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The General Geology of the Kruger National Park

I.C. SCHUTTE

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Geological units and new data gathered during regional mapping of the Kruger National Park are summarised. A simplified geological map is presented in conjunction with this paper. A large number of new geological formations have been recognised in the course of this regional mapping and new names have been proposed for these units. Some of these names have not yet been officially recognised by the South African Committee for Stratigraphy (SACS). On-going work by the Geological Survey and other organisations is likely to lead to further additions to and refinement of the data presented in this paper. The Goudplaats and Makhutswi Gneisses are the oldest rocks known in the park. They form the sialic basement of the various greenstone belts represented by the Murchison and Barberton sequences. The age relations of the Orpen Gneiss* have not yet been established. Tonalitic and trondjemitic gneisses constitute the first phase of intrusion of the Nelspruit Granite Suite. The Shamiriri, Macetse* and Baderoukwe Granites, and the Cunning Moor Tonalite* intrudes rocks of Swazian age during the succeeding Randian Erathem. At the commencement of the Mokolian Erathem syenite of the Phalaborwa Complex intruded the Makhutswi Gneiss. Subsequently extrusion of lavas and deposition of sediments of the Soutpansberg Group of Mokolian age took place in a fault-bounded trough in the northern part of the park. Diabase intruded the Group in the form of sills. Pre-Karoo dykes of various ages occur throughout the area. The Timbavati Gabbro represents the youngest Pre-Karoo intrusion. The Late Palaeozoic to Mesozoic Karoo Sequence extends from north to south along the eastern edge of the park and consists of sedimentary rocks overlain by basalt and rhyolite. The last phase of Karoo volcanism is represented by granophyre, gabbro and microgranite. The sedimentary Malvernia Formation of Cretaceous age unconformably overlies the basalt in the northern part of the park. Quarternary surficial deposits blanket the older rocks in places.
* Not yet approved by SACS.

Key words: Archaean, granite, gneiss, greenstone, sedimentary, igneous, Karoo, Lebombo, nephelinite, basalt, picrite basalt, rhyolite.

I.C. Schutte, Geological Survey of South Africa, Private Bag X112, Pretoria, 0001.

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Introduction

In response to a request by the National Parks Board of Trustees the Kruger National Park (KNP) was mapped by the Geological Survey of the Republic of South Africa during the period 1969-1979. Four maps on a scale of 1:100 000, together with accompanying reports, were subsequently completed. Certain areas were later revised in the course of preparing maps for the Geological Survey's 1:250 000-scale map series. This paper summarises the results of the mapping carried out in the KNP by the Geological Survey since 1969.

For the purpose of this publication a slightly simplified geological map (Map; Inside back cover) has been prepared on a scale of 1:500 000. This map reflects the current views of the Geological Survey on the geology of the area.

History of Geological Investigations of the Kruger National Park

The first geological descriptions based on travels through the park were by Mauch (1870), Erskine (1875), and Cohen (1875). Wilson-Moore (1897) described the Karoo sediments as containing coal and plant fossils, as well as lavas north of Lower Sabie. Hall (1912, 1920a, 1920b) described the various gneisses, granite and pegmatites, as well as mica and corundum occurrences along the Olifants River. Rogers (1925) was the first to recognise olivine basalt (limburgite) and nepheline basalt north of Klopperfontein. Du Toit (1929) described the monoclinal structure in the Lebombo Mountains. Kupferbürger (1935) investigated the corundum occurrences along the Olifants River. Taljaard (1938) gave a general account of the geomorphology of the Lowveld in the park.

Brandt (1943, 1946, 1948) mapped a large area east of Phalaborwa in the park, and made a major contribution to the geology of the park. He also gave detailed petrographical descriptions and chemical analyses of the granite, Phalaborwa Complex, Timbavati Gabbro, basalt, rhyolite and granophyre.

Obst & Kayser (1949) described the geomorphology of the park. Lombaard (1952) gave petrographic descriptions and chemical analyses of Karoo lavas and associated intrusive rocks. Van Eeden, Visser, Van Zyl, Coertze & Wessels (1955) and Visser & Verwoerd (1960) described the geology of the northern part of the park and the area to the south of Pretoriuskop respectively. Van der Schijff (1968) gave a general account of the geology and soils of the park. Saggerson & Logan (1970) described the Timbavati Gabbro and Komatipoort Suite in the park, with Logan (1979) giving a detailed petrographic description of the above-mentioned intrusions as well as chemical analyses from the Komatipoort area. Willson (1977) reported on the Komati coalfield situated to the south of the Kruger National Park. Robb (1978) mapped the various granites and undertook petrographical as well as geochemical work outside the KNP in the area between Nelspruit and Numbi Gate.

The author mapped the entire KNP between 1969 and 1979, and brought out five reports: Schutte (1974a, 1974b, 1974c, 1982; Schutte & Clubley-

Armstrong 1982). Geophysical work was done by Gordon-Welsh (1980) and Henthorn (1981). Jantsky, McCourt & Vitry (1980) and McCourt & Brandl (1980) and Brandl *(in press)* did further mapping in the park. Van Vuuren (1979) reported on the oil potential of the Karoo sediments of the park. Bristow (1980) and Walraven (1984) did geochemical and petrographic work on Karoo lavas and the Timbavati Gabbro respectively. Recently, a large amount of information relating to the Lebombo volcanics has been published in a special volume on Karoo volcanism (Erlank 1984).

Physiography of the Kruger National Park

The most outstanding topographic feature is the Lebombo Mountains (Fig. 1) along the border of Moçambique from the Shingwedzi River southwards. Isolated rhyolite flows and granophyre form ridges and koppies just west of and parallel to the mountains. Rocks belonging to the Soutpansberg Supergroup and Karoo Sequence form the Soutpansberg Mountains in the northern part of the area. Granite, gneiss and migmatite form the Malelane Mountains in the south-western part of the Kruger National Park.

Fig. 1. The Lebombo Mountains at Gorge. The rhyolite flow shows columnar jointing along the near-vertical western slope.

The remainder of the park is a gently undulating landscape that forms part of the Lowveld and the rocks here consist of granite gneiss, schists, amphibolites, sediments, basalt and gabbros. South of Pafuri is a flat landscape known as the Nwambia Sandveld that consists of windblown

Pleistocene deposits. A few thermal springs occur in the park. (Fig. 2).

Fig. 2. Mati-o-vila thermal spring. The temperature of the water was 39 °C when the photograph was taken.

Stratigraphy of the Kruger National Park

Swazian erathem (>3 090 *Ma*) **

1. Goudplaats Gneiss*

The Goudplaats Gneiss lies between the Mphongolo River and the Murchison greenstone belt. The composition of the gneiss is mainly tonalitic with a small portion being granodioritic. The gneiss is a medium- to fine-grained rock, and consists of oligoclase, quartz, microcline, biotite and some muscovite. The colour varies from light to dark grey, and exhibits a strong foliation in places where it is characterised by alternating bands of leucocratic and melanocratic material (banded gneiss). The thickness of the individual bands ranges from a few mm to about 20 centimetres. Locally the leucocratic material may form large unfoliated masses cross-cutting older leuco-bands.

* Not yet approved by SACS (South African Committee for Stratigraphy)

** Ma – millions of years

2. Makhutswi Gneiss

The Makhutswi Gneiss occurs south of the Murchison greenstone belt to approximately north of Orpen. It is lithologically very similar to the Goudplaats Gneiss. The contact between the Goudplaats and Makhutswi Gneisses is regarded by Brandl *(pers. comm.)* as arbitrary and parallel to the northern part of the Murchison greenstone belt.

The gneiss has a tonalitic composition, is intensely migmatised and exhibits schlieren of amphibolitic material that could represent mafic dykes. The gneiss is a grey fine- to medium-grained rock and consists of plagioclase, quartz and biotite. Within the gneiss there are xenoliths of schists, amphibolite and banded ironstone. Alternating quartz-feldspar leucosomes define the gneissosity. South of the Olifants River banded gneisses are well developed (Fig. 3). Brandt (1948) shows a part of the gneiss between the Letaba and Olifants Rivers to be a dome. Along the Olifants River younger muscovite pegmatites are intrusive into the banded gneisses.

Fig. 3. Makhutswi banded gneiss (grey) along the northern bank of the Olifants River, some 28 km S.E. of Phalaborwa. The gneiss is cut by leucobands (white).

3. Murchison Sequence

In the KNP the Murchison Sequence consists of the Giyani and Gravelotte Groups.

The Giyani Group was previously known as the Sutherland greenstone belt. It crops out within the Goudplaats Gneiss from Shangoni eastwards. There are also smaller isolated outcrops west of Red Rocks in the surrounding Goudplaats Gneiss. Because of insufficient mapping the Giyani Group cannot be subdivided at this stage. The rocks consist of ultramafic schists, and amphibolite with interbedded banded ironstone. At Busizi serpentinite and metapyroxenite are intrusive into the Goudplaats Gneiss. Birbirite occurs as a weathering product on the serpentinite. Outcrops are generally, partly covered by brownish clayey soils.

The ultramafic schists exhibit a strong foliation, range from fine- to medium-grained and consist of several varieties *viz.* actinolite schist, tremolite schist, chlorite- anthophyllite schist and chlorite schist. Accessory minerals are magnetite, calcite, tourmaline, zoisite and epidote. The colour of the schists varies from grey to dark green.

The amphibolite is a massive medium-grained rock and varies from blackish grey to dark blue in fresh samples. It is generally foliated although a pronounced schistosity is only locally developed. The amphibolite consists of hornblende or tremolite/actinolite, and minor amounts of plagioclase and quartz. The schists and amphibolites are both considered to have been mainly mafic to ultramafic extrusives.

The banded ironstone occurs north of Shangoni. Weathered surfaces are brown to blackish. The rock consists of alternating quartz- and iron-rich bands, and the individual bands range from 1,0 mm to several centimetres in thickness. It is considered to represent mainly chemical precipitates derived from submarine exhalatives.

A number of outcrops of the Gravelotte Group occur east of the Murchison Range in the Makhutswi Gneiss. As in the case of the Giyani Group, insufficient mapping prohibits a subdivision of the Gravelotte Group at this stage. The rocks comprise quartz-mica schist, talc schist and actinolite-tremolite-chlorite schist, amphibolite with banded ironstone, quartzite, serpentinite and marble.

4. Barberton Sequence

Isolated occurrences of serpentinite schist, talc schist, actinolite schist, quartz schist, and amphibolite are present in the vicinity of Malelane. These belong to the lower part of the Onverwacht Group.

5. Orpen Gneiss*

The area to the east and south-east of Orpen consists of a fine-grained grey to dark grey homogeneous gneiss without ultramafic xenoliths. The name Orpen Gneiss* is here proposed by the author, since the best outcrops occur in the vicinity of Orpen along the Timbavati River. The exact age relation with the adjacent Makhutswi Gneiss and Nelspruit Granite Suite has not yet been established.

The gneiss is cut by a few fine- to coarse-grained pegmatite veins. Foliation is present in the rock and is due to the segregation of dark and light minerals. The Orpen Gneiss consists of quartz, plagioclase, biotite and minor amounts of microcline and sphene.

6. Tonalitic and Trondjemitic gneisses

Banded gneiss occurs adjacent to the Onverwacht Group in the vicinity of Malelane. The rock consists of an alternation of light quartz-feldspar leucosomes and dark greenish-black amphibole melanosomes.

7. Nelspruit Granite Suite*

The Nelspruit Granite Suite crops out in the southern part of the Kruger National Park. It consists of banded gneiss, gneiss, migmatite and porphyritic granite. The banded gneisses grade into unbanded gneiss and migmatite. In places a porphyroblastic texture is developed in the gneiss. Aplite veins are intrusive into migmatite in the Bukweneni Spruit approximately 18 km south of Pretoriuskop (Fig. 4). Muscovite pegmatite also intrudes the migmatite in places.

Fig. 4. Aplite veins intrusive into migmatite of the Nelspruit Granite Suite, Bukweneni Spruit, some 18 km South of Pretoriuskop.

South-east of the Mpondo Dam a medium- to very coarse-grained pink granite is present. This could form part of the Salisburykop Granite, but more work is necessary to outline its extent. The pink granite consists of quartz, microcline, orthoclase, feldspar and hornblende. The remaining rocks of the Nelspruit Granite Suite are composed of quartz, microcline, feldspar, biotite and accessory minerals. The composition varies from granitic to tonalitic.

Randian erathem (3 090-2 620 *Ma*)

1. Shamiriri Granite

The Shamiriri Granite occurs south of the Giyani Group as an isolated stock. It is intrusive into the Giyani Group, and is cut by younger aplite veins. The granite is a massive grey medium-grained to porphyritic rock with a granodioritic composition. It contains phenocrysts of microcline-microperthite in a groundmass of oligoclase, quartz, microcline and biotite, with epidote, sphene and ore minerals as accessories.

2. Macetse Granite*

A number of small scattered granite outcrops between the Ngodzi trigonometrical beacon and the Giyani greenstone belt are known as the Macetse Granite. Often they form boulder-strewn koppies up to 100 m high, and also low hummocks.

The granite is a grey to pink fine- to medium-grained rock, and it consists of quartz, microcline, orthoclase, oligoclase, biotite, and minor muscovite. The rock ranges from a granite to a granodiorite in composition. The contact with the Goudplaats Gneiss, into which it intrudes, ranges from transgressive to gradational. It is thought that the Macetse Granite was mainly formed by *in situ* anatexis.

3. Baderoukwe Granite

The Baderoukwe Granite is intrusive into the Gravelotte Group, but the relationship with the Makhutswi Gneiss is not clear. Brandl *(in press)* regards the granite as a late orogenic granite, and he interprets it as slightly altered remobilised Makhutswi Gneiss. The granite is a homogeneous mesocratic biotite-rich rock with a tonalitic composition.

4. Cunning Moor Tonalite*

North-east of Skukuza there are two isolated outcrops of the Cunning Moor Tonalite in the surrounding Nelspruit Gneiss. The tonalite is a light grey medium- to coarse-grained rock, and consists of quartz, plagioclase, microcline, biotite and poikilitic crystals of sphene.

Mokolian erathem (2 070-1 180 *Ma*)

1. Phalaborwa Complex

The bulk of the Phalaborwa Complex is situated south of Phalaborwa, just outside the park. It consists of pyroxenite, glimmerite, syenite and carbonatite (Hanekom, Van Staden, Smit & Pike 1965; Brandl *in press*). In the park itself a few conspicuous syenite intrusions which form koppies (Fig. 5) are part of this complex *e.g* Shikumbu Kop, east of Phalaborwa. The syenite varies in colour from light grey to pink and consists of large phenocrysts of orthoclase in a fine-grained matrix of albite, orthoclase, quartz and aegirine-augite. The geology of the complex is described by Frick (1986). The precambrian granitoid rocks of the KNP are described by Barton, Bristow & Venter (1986).

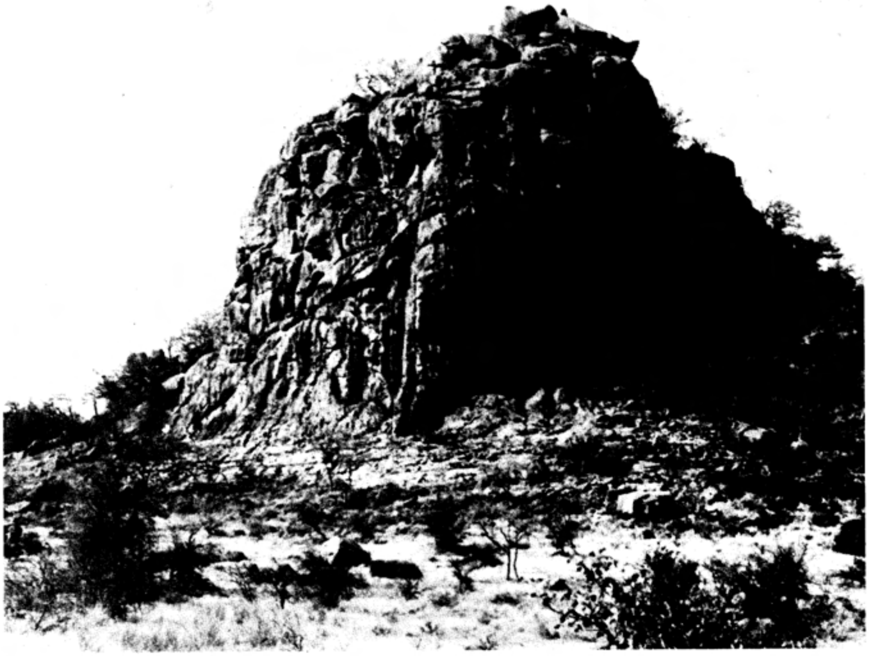

Fig. 5. Syenite koppie, Shikumbu, east of Phalaborwa.

2. Soutpansberg Group

The Soutpansberg Group comprises sediments and volcanic rocks laid down in an elongated fault-bounded trough that developed by rifting along a major zone of weakness between the central and southern parts of the Limpopo mobile belt. According to Jansen (1975) this basin can be regarded as an aulacogen. In the park the Tshifhefhe, Sibasa Basalt, Fundudzi, Wyllies Poort Quartzite and Nzhelele Formations are represented. No major unconformities are present. The following descriptions are based on those given by Brandl (1981).

The *Tshifhefhe Formation* is only sporadically developed. It attains thicknesses of up to 20 m and consists of coarse-grained felspathic quartzite, grit and conglomerate. All the sediments have been epidotised.

The *Sibasa Basalt Formation* forms the flat-lying area south of the Soutpansberg Range. The basalt is blackish to light green in colour and is an aphanitic to fine-grained rock that has been epidotised. It consists of clinopyroxene and plagioclase in a devitrified groundmass. Near the top of the succession amygdaloidal lava is present, and the amygdales are filled with quartz, chalcedony, agate or chlorite. In the basalt there are white to greenish grey and pink interbedded quartzite layers.

The *Fundudzi Formation* consists of a fine- to coarse-grained sandstone and cross-bedded, ripple-marked quartzitic sandstone. West of Dzundwini interbedded light green to blackish medium-grained amygdaloidal basalt up to 50 m thick is present. The amygdales are filled with quartz, chalcedony, chlorite, epidote, pyrophyllite or sericite, and sometimes olivine.

Two rock types are present in the *Wyllies Poort Quartzite Formation* namely a purple or red sandstone and a medium- to fine-grained pink or whitish quartzite or sandstone. The rocks exhibit planar and trough cross-bedding in places, as well as both symmetrical and asymmetrical ripples. The sediments were formed under fluviatile conditions, probably by braided river systems.

Basalt is developed at the base of the *Nzhelele Formation*, and this is the most useful stratigraphic marker in the Soutpansberg Group. The rock is a greenish-grey fine- to coarse-grained amygdaloidal basalt and consists of augite and plagioclase in a microlitic groundmass. Red sandstone overlies the basalt.

Namibian erathem (1 180-570 *Ma*)

1. Timbavati Gabbro

The Timbavati Gabbro comprises mafic to ultramafic rocks that intrude the various older granites and gneisses. The rocks form irregular bodies that are sill-like in nature and dip from 20 – 30 degrees (Fig. 6). At the contact with the host rocks the gabbro possesses a chilled margin in places with the former displaying various degrees of recrystallisation.

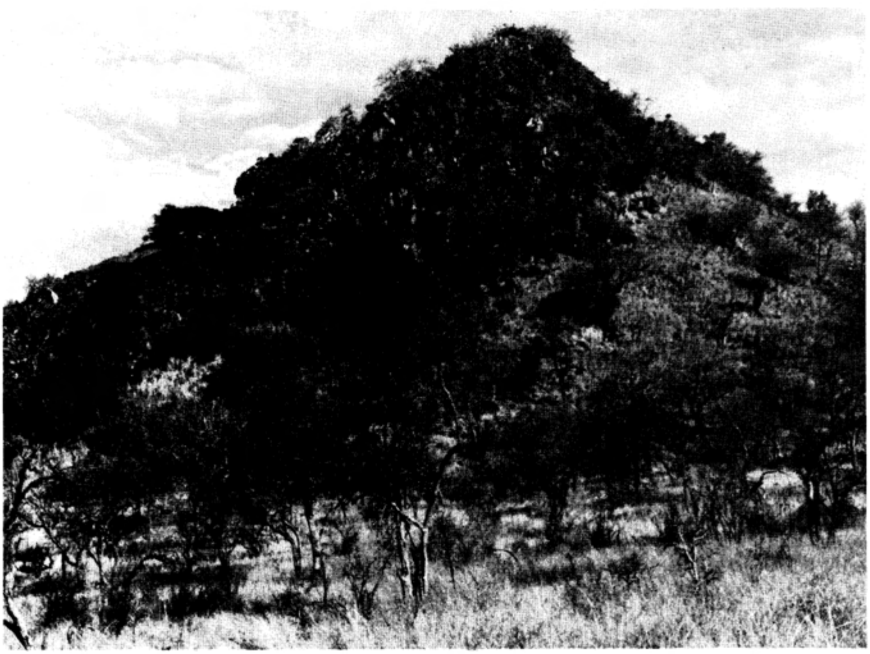

Fig. 6. The Timbavati Gabbro, Skipberg. The lower portion consists of less resistant olivine gabbro while a more resistant gabbro forms the top of the koppie.

The Timbavati Gabbro consists of three rock types, *i.e.* olivine gabbro,

gabbro and quartz gabbro. The rocks are blue-green to green in colour and consist of labradorite/bytownite, hypersthene, augite and olivine (or quartz), with biotite, orthoclase and oxide minerals as accessories. Biotite and chlorite replace the pyroxene and the olivine is altered to serpentine. The geology of the Timbavati Gabbros are described in more detail by Walraven (1986).

Pre-Karoo dykes and sills

Basic dykes (Fig. 7) are abundant in the pre-Karoo rocks. Most of them form a negative relief and outcrops are poor. Age relations could only be determined in some cases. In the area around Skukuza an east-west dyke swarm is pre-Vaalian in age. They are cut by north-north-west to south-south-east shear zones and faults which in places are filled with diabase in the Pretoriuskop-Skukuza area. A diorite intrusion occurs south of Skukuza. East and north of Phalaborwa there are numerous diabase dykes which in places are younger than the Phalaborwa Complex. They are seldom more than 10 m wide.

Fig. 7. Diabase east of Skukuza, about 5 km south of the Orpen Rocks.

Numerous negative-weathering diabase sills and dykes are intrusive into the Soutpansberg Group. The diabase is a dark medium- to coarse-grained rock and consists of plagioclase and pyroxene. Some of the dykes in the

Goudplaats Gneiss may be of the same age, while others might be older.

The Timbavati Gabbro cuts all the above-mentioned dykes.

Palaeozoic and Mesozoic erathems (570 – 65 *Ma*)

Palaeozoic and Mesozoic rocks cover a very large portion of the park along the borders with Zimbabwe and Moçambique. They consist of a sedimentary succession overlain by lavas, except for a small area north of 23° S where lava rests directly on pre-Karoo basement.

1. Karoo Sedimentary Rocks

In the northernmost part of the park (north of 23° S) the sedimentary succession underlying the Clarens Formation attains a maximum thickness of 500 m and has been subdivided into seven formations (McCourt & Brandl 1980). All these units wedge out towards the south. Exposures are poor, and data regarding the lithostratigraphy and thickness of the various formations were primarily derived from boreholes drilled in the Kruger National Park (McCourt & Brandl 1980).

The *Tshidzi Formation* is present locally at the base of the Karoo Sequence and is up to 20 m thick. It consists of diamictite comprising angular and rounded clasts in a bluish-grey sandy muddy matrix. It probably represents a fluvioglacial deposit and may be correlated with the Dwyka Formation of the main Karoo basin.

The Tshidzi Formation grades upwards into the overlying *Madzaringwe Formation* which has a maximum thickness of about 200 m in the park. Up to 40 m of carbonaceous shale, shaly coal and coal are present at the base of the formation. The bulk of the unit comprises alternating layers of micaceous sandstone and shale. The shale frequently contains lenses of white quartz grains. A prominent coal layer which occurs about two-thirds of the way up in the formation is best developed north-east of Punda Maria where it reaches a thickness of 3,9 metres. Thin coal seams are sporadically developed elsewhere in the succession.

The *Mikambeni Formation* comprises grey mudstones and black, generally carbonaceous shale with a few thin sandy layers towards the base. Thin seams of coal occur throughout the succession. Siderite nodules are common near the top. The maximum thickness of the formation in the park is about 150 metres. The Madzaringwe and Mikambeni Formations can possibly be correlated with the Ecca Group of the main Karoo basin.

The *Fripp Sandstone Formation* rests with a sharp contact on the Mikambeni Formation. It consists of white or greyish-white medium- to coarse-grained quartzitic sandstone. Cross-bedding is present and pebble horizons are common. A maximum thickness of 50 m was obtained in the north-eastern portion of the park where the sandstone forms low ridges.

The *Solitude Formation* attains a maximum thickness of about 85 m and is mainly composed of purple and green mudstone and subordinate greenish-grey sandstone. It probably represents a fluviatile deposit. Carbonaceous shale is locally present at the base of the formation.

The *Klopperfontein Sandstone Formation* consists of greyish-white medium-grained feldspathic sandstone resembling the underlying Fripp Sandstone. Cross-bedding is present but not well developed. For both these arenaceous units deposition in braided streams is envisaged (Van Vuuren 1979). The sandstone reaches a maximum of 20 m in thickness.

The *Bosbokpoort Formation* consists of massive red mudstone succeeded by siltstone which occasionally grades into very fine-grained sandstone. The formation is poorly developed. The clayey and silty material of the succession was probably deposited in a flood basin.

In the south of the park the sedimentary succession underlying the Clarens Sandstone is about 300 m thick. It comprises white quartzitic sandstone, arkose, grit, shale and carbonaceous shale (probably equivalent to the Ecca Group) overlain by red mudstone, marl, and sandstone. Calcareous concretions are developed in the white sandstone, and cross-bedding is common. Outcrops are generally poor. The whole succession thins northwards and wedges out underneath the overlying Clarens Formation more or less at 24° S.

Plant fossils (*Glossopteris, Cyclopteris,* Cycads and *Pterophylum*) have been found along the Sabie River (Wilson-Moore 1897) while Brandt (1948) described *Glossopteris* and *Gangamopteris* south of the Letaba River.

The *Clarens Sandstone Formation* overlies the sedimentary units described above, generally with a gradational contact. It can be subdivided into two mappable units in the northern part of the park. The lower *Red Rocks Sandstone Member* attains a thickness 10 to 35 m in the park. This member consists of a fine-grained, pink argillaceous sandstone, containing irregular patches of cream-coloured sandstone. Towards the base the sandstone contains a one-metre-thick layer of limestone and small calcareous concretions. Potholes occur (Fig. 8) in the sandstone and in the vicinity of the Mphongolo River parts of the sandstone grade into conglomerate (Brandl 1981).

There is a gradational contact between the *Tshipise Sandstone Member* and the Red Rocks Sandstone Member. In the northern part of the park the former forms prominent ridges (Fig. 9) characterised by caves and vertical rock faces, with a thickness of about 50 metres. Caves also occur further south. The sandstone is a massive, whitish to cream-coloured, fine-grained equigranular rock which locally shows large-scale cross-bedding. Calcareous concretions (Fig. 10) are often developed near the base.

Between 22 ° 50′S and 24 ° 00′S the Clarens Sandstone lies unconformably on pre-Karoo rocks (Fig. 11). The absence of the lower formations of the Karoo Sequence in this area points to the existence of a pre-Karoo topographic high. Deposition of the formation seems to have occurred mainly in an aeolian environment.

2. Lebombo Volcanic Group

The Lebombo Group embraces the volcanic rocks at the top of the Karoo

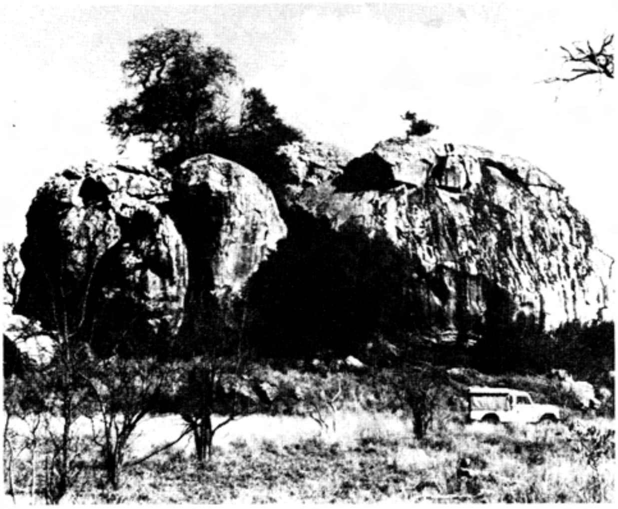

Fig. 9. Clarens Sandstone, approximately 5 km west of Klopperfontein.

Fig. 8. Potholes in the Clarens Sandstone Formation at Red Rocks.

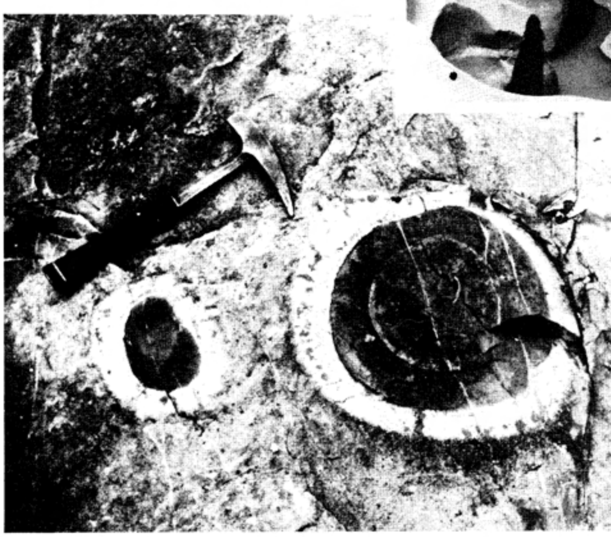

Fig. 10. Concretions in Clarens Sandstone, Hippo Pool, Crocodile River, approximately 3 km S.W. of Crocodile Bridge.

Sequence and is represented here by the Letaba and Jozini Formations.

The *Letaba Formation* consists of extrusive mafic volcanic rocks which rest conformably on the Clarens Formation except at the palaeohigh north of 23° S where it lies directly on the Goudplaats Gneiss. The basalts are considered to represent flood basalts that extruded along fissures associated with the fragmentation of Gondwanaland. Outcrops are poor and are mostly covered by a black turf soil. Some good outcrops do, however, occur along the main rivers.

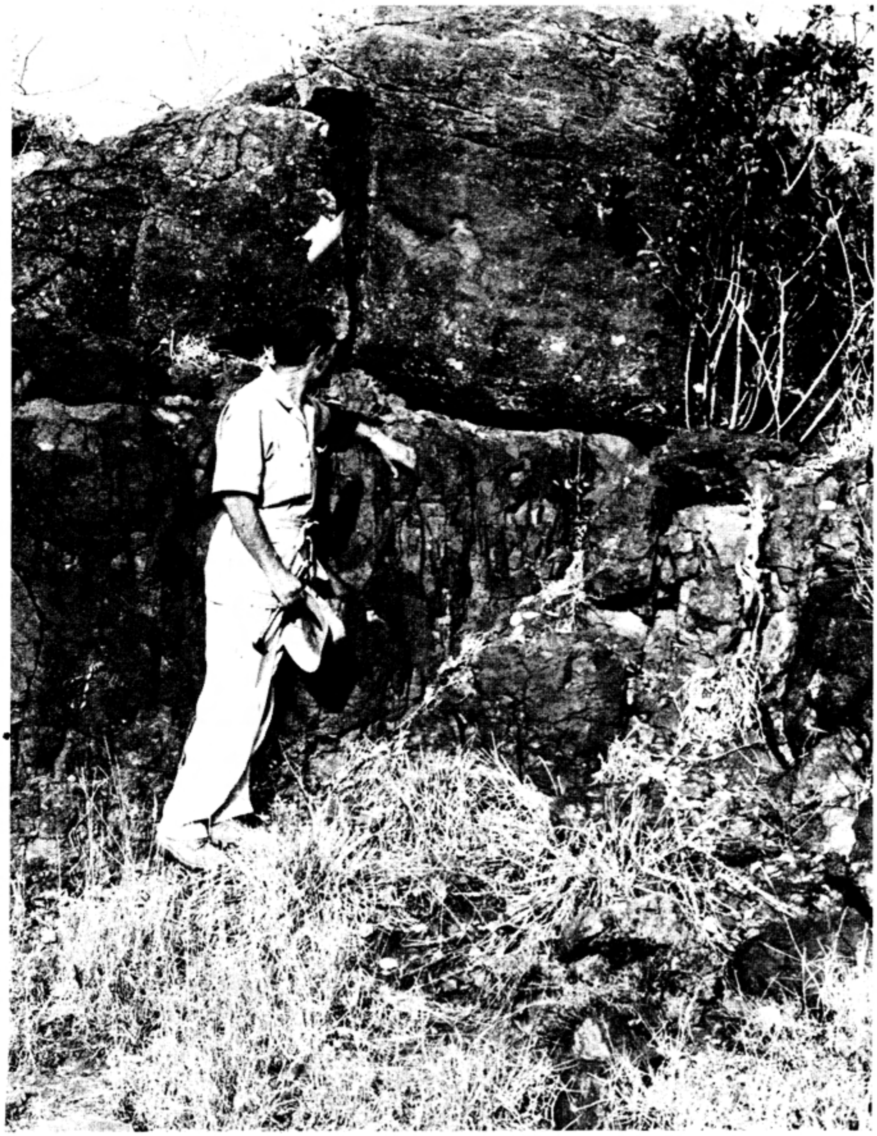

Fig. 11. Clarens Sandstone which lies unconformably on the Goudplaats Gneiss, southern bank of Mphongolo River, some 21 km N.W. of Shingwedzi Rest Camp.

In the north of the park nepheline-bearing basalt at the base of the lava succession is followed by olivine-bearing basalt while tholeiitic basalt (with rhyolite intercalations in places) caps the succession. The same sequence of lava types has been described by Cox, Johnson, Monkman, Stillman, Vail & Wood (1965) north of the park in Zimbabwe. Cleverly & Bristow (1979) subdivided the present Letaba Formation into the *Mashikiri Nephelinite Formation,* the *Letaba Basalt Formation* (olivine-rich basalt) and the *Sabie River Basalt Formation* (tholeiitic basalt). However, these units have not yet been approved by the South African Committee for Stratigraphy (SACS) and the Geological Survey uses the name Letaba for the whole of the basaltic unit underlying the Jozini Formation. According to the above authors the Mashikiri and Letaba Formations wedge out towards the south, so that only the Sabie River Formation is present in the extreme south of the park.

The nepheline-bearing basalt consists of black to dark coloured rocks with clinopyroxene laths, serpentinised olivine and minor amounts of nepheline, and magnetite in a glassy to fine-grained groundmass of nepheline, clinopyroxene, magnetite and amphibole.

The olivine basalt is dark green to purple and occupies a large portion of the basalt area. It consists of flows of serpentinised olivine, clinopyroxene and orthopyroxene phenocrysts in a glassy to medium-grained groundmass of plagioclase, clinopyroxene, sagenite and ore laths. Olivine-poor tholeiitic basalt making up the remainder of the sequence are grey to greenish in colour and consists mainly of augite and plagioclase. Amygdaloidal and porphyritic types have been observed.

Pillow lavas (Fig. 12) occur near Olifants Camp and Crocodile Bridge Camp. They formed when the basalt extruded into water. Breccia pipes (Fig. 13) occur in the Karoo sediments as well as the basalt between Letaba and Satara.

Fig. 12. Pillow lava (Letaba Formation), some 2 km west of Olifants Rest Camp. The space between the pillows consists of hyaloclastite.

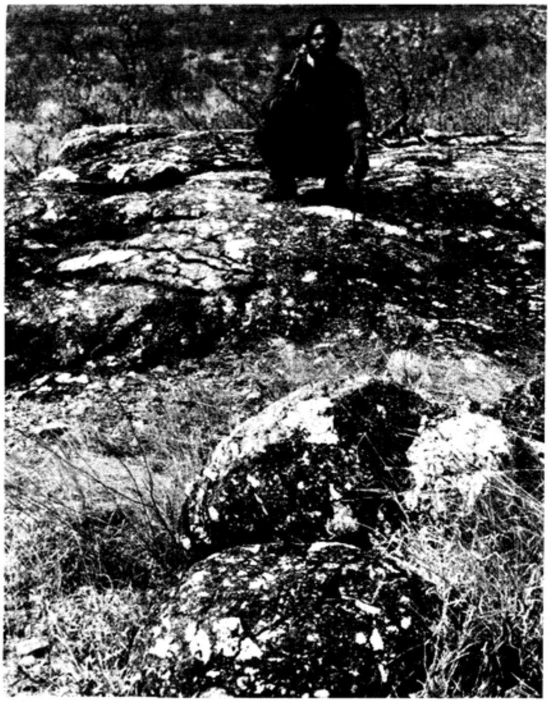

Fig. 13. Breccia pipe near the Shishakashangondo River. It consists of metasomatically altered granite fragments (white) in a basalt matrix (grey), some 4 km S.W. of Roodewal.

The *Jozini Formation* comprises rhyolite to dacite lava flows and forms the Lebombo Mountains due to its resistance to weathering.

Interfingering of basalt and rhyolite flows occurs along the contact between the Letaba and Jozini Formations. The base of the Jozini is taken where the rhyolite flows become dominant.

The rhyolite consists of plagioclase phenocrysts and ferro-augite in a fine-grained groundmass. Sporadic quartz and potassium-feldspar phenocrysts may be developed. The colour of the rocks varies from cream to purple to grey. Individual rhyolite flows up to 150 m thick can be distinguished. They consist of a basal breccia in places, followed by perlite (Fig. 14), a massive to porphyritic zone and a contorted flow at the top (Fig. 15) due to the rapid cooling of the magma. Autobrecciation is apparent locally. Wachendorf (1971, 1973) describes identical structures in successive rhyolite flows in Moçambique.

3. Lebombo Intrusive Rocks

The *Tshokwane Granophyre* is intrusive as irregular bodies and sheets into the Letaba and Jozini Formations. It is resistant to weathering and forms prominent koppies (Fig. 16). The granophyre represents the last phase of Karoo volcanism. It consists of quartz, feldspar, augite and granophyric intergrowths of quartz and feldspar.

Just north of Komatipoort roughly concordant feldspathic gabbro, and

Fig. 14. Perlite (volcanic glass) with rounded to ellipsoidal lithophysae. Jozini Formation, approximately 6 km S.E. of Lower Sabie Rest Camp.

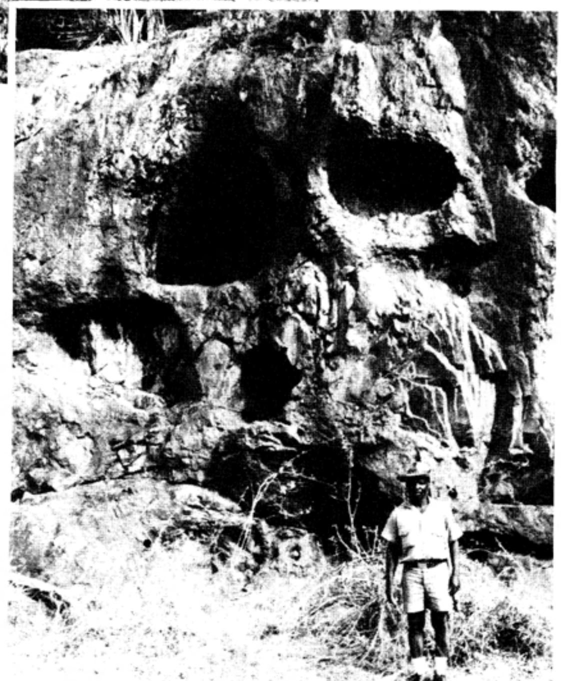

Fig. 15. Contorted tuffaceous rhyolite east of Nwanedzi Rest Camp, adjacent to the Moçambique border. It weathers rapidly and here resembles a primate skull.

granophyre crop out along the Crocodile River. They form part of the *Komatipoort Suite** (Logan 1979) and are cut by granophyric microgranite. According to Logan *(op. cit.)* the feldspathic gabbro is a holocrystalline fine- to medium-grained rock and consists of plagioclase and pyroxene with minor iron oxide, zeolite, chlorite and apatite needles. This gabbro could represent an *in situ* differentiation product. The granophyre consists of feldspar and clinopyroxene phenocrysts in a granophyric groundmass with minor chlorite and hypersthene. The granophyric microgranite consists of quartz and feldspar phenocrysts and granophyric intergrowths of quartz and feldspar.

Fig. 16. Tshokwane Granophyre approximately 2 km N.E. of Nwanedzi Rest Camp.

Dolerite dykes occur throughout the whole area and represent possible feeders of the basic volcanic rocks. Dolerite dykes and sills are locally present in the Karoo sedimentary succession. Rhyolite dykes are common in the Letaba-Satara area and form prominent ridges (Fig. 17) in places. North-east of Klopperfontein a north-north-west to south-south-east dolerite dyke direction was noted. In the southern part of the park a north-south dyke direction was observed in the Karoo lavas and in the pre-Karoo rocks east of Skukuza.

The dolerites are generally dark fine-grained to porphyritic rocks and consist of plagioclase (bytownite), clinopyroxene which has been altered to chlorite, olivine (in places) and magnetite. Microscopically a typical ophitic texture can be seen.

Ijolite is intrusive into Karoo sediments north of Punda Maria. It occurs as sills and dykes. The dark grey porphyritic rock consists of augite and nepheline.

The Lebombo volcanic and intrusive rocks found within the confines of the KNP are discussed in more detail by Bristow & Venter (1986).

4. Malvernia Formation

The *Malvernia Formation* unconformably overlies the lavas of the Karoo Sequence and attains a maximum thickness of about 80 m along the eastern boundary of the park. The thickness decreases towards the west. Whitish, coarse-grained and gritty sandstones (Fig. 18) and conglomerate with limestone and marl intercalations characterise the formation (Schutte 1974a, 1974c). The pebbles of the conglomerate are rounded to subrounded, have a maximum diameter of 50 cm and are derived partly from the Soutpansberg Group and partly from the granitic terrain. The matrix of the arenaceous sediments is usually calcareous.

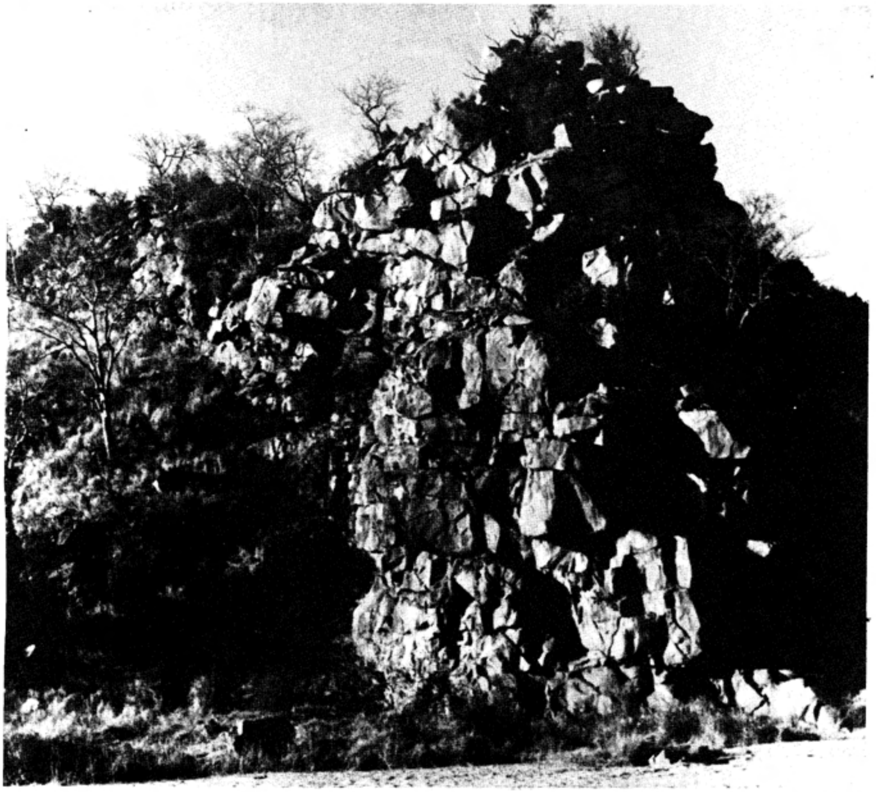

Fig. 17. Rhyolite dyke intrusive into basalt of the Letaba Formation on the Timbavati River, some 7 km north of Roodewal.

The formation is correlated with the Cretaceous period as similar rocks in Moçambique pass laterally in a coast-wise direction into fossiliferous, marine Upper Cretaceous sediments (Haughton 1969; Schutte 1974a, 1974c). The geological map of Moçambique (1968) shows the sediments adjacent to the Malvernia Formation as Cretaceous in age.

Cenozoic erathem (<65 Ma)

1. Surficial deposits

In places older rock units of the KNP are covered by surficial deposits of Quaternary age (Schutte 1974a, 1974c). These include alluvium, scree, calcrete, ferricrete, gravel and sand. Large, fairly thick alluvial deposits are found along the rivers. Pinkish sand, up to 2 m thick, overlies most of the Malvernia Formation and the Jozini Formation at Pumbe Pan. Geological maps of Moçambique (1963, 1968) show the wind-blown sand as Pleistocene in age. High-level gravels occur in places above the present river beds.

Structure

The greenstone belts are remnants of deformed and metamorphosed sedimentary and volcanic rocks and are intruded by various granites. This can be due to tectonism or to granitic diapirism. In the vicinity of the Olifants River the Makhutswi Gneiss is a very prominent east-west striking banded gneiss.

The tectonic directions of the pre-Karoo dykes have been described above.

In the Soutpansberg Group and Karoo Sequence north of 23° S an east-west system of normal faults occurs. Post-Soutpansberg faults were probably reactivated in post-Karoo times.

The Karoo Sequence strata dip towards the east, except in the far north where a change to a northerly dip direction takes place. Steeper eastward dips (up to 35°) are associated with the monoclinal flexure of the Lebombo Mountains (which was first recognized by Du Toit (1929)).

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Fig. 18. Calcareous sandstone of the Malvernia Formation, Malonga.

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