

EXPLANATION: SHEET 2826 (1:250 000)



# WINBURG

COUNCIL FOR GEOSCIENCE

GEOLOGICAL SURVEY OF SOUTH AFRICA



**Cover photograph: The Clarens–Elliot contact pictured against a background of terraces of the Molteno Formation and a valley floor consisting of sediments of the Tarkastad Subgroup.**

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**THE GEOLOGY OF THE WINBURG AREA**

*by*

**C.C. NOLTE**

**Explanation of Sheet 2826  
Scale 1:250 000**

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# THE GEOLOGY OF THE WINBURG AREA

by

C.C. Nolte, B.Sc. (Hons.)

## *Abstract*

The oldest rocks in the map area are granite of Swazian age and the rocks of the Ventersdorp Supergroup of Randian age. The largest portion of the map area is underlain by rocks of the Karoo Supergroup and surficial sediments of Quaternary age.

The Tierberg Formation of the Eccca Group is the lowermost unit of the Karoo Supergroup and comprises bioturbated, dark to bluish-grey, horizontally bedded and ripple cross-laminated siltstone and shale. Overlying the Tierberg Formation is a continuous, erosively based sandstone of the Adelaide Subgroup (Beaufort Group). This subgroup comprises alternating layers of khaki to grey-green mudstone, siltstone and fine- to very coarse-grained sandstone with subordinate conglomeratic material exhibiting trough cross-bedding, cross lamination and parting lineation. The overlying Tarkastad Subgroup outcrops in the east of the map area and comprises purple and blue-green mudstone with interbedded light-green to yellow, trough cross-bedded and cross laminated fine- to medium-grained sandstone. A southerly source area is inferred for sediments of the Beaufort Group.

The Molteno Formation comprises thick, continuous, coarse-grained sandstone lenses which erosively overlie the Tarkastad Subgroup and shows two complete upward-fining fluvial sequences. Sedimentary structures include trough and tabular cross-bedding with an inferred south and south-easterly source area. The lithological contact between the Molteno and the overlying Elliot Formation is transitional, the latter being characterised by red and purple mudstone and siltstone with subordinate interbedded thin, yellow to light-grey, fine- to medium-grained sandstone lenses. The red mudstone of the Elliot Formation grades upwards into massively bedded as well as large cross- and horizontally bedded, orange, fine-grained sandstone of the Clarens Formation. The top of the Clarens Formation is marked by the presence of lava flows of the Drakensberg Formation.

The Karoo Supergroup extending from the Tierberg to the Elliot Formations is extensively intruded by dolerite. Kimberlite dykes and pipes occur in the Theunissen, Hennenman, Marquard and Clocolan districts. Large blanket deposits of red wind-blown sand are distinctive in the west of the map area whereas alluvium is confined to the flood plains of the Vet, Sand and Modder Rivers. In the Hennenman-Soutpan area, deposits of calcrete are found on and close to the contact between the top of the Tierberg Formation (Eccca Group) and the base of the Adelaide Subgroup (Beaufort Group), whereas in other low-lying areas, unconsolidated stratified deposits of Quaternary age, consisting of light-grey clay, silt and thin alternating layers of sand, silt and clay are present.

The most important economic mineral commodity is gold which is mined from the Witwatersrand Supergroup which does not outcrop in the Winburg sheet area. The most important mines are situated around Virginia. Diamonds are mined from kimberlite fissures to the east of Theronkop. In other pipes and fissures mining activity is sporadic while the majority are not economically viable. Salt production mainly occurs in the region of Soutpan. River sand and hewed blocks of Molteno sandstone are used in the building industry, whereas dolerite is used principally for road-construction purposes.

### *Uittreksel*

Die oudste gesteentes in die kaartgebied is van Swaziese en Ventersdorp Supergroep-ouderdom, terwyl die grootste gedeelte van die kaartgebied deur gesteentes van die Karoo Supergroep en oppervlaksedimente van Kwartêre ouderdom onderlê word.

Die Tierberg Formasie van die Eccla Groep is die laagste eenheid van die Karoo Supergroep in die kaartgebied en bestaan uit gebioturbeerde, donker- tot bloueriggrys, horisontaalgelaagde en riffelkruisgelamineerde sliesteen en skalie. 'n Aaneenlopende sandsteen van die Adelaide Subgroep (Beaufort Groep) waarvan die basis geërodeer is, oordek die Tierberg Formasie. Hierdie subgroep bestaan uit afwisselende lae khaki tot grysgroen moddersteen, sliesteen en fyn- tot baie grofkorrelrige sandsteen met ondergeskikte konglomeratiese materiaal wat trogkruisgelaagdheid, kruislaminasie en skeidingslineasie vertoon. Die oorliggende Tarkastad Subgroep dagmaam in die oostelike gedeelte van die kaartgebied en bestaan uit pers en blougrys moddersteen met tussengelaagde liggroen tot geel, trogkruisgelaagde en kruisgelamineerde fyn- tot mediumkorrelrige sandsteen. 'n Suidelike brongebied is vir die Beaufort-sedimente afgelei.

Die Molteno Formasie bestaan uit dik, aaneenlopende, grofkorrelrige sandsteenlense wat erosiegewys die Tarkastad Subgroep oordek en ten minste twee volledige opwaarts fynerwordende fluviale opeenvolgings ton. Sedimentêre strukture sluit trog- en tabulêre kruisgelaagdheid met 'n afgeleide suid- en suidoostelike brongebied in. Die litologiese kontak tussen die Molteno en die oordekkende Elliot Formasie is oorganklik, met laasgenoemde wat gekenmerk word deur rooi en pers moddersteen en sliesteen met ondergeskikte tussengelaagde dun, geel tot liggrys, fyn- tot mediumkorrelrige sandsteenlense. Die rooi moddersteen van die Elliot Formasie gradeer opwaarts in massief-gelaagde en groot kruis- en horisontaalgelaagde, oranje, fynkorrelrige sandsteen van die Clarens Formasie. Die bokant van die Clarens Formasie word gekenmerk deur die teenwoordigheid van lawavloei van die Drakensberg Formasie.

Die Karoo Supergroep strek vanaf die Tierberg tot die Elliot Formasies en is op groot skaal deur doleriet ingedring. Kimberlietgange en -pype kom in die Theunissen, Hennenman, Marquard en Clocolan distrikte voor. Groot kombersafsettings van rooi waaisand is kenmerkend in die weste van die kaartgebied. Daarteenoor is alluvium beperk tot die vloedvlaktes van die Vet-, Sand- en Modderrivier. In die Hennenman-Soutpan omgewing kom kalkreetafsettings op en naby die bokant van die Tierberg Formasie (Eccla Groep) en die basis van die Adelaide Subgroep (Beaufort Groep) voor. Daarteenoor is ongekonsolideerde gelaagde afsettings van Kwartêre ouderdom, bestaande uit liggrys klei, slied en dun afwisselende lae sand, slied en klei in die ander laagliggende gebiede teenwoordig.

Die belangrikste ekonomies ontginbare mineraal in die area is goud wat uit die Witwatersrand Supergroep, wat nie in die Winburgkaartgebied dagmaam nie, gemyn word in myne wat rondom Virginia geleë is. Diamante word in kimberlietsplete oos van Theronkop gemyn. Ander pype en splete word sporadies gemyn, terwyl die grootste groep nie ekonomies lewensvatbaar is nie. Sout word hoofsaaklik in die omgewing van Soutpan gemyn. Riviersand en gekapte blokke Moltenosandsteen word in die boubedryf gebruik, terwyl doleriet hoofsaaklik vir padboudoeleindes gebruik word.

## 1. INTRODUCTION

### 1.1 GENERAL GEOLOGY

The map area is mainly underlain by rocks of the Karoo Supergroup ranging in age from the early Permian (Tierberg Formation) through to the Jurassic (Drakensberg Formation). Basement rocks outcrop only in a few small areas and comprise granite of Swazian age and lavas, fanglomerate and quartz porphyry of the Ventersdorp Supergroup. The western portion of the area is covered by extensive surficial deposits of wind-blown sand and calcrete of Quaternary age. The sequence has undergone very little deformation and is characterised by low dip angles.

The map area includes the magisterial districts of Winburg, Theunissen, Marquard, Brandfort, Bultfontein, Boshof, Bethlehem, Bloemfontein, Clocolan, Excelsior, Ficksburg, Hoopstad, Kroonstad, Ladybrand, Lindley, Ventersburg, Welkom and Wesselsbron or parts thereof.

### 1.2 PHYSIOGRAPHY AND VEGETATION

A large portion of the area lies on the Highveld Plateau (1 200–1 500 m above sea-level) which can be subdivided by a minor escarpment in the northwest linking the towns of Theunissen and Ventersburg. This escarpment forms the transition between early and late Tertiary erosion surfaces. In general, the map area is characterised by an undulating topography with isolated dolerite-capped hillocks. Some of these dolerite caps are saucer shaped. The southwestern and northwestern parts of the map area exhibits a low relief and is extensively covered by aeolian sand sheets. The southeastern areas, however, show more resistant lithologies as well as a greater relief (up to 1 900 m above sea-level). This region is further characterised by broad incised valleys, pediments and monadnocks.

The direction of drainage is oriented towards the northwest via the Vet, Sand and Modder Rivers. The typical dendritic drainage pattern of the region is ascribed to the predominantly horizontal attitude of the lithologies. Flow characteristics of the rivers vary considerably with perennial flow being noted in the east, grading through a narrow belt of periodic flow to dominantly episodic or ephemeral flow in the area west of Bloemfontein. The Vaal Basin catchment covers the entire area except for a small region in the east, where the Caledon River forms the border between the Republic of South Africa and Lesotho and where drainage is directed into the Orange River Basin.

The mean annual surface temperature ranges between 15–17 °C. The higher relief areas to the east are characterised by snow and frost in the winter with mean annual temperatures varying between 12–15 °C. Rainfall is seasonal with a maximum occurring during January to March. Annual evaporation losses from open-water bodies range from 1 250 mm near the Lesotho border to between 1 500 and 1 750 mm for the remainder of the area. Maximum evaporation occurs in the extreme western regions of the map area where losses of up to 2 000 mm are common.

The vegetation is classified as short, temperate grasses (0,4–0,6 m in height) and is regarded as the natural climax vegetation-type for the Highveld Plateau region where the relief is greater than 1 400 m. The landscape is virtually treeless except against sheltered slopes or in strips along river courses. Below the Theunissen–Ventersburg escarpment dry *Cymbopogon-Themeda* dominates while Karoo intruder plants such as *Chryesocoma teriufolia*, occur on trampled areas around water points. The close association between certain vegetation types and soil type was an important aid during mapping. For example, *Acacia karoo* was noted to be restricted to rocky areas and alluvial areas adjacent to river courses. *Imperata cylindrica* was found to be closely associated with water-saturated grey soils characteristic of areas where drainage was limited, whereas well-drained aeolian sands showed dominant growths of *Eragrotis lehmannia*.

### 1.3 PREVIOUS WORK

Mapping of the area commenced in 1977 and was completed in 1987 by personnel of both the Geological Survey and the University of the Orange Free State. Previous geological work is contained within several unpublished reports and theses, most notably those of Behounek (1980) and Bonnet (1977). Coetzee (1960) described the Ecça Group in the vicinity of the Vet and Sand Rivers while the Ecça–Beaufort transition zone was described by Visser and Loock (1974). Pans in the western Orange Free State were described by De Bruijn (1971) and Butzer *et al.* (1974).

## 2. GEOLOGICAL FORMATIONS

The geological units present in the mapped area are shown in Table 1.

### 2.1 SWAZIAN GRANITE

One exposure of basement granite of Swazian age is present on Geduld 37 at latitude 28°01' and longitude 26°27'. Petrographic work by Behounek (1980) showed that the granite is medium to coarse grained, containing abundant microcline, minor albite, altered biotite, interstitial muscovite and occasional graphic intergrowths.

### 2.2 VENTERSDORP SUPERGROUP

Two formations of the Ventersdorp Supergroup, namely the Rietgat and Makwassie Quartz Porphyry Formations outcrop in the northwest. According to Behounek (1980) the Makwassie Quartz Porphyry Formation formed isolated ridges over which sediments and lavas of the Rietgat Formation were deposited. Sedimentation alternated with volcanism during Rietgat times giving rise to a characteristic cyclic succession. The Rietgat deposits also accumulated in down-faulted regions in which fanglomerates were developed, especially close to down-faulted fault scarps (Behounek, 1980).

Table 1 — Geological units present in area 2826 Winburg

AGE	SUPERGROUP	GROUP	SUBGROUP	FORMATION	LITHOLOGY
Quaternary					Alluvium, calcified alluvium and river gravel. Red and grey aeolian sand. Calcrete and surface limestone.
Cretaceous					Kimberlite fissures and pipes.
Jurassic				Drakensberg	Dolerite sills and dykes. Basalt
Permo-Triassic	Karoo			Clarens	Fine-grained sandstone and siltstone. Pale orange to pink.
				Elliot	Brown-red to grey mudstone. Subordinate sandstone.
				Molteno	Sandstone, mudstone and shale. Coarse-grained sandstone.
Permian		Beaufort	Tarkastad		Mudstone and sandstone. Brownish yellow to grey.
		Ecca	Adelaide	Tierberg	Mudstone and sandstone. Khaki to grey. Shale. Dark grey to black.
Randian	Ventersdorp			Rietgat	Andesite
					Makwassie Quartz Porphyry
Archaean					Granite

The Makwassie Quartz Porphyry Formation on Vaalkoppies 8 forms a prominent quartz-porphyry ridge, 5–20 m high and comprises two distinctive lava flows. The upper flow weathers to a bright-red colour and has a submacroscopic texture. This unit is easily distinguishable from the Swazian age basement granite by the absence of microcline and the tendency of the granite to weather to a pinkish grey, as well as the absence of opaque minerals.

The lavas and arkoses outcropping on Geduld 37 and Pietersrust 30 belong to the Rietgat Formation. The arkose is blue grey and is characterised by poor sorting, horizontal and tabular cross-bedding and according to Behounek (1980) was derived from the adjacent basement granite. The lava is a blue-grey, amygdaloidal andesite which is associated with a breccia comprising angular to subangular granitic boulders with a maximum diameter of 0,3 m. The extreme range of particle size and heterolithological nature of the clasts suggests that this unit was deposited as a pyroclastic vent breccia (Behounek, 1980). On Goudkoppie 461 an exposure of poorly sorted conglomerate of the Rietgat Formation is present. This unit comprises angular to subangular (10–50 cm) quartzite boulders as well as minor granite and angular to well-rounded andesite pebbles (Behounek, 1980). On Vaalbank 186 the Rietgat Formation outcrops as an arkose with scattered pebbles (5 cm) of amygdaloidal lava with vein quartz. Palaeocurrent measurements from trough cross-bedded units indicate a northeasterly provenance area.

## 2.3 KAROO SUPERGROUP

The lithological units comprising the Karoo Supergroup are shown in Table 1. A sufficient number of vertebrate fossils have been collected in the area enabling the identification of 8 biozones. These range from the *Aulacephalodon*–*Cistecephalus* Assemblage Zone in the Adelaide Subgroup to the *Massospondylus* Assemblage Zone of the Elliot and Clarens Formations.

### 2.3.1 Ecca Group

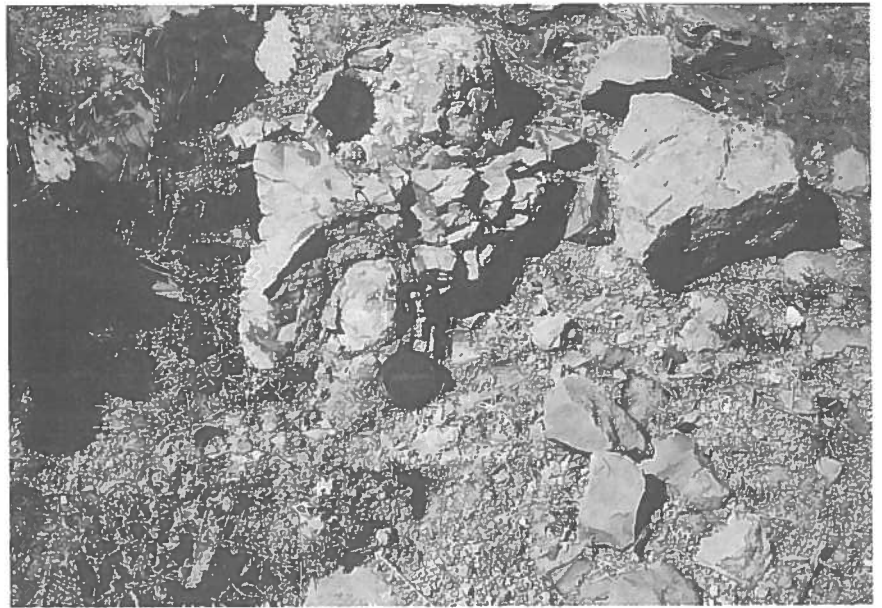
An extensive aeolian sand cover obscures the Ecca Group over large areas. In a borehole at Glen the Ecca Group has a total thickness of approximately 434 m of which 396 m comprise shale and 38 m sandstone (Theron, 1970).

#### 2.3.1.1 Tierberg Formation

The Tierberg Formation comprises grey to black well-bedded shales (Fig. 1) with subordinate thin siltstone and light-grey, fine-grained sandstone. Loock and Grobler (1988) described carbonate concretions occurring in well-defined beds especially towards the top of the Tierberg Formation (Fig. 2). The Tierberg Formation was deposited under reducing conditions in an inland-sea setting where deposition occurred through the suspension settling of silt- and clay-grade material. A progressive shallowing of water depth prevailed with time, which culminated in the progradation of fluvially constructive deltas from the northeast.



**Fig. 1 -- Well-bedded black shale of the Tierberg Formation at Soutpan.**



**Fig. 2 -- Calcareous concretions which characterise both the top and bottom of the Tierberg Formation as well as the base of the Adelaide Subgroup.**

The best-exposed outcrop of the Tierberg Formation is found on Basberg 416 to the east of the Bultfontein–Bloemfontein road and shows repeating couplets of dark-grey shale and fine-grained light-grey sandstone (Fig. 3). The sandstones of the upper part of the Tierberg Formation are horizontally bedded and ripple-drift cross laminated (Behounek, 1980). Bioturbation is present locally as well as calcareous concretions 20–80 cm in diameter which occur within the lower sandstones of the Tierberg Formation (Fig. 2). Since the bedding within the concretions is continuous with the sandstone bedding, a post-depositional replacement genesis is suggested for the formation of these concretions. In some instances the growth of these concretions resulted in a volumetric expansion and consequently in warping and doming of the overlying sediments. Bioturbation in the form of horizontal and vertical burrows as well as ripple marks are present, but is confined only to siltstone lenses. A thin concretion-rich horizon occurs 20 m below the top of the Tierberg Formation in which the remains of *Palaeoniscid* fishes were found. This fossiliferous zone was first discovered on Middelkop 622, about 10 km north of Soutpan with subsequent work by Loock and Grobler (1988) showing that this fossiliferous horizon can be traced westward from Middelkop 622 to Rondefontein 322, Vaalbank A 584 and Klipfontein 717.

The light colour of the siltstone and shale towards the top of the Tierberg Formation is ascribed to a progressive upward increase of siltstone and fine-grained sandstone. This feature, coupled with the presence of bioturbation and ripple marks, indicates the presence of current action and non-reducing conditions. It is suggested that much of the Tierberg Formation was deposited within a prodelta environment.

The lithostratigraphic boundary between the Tierberg Formation and the overlying Beaufort Group was taken at the base of the first prominent sandstone in the succession.

### 2.3.2 Beaufort Group

The Beaufort Group is represented by the Adelaide and Tarkastad Subgroups (Table 1).

#### 2.3.2.1 Adelaide Subgroup

In general, the Adelaide Subgroup comprises a sequence of alternating sandstone, siltstone, mudstone and shale beds (Fig. 4). The mudstones and shales (0,25–10 m thick) are blue grey, laterally persistent and show varying degrees of induration, whereas the sandstone units are lenticular and vary in colour between buff white and white. The sandstone beds range in grain size from very fine-grained to coarse-grained arkose and may contain channel-lag sediments (Allcock and Zawada, 1983) which are comprised of angular to well-rounded granite, gneiss or quartzite pebbles (diameters of up to 10 cm).

Work by Behounek (1980) on Basberg 416 (Fig. 5) has illustrated a number of other important features of the sandstones of the Adelaide Subgroup which are listed below:

<b>LEGEND</b>	
<b>LITHOLOGY</b>	
	Shale / mudstone
	Siltstone
	Rhythmite
	Sandstone
	Conglomerate
	Dolerite
	..... Predominantly coarse - - - - - Predominantly fine = : muddy ● matrix supported ● intraformational
<b>CYCLE</b>	
	Fining upward
<b>CONTACT</b>	
	Sharp
	Eroded
<b>SEDIMENTARY STRUCTURE</b>	
	No visible structures
	Horizontal lamination
	Micro cross-lamination
	Planar cross-bedding
	Cross-bedding (general)
	Trough cross-bedding
	Flute casts
	Groove casts
	Load casts
	Convolute lamination
	Clastic dykes
	Desiccation cracks
	Ripple drift-lamination
	Concretions
	+ Bioturbation    Burrows, tubes
<b>BED THICKNESS</b>	
	Very thin bedded (1-3 cm)
	Thin bedded (3-10 cm)
	Medium bedded (10-30 cm)
	Thick bedded (30-100 cm)
<b>COLOUR</b>	
ylw	Yellow
grn	Green
blu - gry	Blue-grey
prpl	Purple
<b>TEXTURE</b>	
f	Very fine grained
f	Fine grained
m	Medium grained
c	Coarse grained
c	Very coarse grained
<b>FOSSILS</b>	
	Vertebrata
	Silicified wood
<b>COMPOSITION</b>	
ca	Calcareous
cb	Carbonaceous
<b>GEOMETRY</b>	
	Lenticular unit
	Lenticular bedded

Legend for Figures 3, 5, 8, 9, 11 and 12.

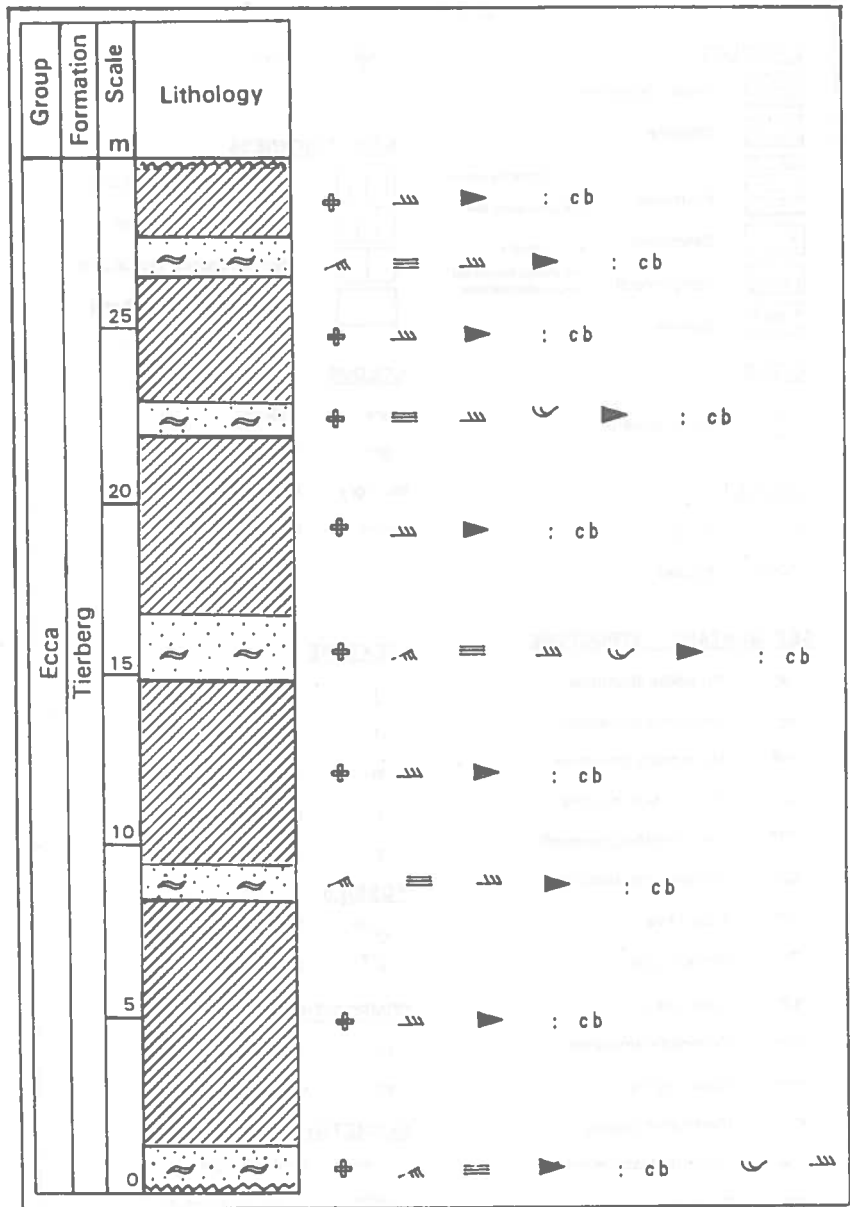


Fig. 3 — Lithostratigraphic section of the Tierberg Formation directly below the Ecca-Beaufort contact at Basberg 416 (modified after Behounek, 1980).



**Fig. 4 – Alternating sandstone, siltstone and shale lithologies of the Adelaide Subgroup.**

- 1) The texture of individual beds tend to change laterally.
- 2) Sandstones are texturally immature and poorly sorted.
- 3) Horizontal and tabular cross-bedding are the most commonly observed sedimentary structures. Micro-cross-lamination and ripple marks are subordinate and only occur within specific horizons (Fig. 6).
- 4) Mud-pebble conglomerates are present immediately above the shales of the Eccla Group.
- 5) Granite and quartzite pebbles (with diameters up to 5 cm) are present on the lower bounding surfaces of cross-bedded units.
- 6) Only isolated bioturbation was observed.
- 7) The mean palaeocurrent direction is  $280^{\circ}$ .
- 8) Large calcareous concretions are present near the base of the Adelaide Subgroup (Figs 5 and 7).

Palaeocurrent and petrographic data presented by Behounek (1980) as well as the presence of granite pebbles indicate a predominantly granite provenance towards the east and southeast. The depositional environment of the Adelaide Subgroup has been interpreted as an ephemeral braided-river system that was subject to catastrophic flood conditions.

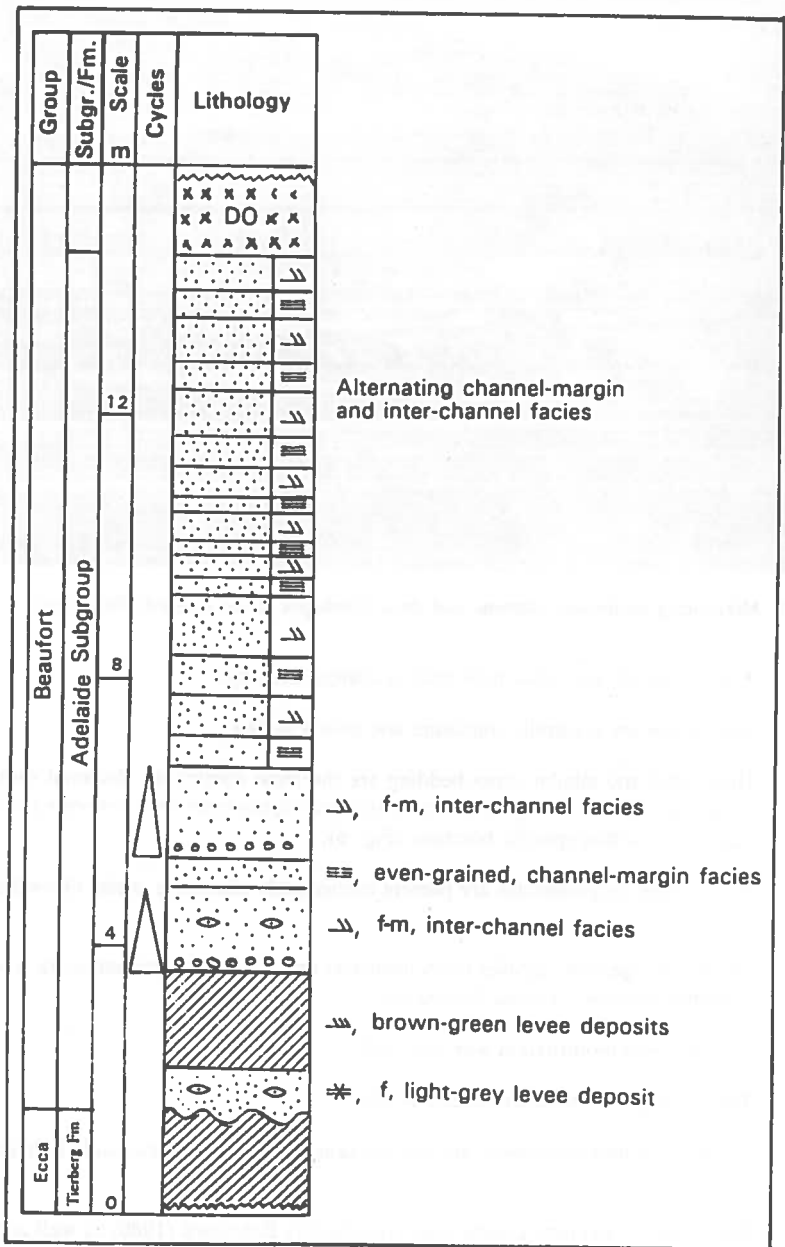


Fig. 5 — Lithostratigraphic section of the Adelaide Subgroup at Basberg 416 (modified after Behounek, 1980).



**Fig. 6 — Ripple marks on a sandstone bed of the Adelaide Subgroup.**

#### *2.3.2.2 Tarkastad Subgroup*

The Tarkastad Subgroup forms prominent plateaus, table mountains, buttes and sandstone shelves and is characterised by fine- to medium-grained, yellow and khaki-coloured feldspathic sandstones with an abundance of brightly coloured mudstones (red, purple, blue and green), especially in the area around Arlington. The sandstones of the Tarkastad Subgroup tend to be thicker and more prominent than those of the Adelaide Subgroup and are especially well developed at the top and bottom of the subgroup. In addition, the sandstones show trough cross-bedding, primary current-lineation and ripple marks with palaeocurrent trends showing a south and southeasterly source area.

Bonnet (1977) measured part of the Tarkastad Subgroup (112 m) on Retreat 329 (Fig. 8) and noted that the sandstone/mudstone ratio was 0,96. He further noted that the



Fig. 7 — Large calcareous concretions in the lowermost sandstones of the Adelaide Subgroup.

sandstones have a mean grain size of approximately 0,25 mm with purple mudstones occurring towards the base, whereas green-coloured mudstones are present at the top of the Tarkastad Subgroup. Petrographic work by Bonnet (1977) showed that the sandstones could be classified as arkosic wackes comprising quartz, feldspar, biotite as well as a clay and silica matrix.

#### 2.3.2.3 Palaeontology of the Beaufort Group

On Retreat 329 an unidentified amphibian skull as well as some small, sharp teeth were found within a clay-pellet conglomerate of the Adelaide Subgroup. Fossil trees of the *Dadoxylon* genus occur in the vicinity of De Rust Pan which, according to Botha and Visser (1970), are common throughout the Beaufort Group, particularly in the Winburg and Senekal districts. Of interest is the wall surrounding Senekal's Dutch Reformed Church which is decorated with fossil trees up to 30 m in length. A region known for its fossil wood extends from west of Senekal to Harrismith. In the Senekal district this east-west zone covers an area of 30 by 12 km with the highest occurrence of fossil wood being found on Langlaagte 389-Waterloop 698, Onze Rust 700, Helderwater 701 and Blinkwater 702. The *Dadoxylon* genus includes the species *Dadoxylon arberi* Seward 1919 and *Dadoxylon sclerosum* Walton 1925. The latter was a 10-18-m-high tree bearing needle-like leaves with primitive cones and was adapted to a cool climate during the Carboniferous and became extinct during the Triassic.

Three biozones occur in the Adelaide Subgroup. Fossils of *Aulacephalodon*, one of the zone fossils of the *Aulacephalodon-Cistecephalus* Assemblage Zone, has been

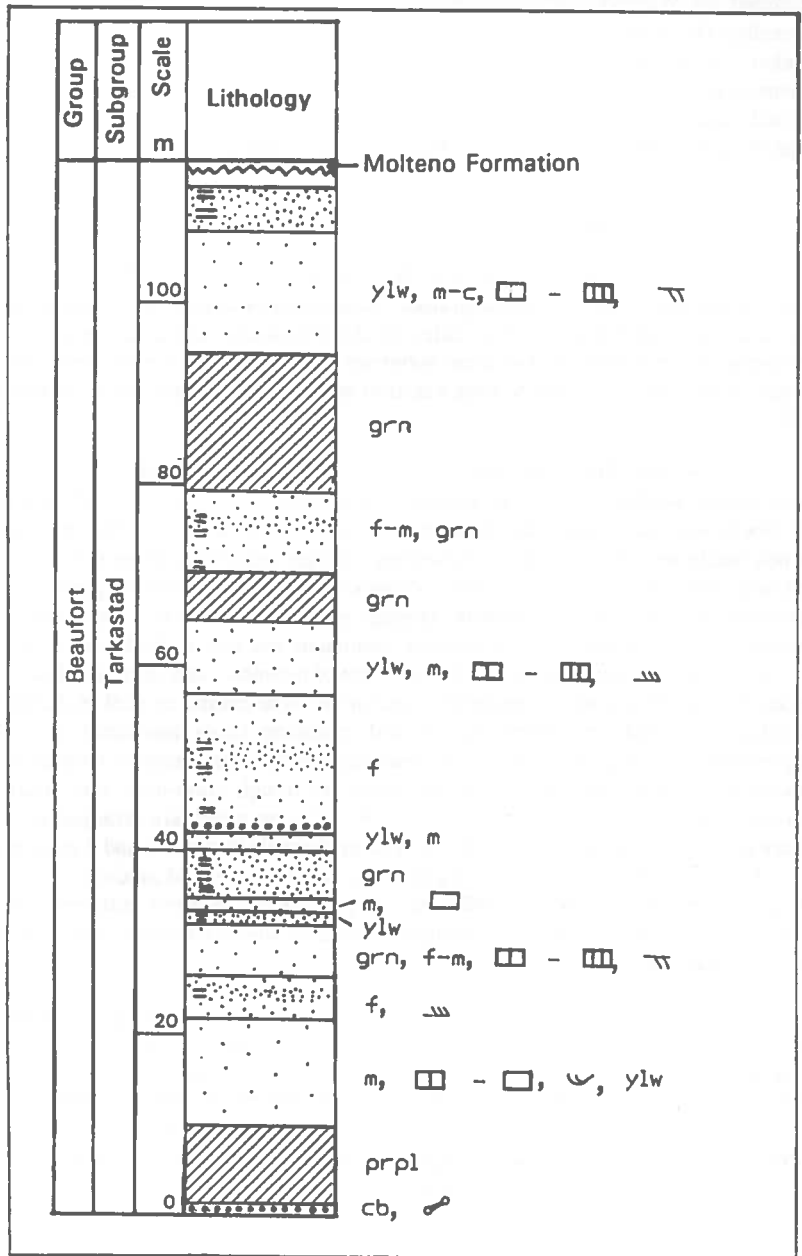


Fig. 8 — Lithostratigraphic section of the Tarkastad Subgroup at Retreat 329 (modified after Bonnet, 1977).

recovered on Waterval 287. *Dicynodon lacerticeps*, one of the zone fossils of the succeeding *Dicynodon lacerticeps-Whaitsia* Assemblage Zone, is known to occur on the Senekal commonage (Kitching, 1977). This biozone is succeeded by the *Lystrosaurus-Thrinaxodon* Assemblage Zone which straddles the boundary between the Adelaide and Tarkastad Subgroups. Fossils of *Lystrosaurus* have been recorded on the farms Wessels Punt 2315, Magdala 97, Halfweg 356, Brandford 320 and Kruis Vlei 279.

### 2.3.3 Molteno Formation

The contact between the Tarkastad Subgroup and the overlying Molteno Formation is taken at the base of the first coarse-grained, glimmering sandstone in the succession. In most cases this contact is obscured by fallen blocks of Molteno sandstone due to the rapid weathering of the underlying Tarkastad Subgroup. Where outcrop is good, however, the Molteno Formation is observed to form a distinct break of slope which can be clearly seen on Mequatlingsnek 131.

The Molteno Formation comprises the following lithologies: 24% coarse- to very coarse-grained sandstone; 41% fine- to medium and medium- to coarse-grained sandstone; 15% fine to very fine-grained sandstone and 20% argillaceous sediments. The very coarse-grained sandstone show planar cross-bedding, trough cross-bedding and channel fills (Eriksson, 1983) (Fig. 9). Subrounded, sometimes subangular pebbles of quartz and less commonly feldspar, with diameters ranging between 0,2–2 cm, characterise the conglomeratic sandstones which are laterally continuous and vary in thickness of between 0,1–1 m. Conglomeratic lenses with a lateral extent of between 1 and 10 m and thicknesses ranging between 10 and 40 cm frequently occur at the basal contact as well as the base of individual cross-bed sets. Flute moulds and mudstone clasts associated with non-conglomeratic coarse-grained sandstone also occur at the basal erosive contact of the Molteno Formation. Occurring above the latter are trough cross-beds with widths of between 1 and 5 m and depths ranging from 30 to 50 cm which are arranged in either solitary or grouped sets (Eriksson, 1983) as well as channels between 1 and 3 m deep and 15 to 25 m wide which truncate the conglomeratic and cross-bedded sandstone in places. Petrographic work by Eriksson (1983) has shown that the Molteno sediments can, in general, be classified as quartz-rich feldspathic wackes with a relatively high content of interstitial material.

The fine- to medium-grained sandstones are also planar or trough cross-bedded with planar cross-bedded sets varying in thickness of between 0,1 and 2 m. These are arranged in grouped tabular sets with foreset angles between 10 and 21°. The trough cross-bedded sandstones, on the other hand show channel fill structures, small- to medium-scale tabular planar cross-beds (set thicknesses of between 5 and 80 cm and foreset angles ranging from 5 to 20°), scour marks, ripples and mudstone lenses with trough cross-beds 1–4 m wide and depths of between 20 and 80 cm.

The argillaceous beds of the Molteno Formation range in thickness between 1 and 20 m, but exposure is usually poor. Clastic dykes of up to 70 cm width as well as plant

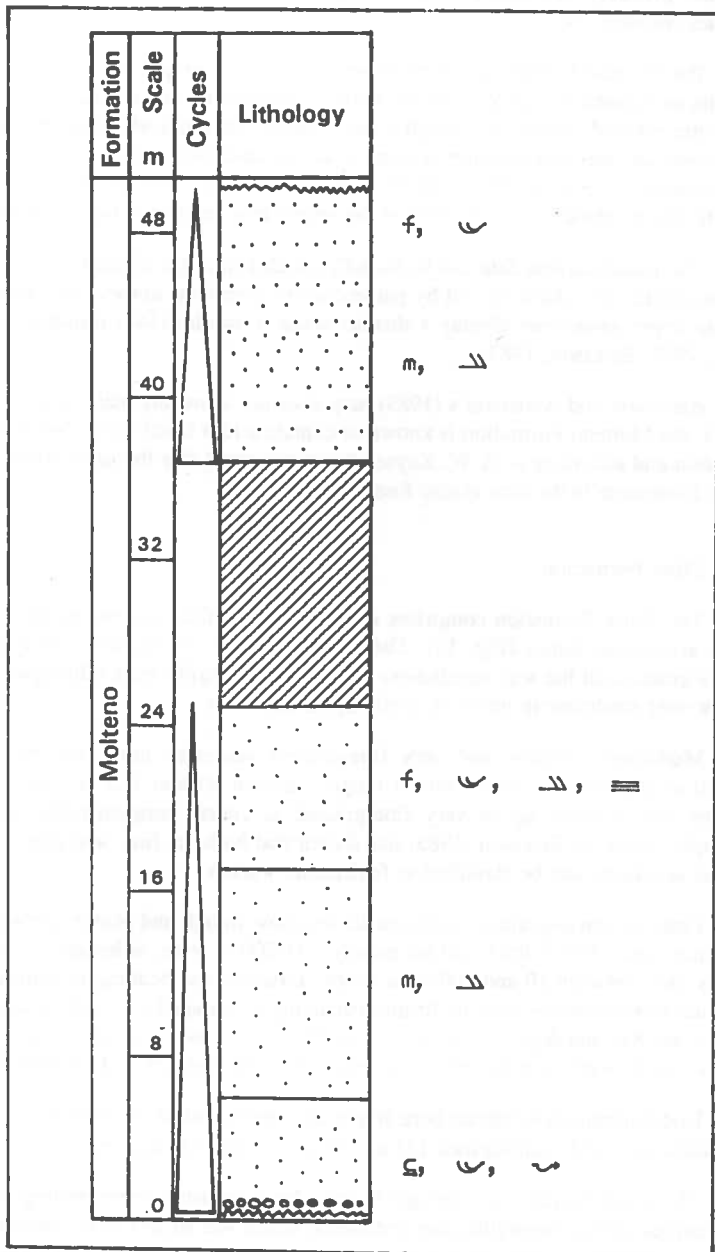


Fig. 9 — An idealised lithostratigraphic section of the Molteno Formation (modified after Eriksson, 1983).

fragments, probably belonging to the widespread *Dicroidium* flora occur within the mudstones (Bonnet, 1977).

The Molteno Formation comprises several upward-fining sedimentary sequences which thin as a clastic wedge towards the north. The combination of a basal erosive contact, the presence of channel fill trough cross-bedding, the relatively immature nature of the sediments and the predominance of cross-stratified sandstones in this unit is compatible with a braided-river model (Miall, 1978; Rust, 1978). The coarse-grained nature of the sediments reflects marked tectonic uplift of the source area, leading to rapid sedimentation.

The palaeocurrent data can be broadly divided into two distinctive groups. The lower sandstones are characterised by palaeocurrent directions towards the west (300°) while the upper sandstones display a distinct south to north (354°) transport direction (Bonnet, 1977; Eriksson, 1983).

Anderson and Anderson's (1983) map does not show any plant fossil localities. However, the Molteno Formation is known to contain a rich fossil flora elsewhere in the Karoo basin and according to A.W. Keyser (pers commun.) it is therefore likely that the Molteno Formation in the area is also fossiliferous.

#### 2.3.4 Elliot Formation

The Elliot Formation comprises massive, red argillaceous sediments with subordinate arenaceous lenses (Fig. 10). The contact between the Molteno and Elliot Formation is gradational but was nonetheless defined where argillaceous lithologies become dominant over sandstone in terms of stratigraphic thickness.

Mudstone, siltstone and very fine-grained sandstone constitute 92% of the measured stratigraphic thickness which ranges between 80 and 110 m (Fig. 11). The remaining 8% is made up of very fine-grained to coarse conglomeratic sandstone. Petrographic work by Eriksson (1983) has shown that both the fine- and coarse-grained sandstone sediments can be classified as feldspathic wackes.

Fine- to coarse-grained sandstone lenses show trough and planar cross-bedding. These lenses are 1,5–6 m thick and are mainly 100–200 m wide, although in some cases they may vary between 10 and 300 m in width. Trough cross-bedding is more common than planar cross-bedding with the former occurring as grouped sets with trough widths between 2 and 8 m and depths of between 20 and 70 cm. Palaeocurrent data are limited but a tentative north-northwesterly trend was determined (Bonnet, 1977; Eriksson, 1983).

Undifferentiated vertebrate bone fragments were found on seven different locations in red mudstone on Mequatlingsnek 131 and Wintershoek 333 (Bonnet, 1977).

The Elliot Formation is thought to have been deposited from settling of loessic dust (preserved as massive argillaceous sediments) which was subject to intermittent fluvial processes (preserved as local sandstone lenses). Subdued uplift of a south-southeasterly sedimentary source supplied material to low sinuosity braided rivers (Eriksson, 1983).

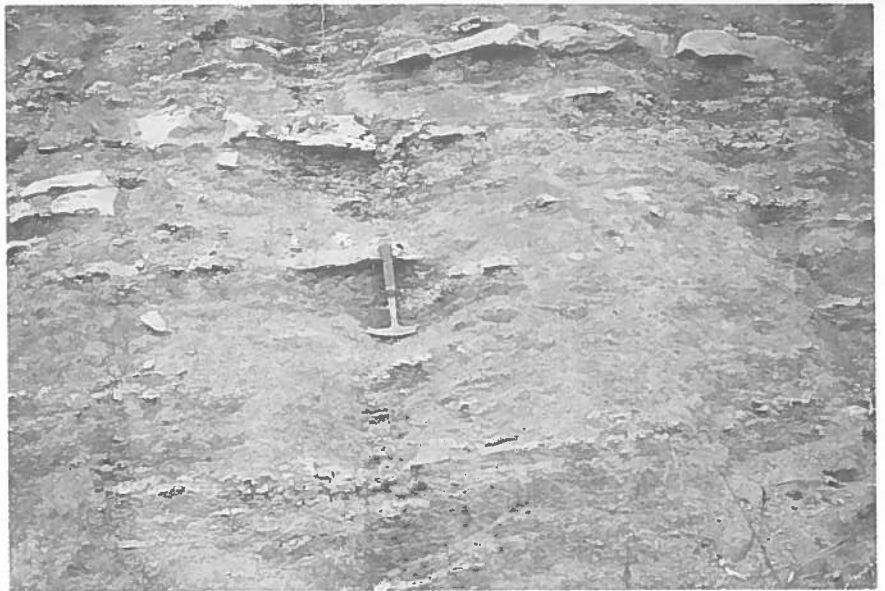


Fig. 10 — Mudstone with subordinate lenses of sandstone in the Elliot Formation.

#### 2.3.5 Clarens Formation

The Clarens Formation comprises 66% very fine-grained, pale-orange to pink sandstone, 21% mudstone and siltstone, 11% fine- to medium-grained sandstone and 2% medium- to very coarse conglomeratic sandstone (Fig. 12). The main sandstone of the Clarens Formation has an average thickness of 145 m and thickens from east to west.

A gradational contact characterised by interfingering, exists between the Elliot and Clarens Formations (Bonnet, 1977). Although the upper contact with the volcanic rocks of the Drakensberg Group is generally sharp, small, irregularly shaped basaltic beds are present below the contact suggesting that minor volcanism occurred prior to the cessation of sedimentation (Eriksson, 1981).

Petrographic work by Eriksson (1983) indicated that these sediments are quartz-rich feldspathic wackes exhibiting subangular grain shapes and a matrix consisting predominantly of chloritic clay-grade material.

Massive bedding and large-scale planar cross-bedding characterise the very fine- to fine-grained sandstones of the Clarens Formation. The large-scale planar cross-beds are distinguished by their higher foreset inclination ( $5-34^\circ$ ). Most foreset laminae display sharp, angular rather than asymptotic contacts, with set thicknesses ranging from 0,5 to 5 m. Other sedimentary structures include planar stratification, convolute stratification and minor channels as well as *Planolites* burrows and current ripple marks (Beukes, 1969; Eriksson, 1981).

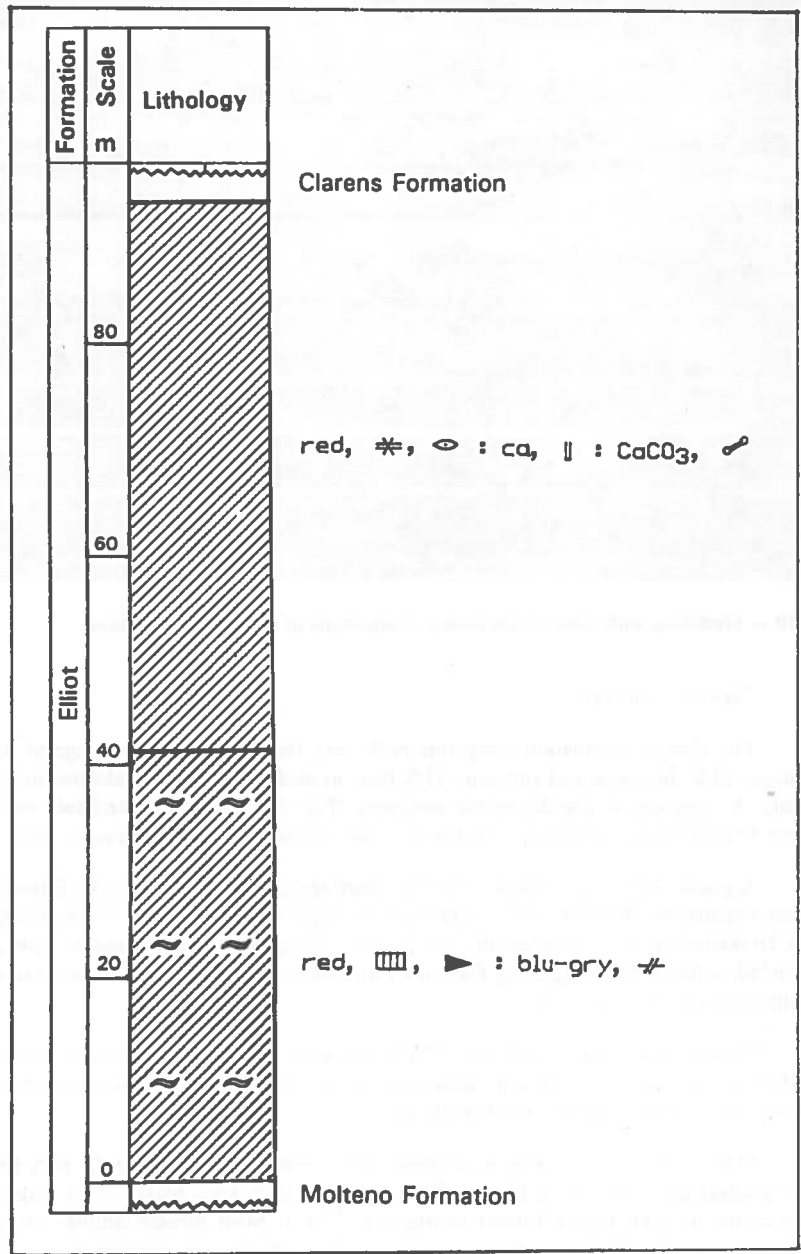


Fig. 11 — Lithostratigraphic section of the Elliot Formation at Sherwood 116 (modified after Bonnet, 1977).

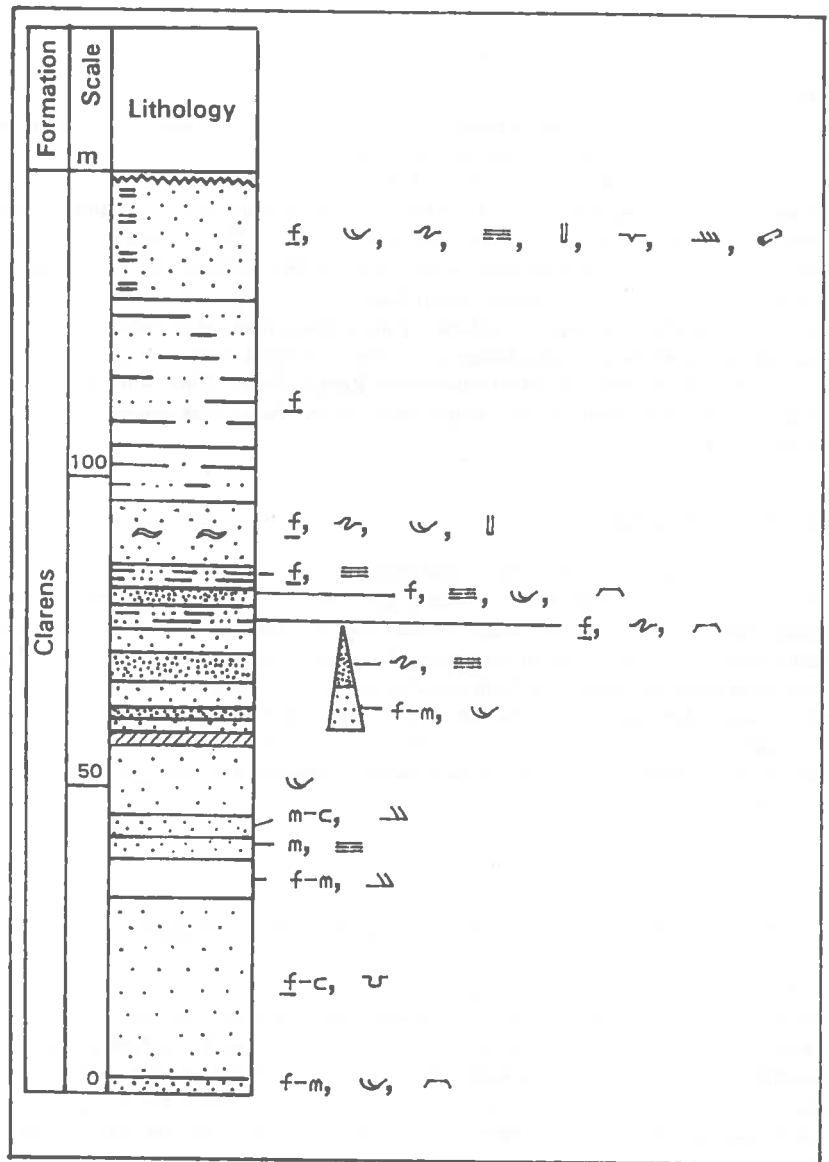


Fig. 12 — A representative lithostratigraphic section of the Clarens Formation (modified after Eriksson, 1983).

The lowermost part of the Clarens Formation was probably deposited by alluvial fans trending towards the east-southeast while the rest is of aeolian origin. The palaeoclimate was semi-arid with intermittent rain-storm events which led to the formation of rare playa-lake deposits (Eriksson, 1983).

Dinosaur footprints in very fine- to fine-grained sandstone of *Dinopertadiscus vandijki*, *D. centus*, *Malapopentapodiscus supersaltator* and *Vandijkopentapus giantscastlensis* were reported by Eriksson (1983). These dinosaurs varied in stature from sparrow to ostrich size and were bipedal and quadrupedal. A large collection of dinosaurs and other Triassic fossils was made by Prof. J.W. Kitching of the Bernard Price Institute for Palaeontological Research of the University of the Witwatersrand. A subdivision into 3 biozones was proposed by Kitching and Raath (1984). They recognised a lower *Euskelosaurus* Range Zone and an upper *Massospondylus* Range Zone. An acme zone for *Tritylodon* was recognised. The *Euskelosaurus* Range Zone occupies the lower third of the Elliot Formation while the upper two thirds of the formation and the Clarens Formation are included in the *Massospondylus* Range Zone. The *Tritylodon* Acme Zone occurs in the Elliot Formation within the *Massospondylus* Range Zone. This lithological and biostratigraphic subdivision can be clearly seen on the Farm Makoatleng 302 in the Clocolan District.

#### 2.3.6 Drakensberg Formation

The contact between the Clarens and Drakensberg Formations is taken at the base of the first continuous basalt flow. Normally this contact is sharp and easily defined. Intercalations of sandstone and basalt indicate that the earliest volcanic activity and sedimentation of the upper part of the Clarens Formation occurred simultaneously. The basaltic lavas range in composition from enstatite-andesites to olivine-rich basalt with their textures varying between ophitic and subophitic. The Drakensberg Formation comprises a great number of horizontally bedded flows of variable thickness. The estimated total volume of basalts presently exposed in the Lesotho Highlands is 26 000 km<sup>3</sup> (Marsh and Eales, 1984).

#### 2.3.7 Dolerites

Nearly all the intruded dolerites occur as sills, dykes, conical sheets, sheets or irregular bodies, and are chemically similar to the basalts of the Lesotho Highlands. The majority of these intrusions are younger than the Jurassic basalts and were probably emplaced during the waning stages of the Drakensberg volcanism (Du Toit, 1921). The frequency of intrusions decreases progressively upwards within the Karoo Supergroup with a maximum abundance occurring within the strata of the Beaufort Group. A marked decrease in linear, dyke outcrops occur towards the northwestern portion of the area where sills dominate (Behounek, 1980) whereas conical sheet intrusions become scarce north of 29°30'.

South of Winburg, weathering of the dolerite sheets give rise to an undulating surface on which Karoo vegetation replaces the grass types. The recognition of dykes was facilitated by noting the presence of *Acacia karoo* within the immediate vicinity of the

dyke. Bonnet (1977) measured dykes ranging from 0,7 m to several metres in width and sheets with a maximum thickness of 30 m, and also noted that some dolerite sheets had been intruded by younger dykes.

Petrographically the dolerites in the Winburg area consist of labradorite, augite and serpentinised olivine (Bonnet, 1977).

The contact metamorphic effect of the dolerite on the shales of the Tierberg Formation varies from slight induration to the formation of hornfels with the overlying shales being more affected than those underlying the dolerite sills. Mudstones of the Adelaide Subgroup show distortion of layering and a bleached colour in close proximity to a dolerite contact.

### 3. QUATERNARY DEPOSITS

In area 2827C, partially consolidated Quaternary sediments occur in the river valleys. Isolated occurrences were noted on the escarpment, but are not as well developed as those forming flat pediments against the main escarpment (Bonnet, 1977). These deposits are characterised by extensive erosion in the form of deep dongas (Fig. 13), and are considered similar to the Cornelia Beds and sediments found further north in the Paul Roux and Senekal districts (Botha and Linstrom, 1975). The lower portion of these Quaternary sediments are clay rich and massive and the upper parts are darker and contain calcareous nodules and remains of plant roots. Fossil teeth belonging to *Phacochoetus* (warthog) and some bone fragments occur within Pleistocene and recent deposits of the Sandspruit on Bankfontein 34. In addition, Bonnet (1977) noted that the fresh-water mussel, of the genus *Unio* is present. A fossil of the extinct elephant, *Mammathus subplanifrons* was discovered where the railway line crosses the Sand River at Virginia.

A Pleistocene spring deposit at Florisbad north of Bloemfontein yielded a skull of a very primitive form of *Homo sapiens*, known as Florisbad Man. The relative age of the deposit is estimated to be Upper Palaeolithic (Brink 1987). The site has yielded a rich assemblage of Middle Stone-Age mammals. The human skull was found in what is thought to be a carnivore assemblage predating the Middle Stone Age (Brink, 1987). The geology of this interesting site was described by Fourie (1953) with Joubert and Visser (1991) giving a more recent account of the same deposit.

#### 3.1 CALCRETE

The most common type of calcrete found in the map area was laminated hardpan calcrete which is restricted to higher ground away from drainage channels. Calcrete covers large areas in the western and northwestern parts of the map area. The more extensive deposits are located on low-lying plains while smaller deposits occur on higher ground as thin crusts overlying dolerite and Ecca Group shale. According to Netterberg (1969), nodular and hardpan calcrete can be identified in the map area. Nodular calcrete attains thicknesses of 10 m while hardpan calcrete is seldom thicker than 3 m. Nodular calcrete with nodule diameters of up to 4 cm is frequently found on pan floors whereas hardpan



Fig. 13 — Dongas developed in Quaternary sediments.

calcrete was noted to overlie nodular calcrete. This calcrete can contain small fragments of Tierberg shale and where total calcification of Ecca Group sediments had occurred, undulatory lamination was noted. Shattered hardpan calcrete was only observed in isolated cases, particularly overlying dolerite sills.

### 3.2 AEOLIAN SAND

The area bound by longitudes  $25^{\circ}15'$  to  $27^{\circ}5'$  and latitudes  $27^{\circ}25'$  to  $28^{\circ}30'$  is mainly covered by aeolian sand and sandy soils (Harmse, 1963). These sands range in colour from red to brown to light grey and occur as sand sheets or dunes. The sheets vary in thickness between a few mm to more than 5 m with small dunes overlying these sand sheets (Behounek, 1980). The colour of the red sands is due to hematite coating quartz and feldspar grains. Grey and brown sands predominate where calcrete and Tierberg shales are present, especially where the water table is high (Du Toit, 1954).

Harmse (1963) considered aeolian sand as a distinct geological formation and further stated that the sand incursion can be correlated with three arid periods during Pleistocene times. During the Early to Middle Pleistocene, older red sand was deposited as dunes bordering rivers. Aeolian sand, in the form of seif dunes with a southeasterly trend, was deposited during late Middle Pleistocene to early Upper Pleistocene. Deposition of garnet-bearing sand, as river-bordering dunes occurred during the late Upper Pleistocene (Harmse, 1963).

### 3.3 ALLUVIAL DEPOSITS

The prominent rivers in the mapped area are the Vet, Sand and Modder Rivers. These rivers have valley widths of 1 km with a depth of 20-70 m with much of the alluvium comprising cross-bedded, lenticular conglomeratic material containing fossil wood (Coetzee, 1960).

### 3.4 SOIL

A large part of the mapped area is covered by various soil types. Towards the west and northwest, soils have been mixed by aeolian deposition and are considered to be inherently infertile (Harmse, 1963). This condition is further exacerbated in the case of grey sandy soils which are intermittently or permanently saturated by ground-water seepage.

### 3.5 PANS

Two types of pans have developed in the area, one of which is related to present streams or palaeostreams. Pans that are unrelated to the present-day drainage develop either on conically-shaped dolerite sills or on wind-deflated hollows within aeolian sheet deposits. The conical dolerites give rise to an inward drainage pattern which results in a basin of up to 3 m deep. Pans that are related to present-day streams tend to be large elongated pans. They are more than 250 m in length and are bordered by dolerite outcrops whereas the circular pans with diameters of more than 150 m are usually deeper (Behounek, 1980). Often the larger pans are restricted to clay-rich areas and are underlain by the shales of the Tierberg Formation. The pan floors are 10-13 m below the surface of the inter-river area and internal drainage is a common feature.

Soutpan is a typical example of a large pan and is one of a series of pans that are developed along a complex palaeodrainage network trending to the north, northeast and west. The palaeostreams follow broad, shallow valleys which are up to 9 km wide and 30 m deep (Loock and Grobler, 1988) (Fig. 14).

## 4. ECONOMIC GEOLOGY

A wide variety of minerals are present in the map area. Gold, however, is by far the most important economic mineral found in the area.

### 4.1 GOLD

Although no outcrops of rocks of the Witwatersrand Supergroup are present in the map area, a brief discussion of the general geology relating to the occurrence of gold is given in view of its economic importance to the region.

The Free State Goldfield is a triangular-shaped area of approximately 350 km<sup>2</sup> and stretches for 32 km south of Allanridge to Welkom and then for 22 km east of Virginia.

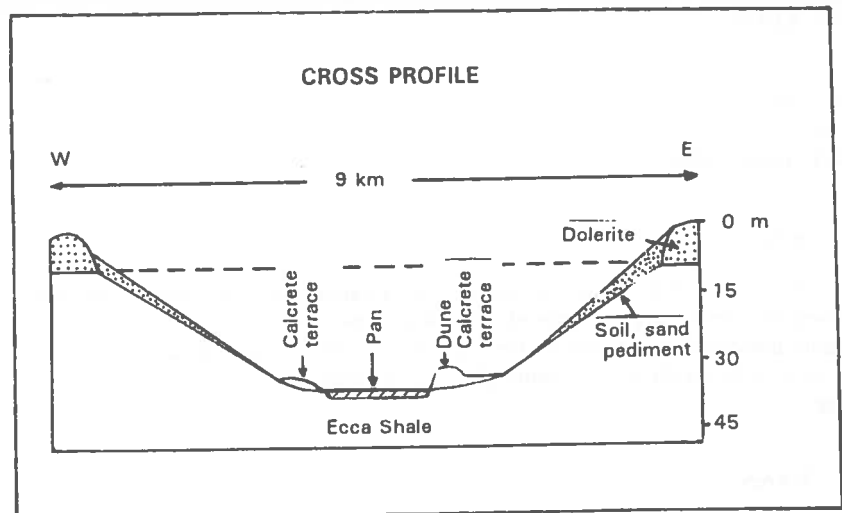


Fig. 14 — Cross-section through Soutpan (after Loock and Grobler, 1988).

Mines falling within the mapped area are St Helena, President Brand, President Steyn, Beisa, Beatrix and Oryx. The Free State Goldfield was first discovered in 1933 when the exploration hole WE 1 intersected Witwatersrand quartzites. By the end of 1983, the Free State Goldfield had mined 8,7 million kg of gold.

The Free State Goldfield is stratigraphically placed within the Central Rand Group which has been subdivided into the Johannesburg and Turfontein Subgroups (Fig. 15). In the following discussion a brief account is given of some of the more important placer deposits within the Central Rand Group.

#### 4.1.1 Basal reef placer

The Basal reef is a pebbly, siliceous quartzite with variable amounts of conglomerate and heavy minerals. Pyrite is the most abundant detrital mineral; other common minerals include chromite, zircon and leucoxene. The Basal reef exhibits trough and planar cross-bedding as well as horizontal bedding and is thought to have been deposited in a braided-stream environment. Gold concentrations are generally associated with the conglomerate facies in the proximal portion of the Basal reef (Minter, 1978) whereas lower gold concentrations are present in the finer-grained distal portions of the Basal reef.

#### 4.1.2 Saaiplaas placer

This placer deposit occurs within the Harmony Formation and consists of a complex of channel bodies which vary in width between 100-200 m and in thickness from 1-3 m. Dominant sedimentary structures include trough cross-beds and flat lamination. The

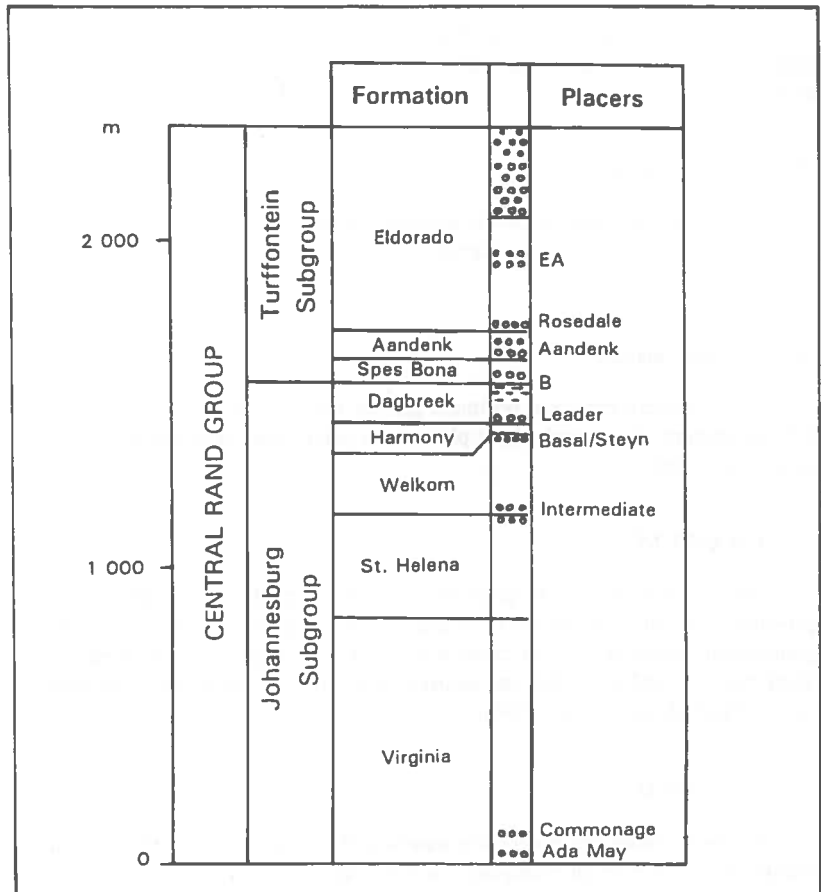


Fig. 15 — Lithostratigraphic column of the Central Rand Group in the Welkom Goldfield (modified after Minter et al. 1986).

highest concentrations of gold are found within the flat-laminated zone which is characterised by numerous pyritic laminations and the sporadic presence of kerogen (Minter et al., 1986).

#### 4.1.3 Leader placer

This placer is developed over the entire goldfield but is not of economic importance in the northern part of the Free State Goldfield. It is approximately 1 m thick and comprises a heterogeneous assemblage of massive gravel, matrix-supported gravel, gravel lags, trough cross-beds and horizontally bedded quartzites. The base of this placer has a gold concentration of between 4 and 7 g/ton.

#### 4.1.4 B placer

This placer occurs at the base of the Spes Bona Formation and is characterised by discrete, interconnected channelways, 200 m wide and 2 m thick and show an average gold content of 25 g/ton (Minter et al., 1986).

#### 4.1.5 Aandenk placer

These placers comprise pebbly siliceous quartzites and conglomerates set within channel complexes. These lobe-like deposits are limited in extent and are only sporadically mined (Minter et al., 1986).

#### 4.1.6 Aldorado placers

These placers represent pediment gravels that are derived from erosion of the underlying placers. In general, these placers are patchy and only intermittently mined (Minter et al., 1986).

### 4.2 URANIUM

Uranium is mined as a by-product of gold within the Free State Goldfield. Within the proximal facies of the Steyn placer, uraninite concentrations are 5-10 times higher than the gold content, while in the distal facies it is 25-40 times higher. The average content of the Basal reef is 0,167 kg/t while the recovery grade for the Leader reef ranges between 0,1 and 0,4 kg/t (Minter et al., 1986).

### 4.3 DIAMONDS

Kimberlite pipes and dykes occur mainly in the Henneman and Theunissen districts with minor occurrences in the Marquard and Clocolan districts (Table 2). The kimberlite pipes and dykes have been worked from time to time due to the high quality of diamonds recovered. Very few have, however, been of significant economic importance owing to the comparatively small volume occupied by the pipes and dykes.

The kimberlite dykes differ from pipes in that the dykes contain less xenoliths, are less brecciated, more porphyritic and are nearly always micaceous.

The Star Diamond Mine is briefly discussed in view of having produced small diamonds of very high quality and good colour. The mine is situated on Wynandsfontein 53 approximately 12 km north of Theunissen. Mining operations have concentrated on fissures and blows which contain typical blue-ground kimberlite. More specifically, the kimberlite from the Star Diamond Mine is comprised of a serpentinised olivine-pyroxene-phlogopite peridotite which appears brecciated (Allen, 1961). The highly micaceous nature is ascribed to either local segregation or country-rock contamination.

**Table 2 — Kimberlite occurrences in the area 2826 Winburg.**

OCCURRENCE	LOCATION
Ayah 421	Farm Ayah 421, northeast of Virginia
Bluegum 616	Farm Bluegum 616, Hennenman district
Byrne	Wynandsfontein 53, Theunissen district, 8 km from Theron
Deeldam	8 km from Theron Siding, close to Phoenix
Driehoek	Driehoek 500 and Thor 349. 19 km from Theunissen adjacent to Driekopjes
Driekopjes	Welgegund 356, 5 km NNW of New Thor
Ferreiras Rust 163	Rietspruit Railway Line, Hennenman district
Kaal Valley	13 km NW of Virginia Siding, on Kaalvallei Diamond Mine 12
Lion Hill	On Vergelegen 85 near Theron Siding
Lovedale	Southeast of Monastery, Clocolan district
Monastery	96 km SE of Winburg Road Station, Marquard district
Monteleo	Approximately 2 km west of Lion Hill
Myfornes	East side of Theronkop
New Compound	At Welgegund (on Hendriena 563) 9 km NW of Theron Station
New Thor	On Vrede Rust 298, 5 km west of Monteleo
Onverwag 251	Onverwag 251, Hennenman district
Phoenix	2 km NE of Theron Siding
Sweet Home 248	Adjacent to New Thor
Schuins Hoogte	On Schuins Hoogte 55, Clocolan district
Spioenkop	Farm Spioen Kop 326, ± 10 km southeast of Excelsior
Theron	Wynandsfontein 53, east of Phoenix

#### 4.4 SALT

Salt pans from which commercial exploitation occurs, are situated in the area west of Brandfort. The brines consist predominantly of sodium chloride with potassium, magnesium and calcium as impurities (Table 3) (Hugo, 1974).

The large Haagenstad (Florisbad) Salt Pan lies 37 km north-northwest of Bloemfontein and covers an area of 1 411 ha (Table 4). Information obtained from

**Table 3 — Analyses (mass percentage) of salt produced at Florisbad and Kristalpan (after Hugo, 1974).**

PAN	SAMPLE	Na	K	Mg	Ca	F	Cl	CALCULATED NaCl
Florisbad	Best grade	38,19	0,07		0,27		58,75	98,7
Florisbad	Best grade	40,20	0,06	0,22	0,28	4x10 <sup>-5</sup>	59,60	97,9

**Table 4 — Details of certain salt-producing pans in the Orange Free State.**

PAN	DISTRICT	Size of pan (ha)	Floor depth (m)	Soil type	Rock type	Vegetation
Haagenstad	Brandfort	1411	45	Clay, 0,5 m thick	Ecca shale, sandstone and dolerite	Very sparse
Kristal or Skoppan	Brandfort	107	24	Clay	Dolerite and Ecca Group shale	None

boreholes indicates that most of the underground brine is stored above a depth of 18 m. Brines from shale have a higher salinity than those from dolerite areas although the salinity can vary widely in each of the lithologies.

According to Hugo (1974) the average yield of salt is approximately 58 tons per borehole per annum.

#### 4.5 HELIUM

In 1957 helium was discovered in gas collected from borehole AD1A of the Virginia Gold Mining Company Ltd. Since then it has been found in nearly all gas samples taken from the mine where contents vary between 0,1 and 13,3 %. The helium is thought to have originated from the strata of the Witwatersrand Supergroup through the radioactive decay of uraninite contained within Upper Witwatersrand conglomerates.

Minor amounts of helium have been noted in natural springs, in particular on the farm Florisbad in the Brandfort district.

#### 4.6 DOLERITE

Dolerite is widely used in road construction. Weathered dolerite is used as a substratum while the fresh dolerite is used in the tar mixture for road metalling.

## 4.7 SANDSTONE

River sand and especially sandstones of the Molteno Formation are used as local construction materials.

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