does not post-date them.

Except for the age of the Cretaceous faulting, this explanation, in essence, is consistent with ideas currently held on the history of the Cape Fold Belt (17, 8).

CONCLUSION

The survey of only so small a portion of the Cape Fold Belt has shown the writer, that Eastern Cape Province geology is a great deal more fascinating and problematic than is generally accepted by students. It is regrettable that so few students have chosen the Eastern Cape for research work, but instead have decided on projects elsewhere with an economic bias. The absence of economic mineral deposits of significance tends to make the area unattractive. Yet, the number of research projects, as interesting as economic ones, is unlimited. More concentrated research work would greatly add to our knowledge regarding geological events which have taken place since the beginning of deposition of the Cape System - a period covering the last 400 million years of the geological history of Southern Africa.

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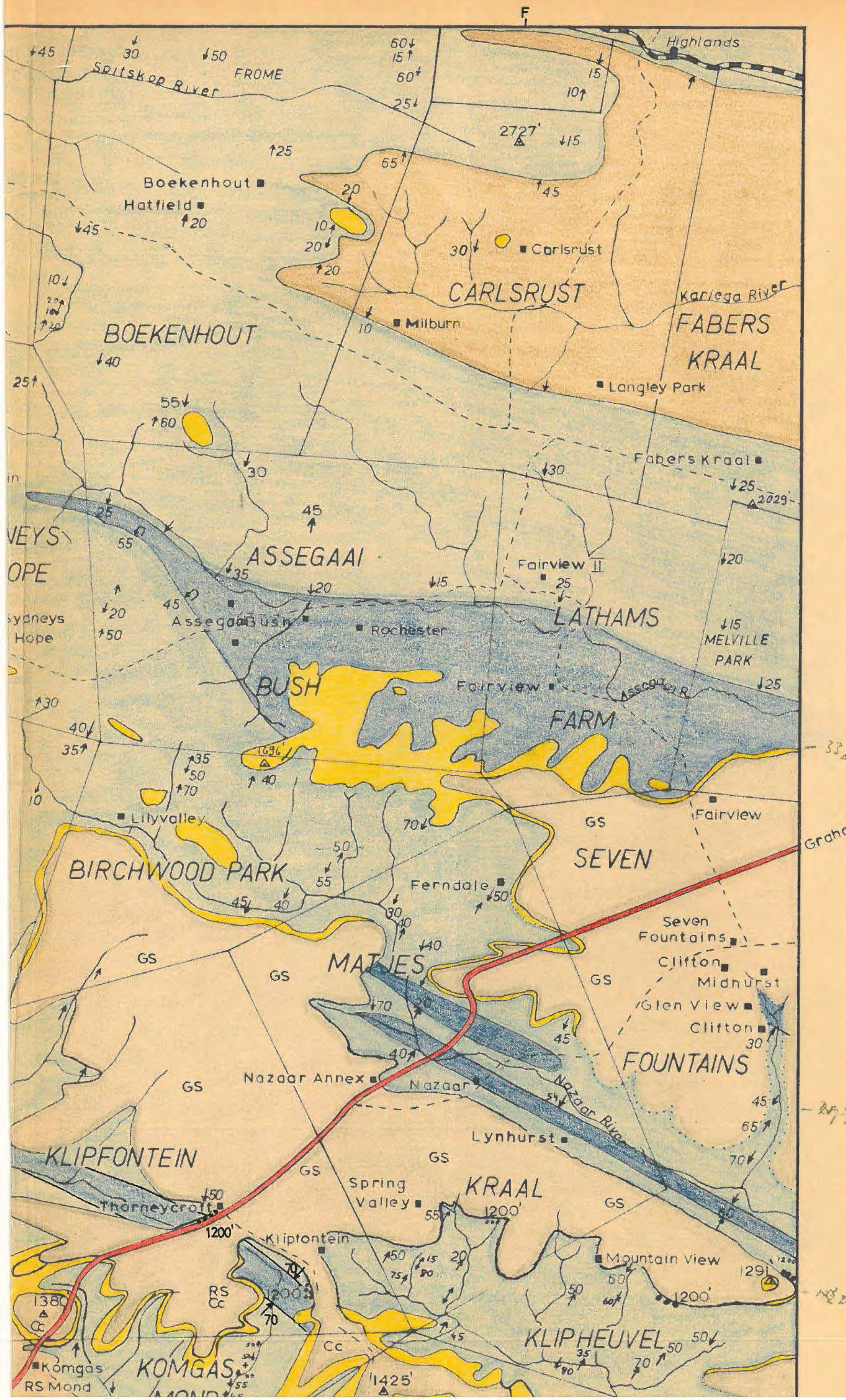
MAPS AND SECTIONS



GEOLOGICAL MAP OF A PORTION OF SOUTH-WESTERN ALBANY

⌒	ALLUVIUM		TERTIARY TO RECENT
(yellow)	SILCRETE	Cc,RS,GS — WINDBLOWN SANDS: Cc-Calcrete, RS-Red Sands, GS-Gray Sands	
•••••	HIGH-LEVEL GRAVELS (marine ?)		
(green)	SANDSTONES, CONGLOMERATES	WOOD BEDS	CRETACEOUS SYSTEM
(red)	TUFFS	STORMBERG SERIES	KARROO SYSTEM
(dark blue)	SHALES, SANDSTONES	WITTEBERG SERIES	CAPE SYSTEM
(light blue)	QUARTZITES		
(buff)	SHALES, SANDSTONES	BOKKEVELD SERIES	

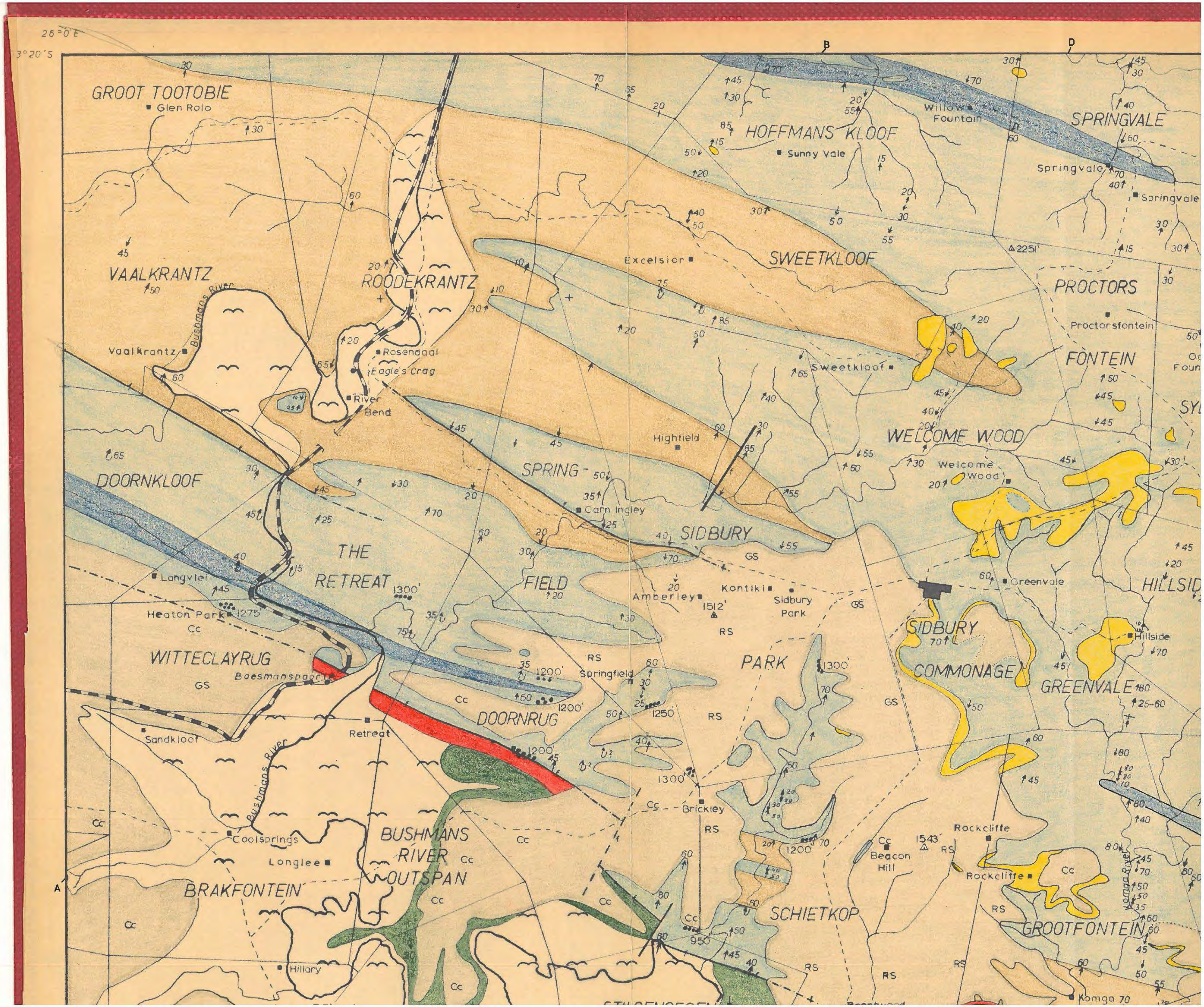
- Fault
- Possible position of a fault
- 45 Direction of dip and amount in degrees
- Horizontal strata
- Vertical strata
- Overfolded strata
- Anticline
- Syncline

N

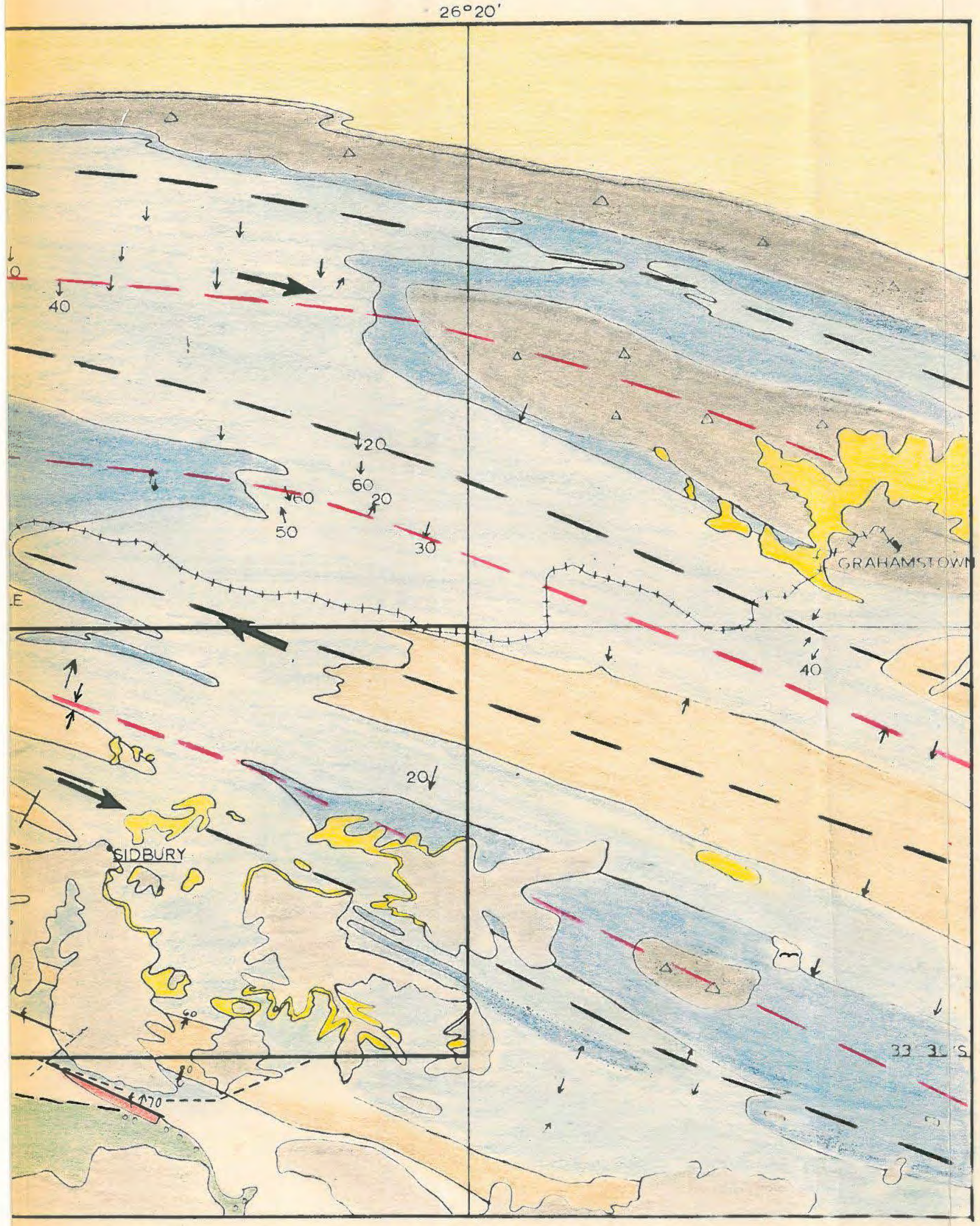
SCALE 1 : 62500

0 1 2 3 4

MILES



26°0'E
33°20'S
B
D
A
GROOT TOOTOBIE
Glen Rolo
HOFFMANS KLOOF
Sunny Vale
Willow Fountain
SPRINGVALE
Springvale
VAALKRANTZ
ROODEKRANTZ
Bushmans River
Vaalkrantz
Rosendaal
Eagle's Crag
River Bend
Excelsior
SWEETKLOOF
Sweetkloof
PROCTORS
Proctorsfontein
FONTEIN
WELCOME WOOD
Welcome Wood
DOORNKLOOF
SPRING-
Highfield
Carn Ingley
SIDBURY
FIELD
THE RETREAT
Langvlei
Heaton Park
WITTECLAYRUG
Boesmanspoort
Amberley
Kontiki
Sidbury Park
Greenvale
HILLSIDE
Hillside
SIDBURY COMMONAGE
GREENVALE
PARK
Springfield
DOORNRUG
Sandkloof
Retreat
Brickley
Coolsprings
Longlee
BUSHMANS RIVER OUTSPAN
BRAKFONTEIN
Rockcliffe
Beacon Hill
SCHIETKOP
GROOTFONTEIN
Komga River
Hillary
Komga



REGIONAL GEOLOGICAL SETTING OF AREA SURVEYED

ALLUVIUM } TERTIARY TO RECENT
SILCRETE — WINDBLOWN SANDS (and marine limestones?)

SUNDAYS RIVER BEDS
WOOD BEDS
ENON CONGLOMERATES } UITENHAGE SERIES — CRETACEOUS SYSTEM

VOLCANIC ROCKS — STORMBERG SERIES
SHALES, SANDSTONES — ECCA SERIES
SHALES
TILLITE } DWYKA SERIES
} KARROO SYSTEM

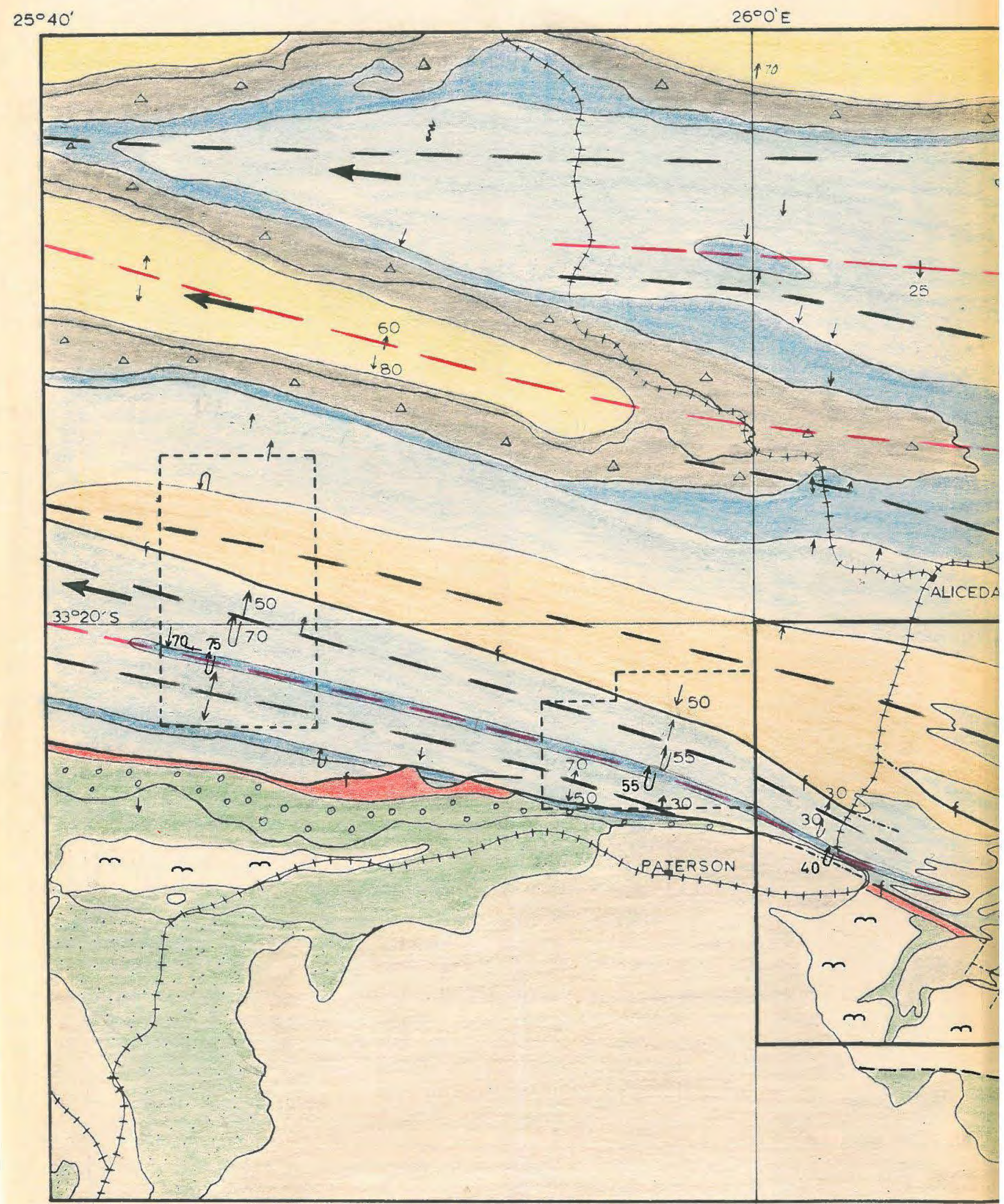
SHALES, SANDSTONES
QUARTZITES } WITTEBERG SERIES
SHALES, SANDSTONES — BOKKEVELD SERIES
} CAPE SYSTEM

Fault
Possible position of a fault
45 Direction of dip and amount in degrees
Overfolded strata
Anticline
Syncline
Direction of pitch

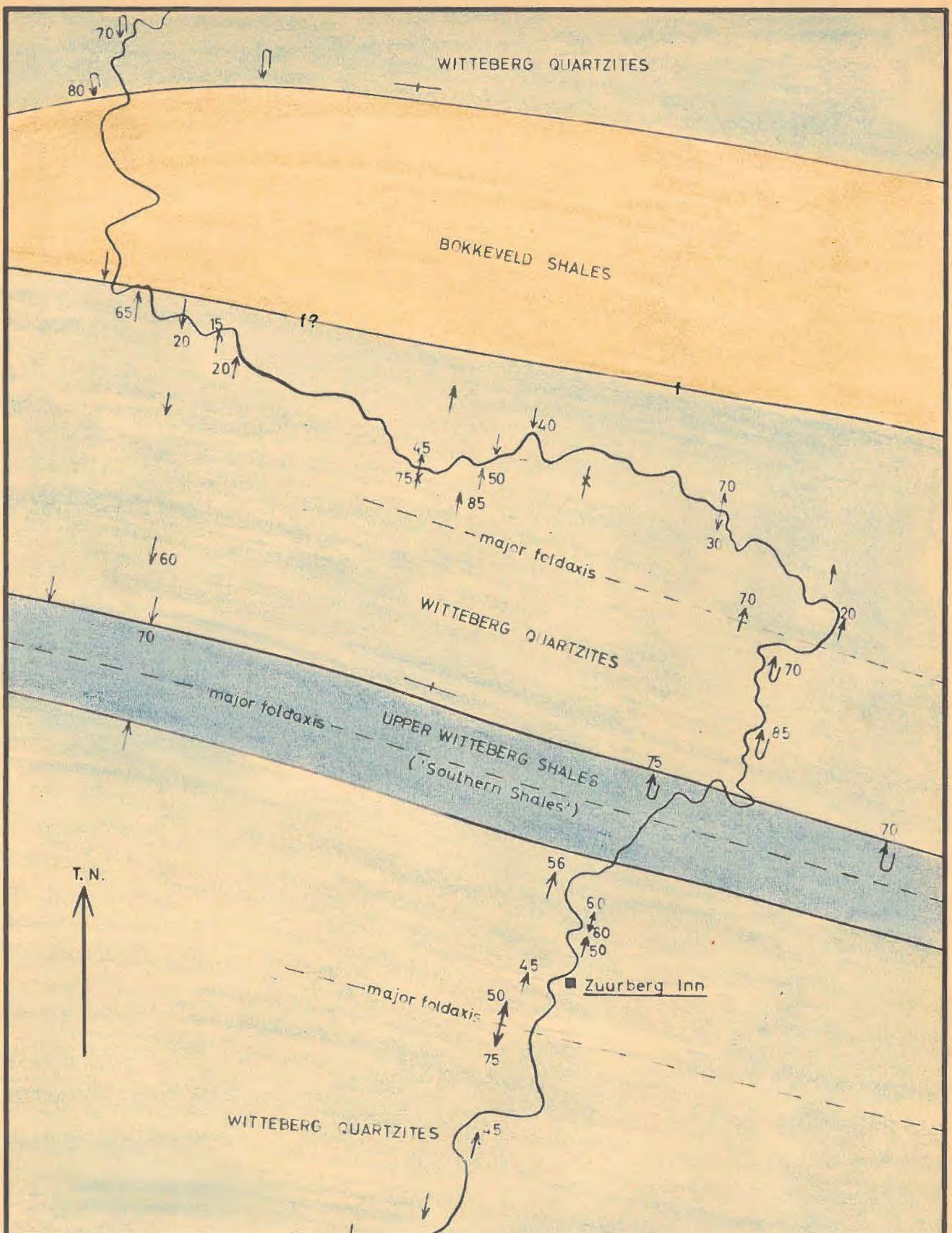
N

Area investigated - inset heavy frame
Reconnaissance mapping - broken frame

0 5 10 15
MILES



Regional Geology adapted from Cape Sheet 9 - Port Elizabeth, Geological Survey of South Africa, 1928.



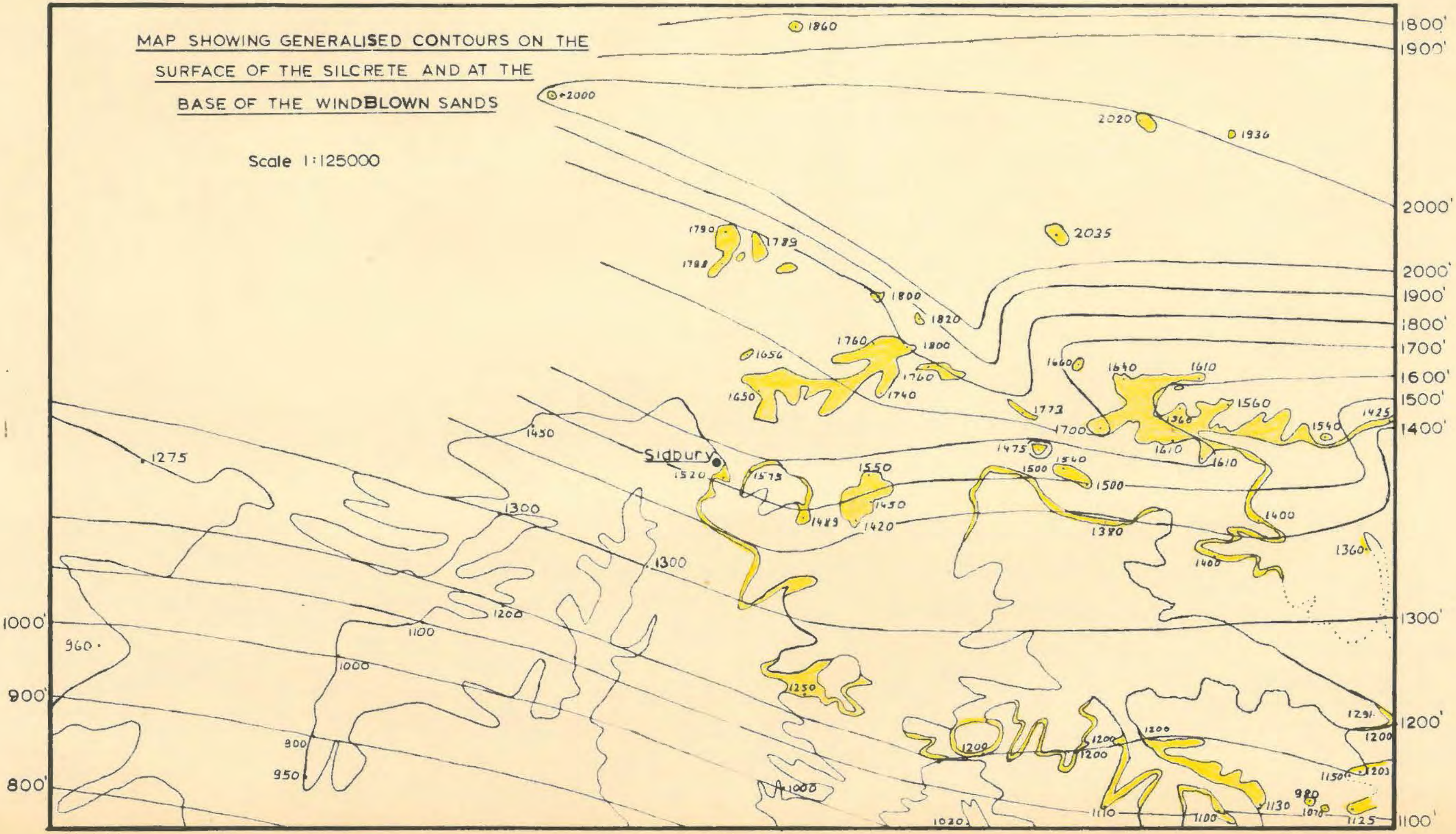
THE GEOLOGY OF THE OLD ZUURBERG PASS

0 1 MILES 2 3

SCALE (approx.) 1 : 43,000
(1" = 3600')

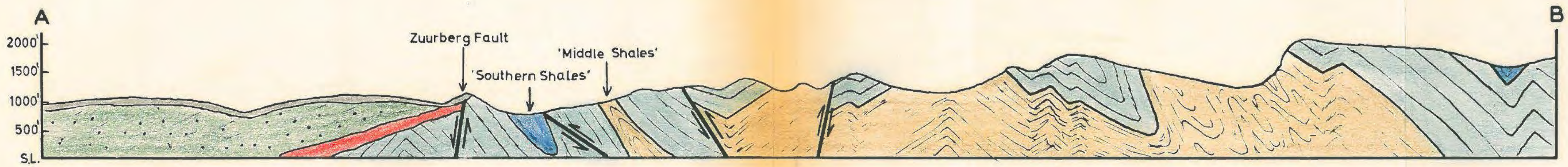
Map traced from aerial photographs and reduced in scale.

MAP 3.


MAP SHOWING GENERALISED CONTOURS ON THE
SURFACE OF THE SILCRETE AND AT THE
BASE OF THE WINDBLOWN SANDS
Scale 1:125000
Sidbury
1800'
1900'
2000'
2000'
1900'
1800'
1700'
1600'
1500'
1400'
1300'
1200'
1100'
1000'
900'
800'
1860
+2000
2020
1936
2035
1790
1789
1788
1800
1820
1760
1800
1656
1650
1760
1740
1773
1700
1660
1640
1610
1560
1540
1425
1610
1610
1475
1540
1500
1500
1275
1450
1520
1575
1550
1450
1489
1420
1380
1400
1360
1400
1300
1300
1200
1100
1000
960
1250
1200
1200
1200
1200
1291
1200
1203
1150
980
1070
1125
1130
1100
1110
1020
1000
900
950

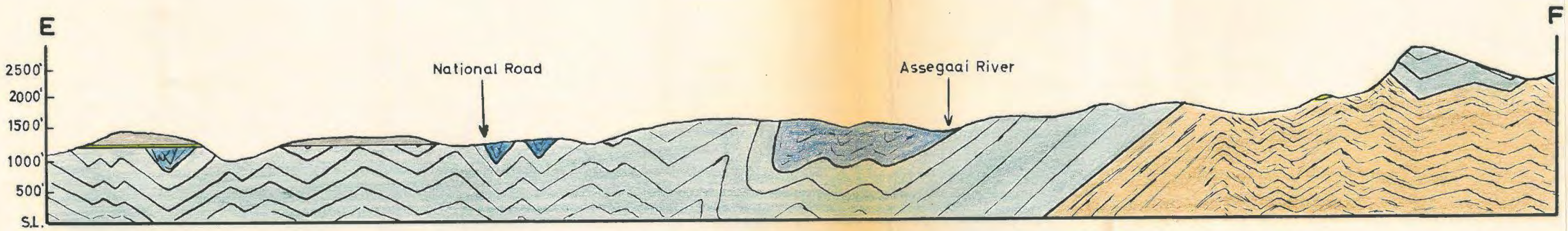
MAP 4

SECTION I.



SECTION IA.

SECTION 2.



SECTION 3.

SECTIONS ALONG LINES A-B, C-D, E-F, SHOWN ON MAP I.

- ALLUVIUM
- SURFACE SANDS
- SILCRETE
- WOOD BEDS
- VOLCANICS
- U.W. SHALES
- WITTEBERG QTZ.
- BOKKEVELD

HOR. SCALE 1 : 62500

VERT. SCALE 1 : 24000