RESHAPING AND RETREAT OF THE NATAL DRAKENSBERG ESCARPMENT, S AFRICA

Peter Svensson

Department of Physical Geography
GÖTEBORG 2000
RESHAPING AND RETREAT OF THE NATAL DRAKENSBERG ESCARPMENT, S AFRICA

Peter Svensson
The formation of the Natal Drakensberg has always fascinated people and it has been given names as Quathlamba (Barrier of spears) in Zulu and Drakensberg (The dragons mountain) in Afrikaans. The reason for both of the names is easy to understand when you see the mountain formation rise into the sky. The kind of mountain formation that the Drakensberg is belongs to passive margins, with its origin in the break-up of Pangea. There is normally an escarpment at these passive margins which follows the rift. On top of the escarpment there is a paleoplain. The paleoplain is a high plateau with a gentle slope in the opposite direction of the escarpment. The topography in the Natal Drakensberg is one of the most spectacular at passive margins with a relative relief of 1000 m at places. This makes a difference compared to the paleoplain with a relief amplitude of 300 m. This study concerns the escarpment and the paleoplain nearby. The large scale development of passive margins is only described in the introduction.

The drainage patterns are used to understand the former geomorphology with, for passive margins, typical drainage divide and river catchment. Field studies were made in three different areas which were chosen with the help of topographic maps. These areas was air photo interpreted and together with field mapping made out the base for the geomorphological maps.

The field studies developed a great interest in what role weathering plays. The fast weathered basalt has a greater chance to weather in the lower warmer and more humid areas. This causes undermining of the escarpment and increases opportunities for mass movments in the upper parts. The following features were observed in the field study at the escarpment; deep weathered ridges, deep weathering in roadcuts, tor formations, falls, slides, talus and solifluction. A different environment was observed up on the top of the paleoplain with valley asymmetry and valley side tors. Falls and slides were also observed in this area but not to the extent same as in the escarpment.
SAMMANFATTNING

Drakensbergen i Sydafrika har alltid fascinerat människan och dess spektakulära geomorfologi har gjort att den givits namn så som Quathlamba (Barrier of spears) på Zulu och Drakensberg som kommer från Afrikaans. Betydelsen av namnet Drakensberg förstår vi även på svenska, när man ser denna drakryggskönande bergskedja resa sig upp mot skyn.

Drakensbergen hör till den typ av bergsformationer som tillhör passiva kontinentkanter med sitt ursprung i uppbyrtrandet av Pangea. Dessa bildar oftast ett escarpment som ligger längs med uppbrytningsriften. Ovanför escarpmentet ligger en upphöjd denudationsyta som utgör en högplatå som sluttar svagt åt motsatt håll. Topografin i Natal Drakensbergen hör till en av de mer spektakulära bland escarpmenten med en höjdskillnad på upp mot 1000 m på sina håll. Detta står som en tydlig kontrast till högplatån där den relativa höjdskillnaden sällan överstiger 300 m.

Detta arbete avser att studera själva escarpmentet och paleoytan i dess närlighet. Uppkomsten av Passive margins behandlas enbart i inledande text.

Dräneringsmönstret har använts för att förstå tidigare utseende av morfologin med för passive margins typiska drainage divide och river catchment.

Fältarbete utfördes vid tre studie områden som valdes ut med hjälp av topografiska kartor. Dessa områden flygbildstolkades och detta ihop med fältkartering var grunden för de geomorfologiska kartor som gjordes.

# INTRODUCTION

The geomorphic evolution of passive continental margins and great escarpments

# OBJECTIVE

Regional setting of the study area

## The Great Escarpment and the paleoplain

### The Natal Drakensberg escarpment

- Geology
- Topography

### Climate in the past, and today

# METHODOLOGY

# RESULTS

### The paleoplain near Sani Pass

- Drainage pattern
- Mapping in the valley south of Sani pass

### The escarpment in Sani Pass

- Deepweathering in roadcuts

### The footslopes of Sani Pass

- Salt and Pepper

### The escarpment

- Bannermans pass

# DISCUSSION

### Drainage

### Deepweathering

### Debris origin

### Mass movement

# CONCLUSIONS

# ACKNOWLEDGEMENT

# REFERENCES
INTRODUCTION

The geomorphic evolution of passive continental margins and great escarpments

There are two types of continental margins, active and passive. At all margins there are two aspects of interest, the evolution of the landward side and the sedimentation offshore. Active margins are associated with convergent boundaries (when two plates are moving against each other) or transform boundaries (when two plates are moving along to each other). Passive margins on the other hand are associated with divergent boundaries (when two plates are moving away from each other) and has its origin in a rift (Tarbuck and Lutgens 1993).

Passive margins are normally uplifted and tilted areas with their origin in the break-up of Pangea. The break-up of Pangea started about 180 My and many new continental margins were created. A passive margin was created in southern Africa when it was separated from Antarctica. Other well known passive margins in the world are Serra do mare in Brazil, Western Ghats in India, Great Escarpment of eastern Australia, the Scandies in Scandinavia (Lidmar-Bergström and Ollier 1996).

Passive margins go through two steps of evolution: one rifting step generally characterised by thinning of the lithosphere and probably associated with uplift of the landward side, and one subsidence step, probably later when the seaward side subsides, as a consequence of cooling and sediment loading, on the new continental edge.

This kind of tectonic evolution is of great importance on a continental scale because it leads to the establishment of new base levels for continental erosion. These kind of margins have a much lower level of tectonic activity compared to the active (Summerfield 1991).

Like most passive margins, southern Africa is edged inland by asymmetric marginal bulges. King calls these rims highlands (Ollier 1991).

There are many possible reasons for the formation of marginal swells and for uplift in general. Possible causes are (Ollier 1991):

1. Passage of the continental margin over a zone of anomalous high heat flow.
2. Thermal expansion of a mantle plume beneath the continental margin.
3. Isostatic response to erosion of the continental margin, especially by escarpment retreat.
4. Uplift to compensate for subsidence offshore, caused in turn by loading of deposited sediments. Mechanisms 3 and 4 usually work together.
5. Underplating of the continental margin by masses of light rock.
6. Intrusion of large amounts of igneous rock.
7. Delayed response to erosion of earlier orogenic belts.
8. Subsidence of basins on each side of an originally high continental margin.

The uplift, rifting and continental rupture which leads to the formation of passive margins is of great importance for all attempts to understand the geomorphology on a continental scale. Many, but not all of the passive margins, have major escarpments (Ollier 1991).

Our knowledge about vertical movements in passive margins refers to a large extent to the sediment at the edge of the margin. This sediment has been checked with seismic stratigraphy together with borecores. They show a wedge with sediment that becomes thinner the further offshore you get. The sediment is divided in synrift sediment which is deposited during the rifting and postrift sediment which is deposited thereafter (Partridge & Maud 1987).

The geomorphological evolution of escarpment in connection with passive margin tectonics is one of the most debated issues in geomorphological theories. The escarpments forming the
margins of the rifts are thought to have migrated inland by nearly parallel retreat occurring from the late Cretaceous through the Cenozoic. Rates of retreat have been calculated to 1-2 km/My (Selby 1993). Erosion by rivers combined with structural control explains a great deal and was postulated by (Rogers 1920). King’s (1962) parallel theory of retreat is of great importance for the understanding of the evolution of escarpments. There are four elements in what is called a standard slope. The four elements are crest (on top of the slope with no erosion), the scarp (the steep part with fast mass movement), the debris slope and on the end of the slope, the pediment (with slow mass movement). They are all natural products of the development of the slope. The full development of a standard hillslope depends on local circumstances, if there is bedrock or/and the right kind of relief. The scarp retreats parallel to itself during the development of the slope. It has been shown, through observations, that the debris slope are not growing upwards to cover the scarp. This shows that there is a balance between onloading and removal of debris (Young 1972).

It has been shown that cliff gradients and forms may be controlled by mass strength of their rocks. All available data indicate that strength-equilibrium hillslopes are common on escarpments and in mountains where slope undercutting, talus and soil cover, inherited slope forms, and structural controls are not dominant. For hillslopes to reach a state of strength equilibrium they must be able to retreat sufficiently for the effects of any extraneous control, such as faulting and undercutting. Such retreat requires considerable periods of time for known rock-slope retreat rates are of the order of 20-6000 m/My. Sites where strength-equilibrium slopes have been identified include mountain slopes in Antarctica, slopes on cliffs formed in relatively weak sedimentary rocks in humid areas of northern New Zealand, inselbergs in the Namib desert, escarpments around the margins of southern Africa, slopes in the Cape Mountains, and limestone in the Napier Range of northern Australia (Selby 1993).

If strength increases or decreases into the outcrop then the hillslope angle will increase or decrease in conformity as the slope retreats. This theory has, so far, been tested on equilibrium slopes on sandstones, tillites, shales, dolomite, marble, dolerite, gneiss, schist, basalt, pegmatite, and some granites; there was much variety in bedding and joint patterns. A particular example of undercutting is spring sapping which work headwards towards the source of water. This situation has been recognized in many areas of soluble rocks (Selby 1993).

**OBJECTIVE**

This study is about passive margins and the Great Escarpment in South Africa. Field studies has been made in the Natal Drakensberg and on the Lesotho plateau.

The purpose of this study is to describe the geomorphology of the Drakensberg in order to explain what kind of processes that are responsible for the development of the escarpment. The following questions have been tried to be answered by going through literature and looking at the landscape in areas up on the Lesotho plateau and down in the Escarpment

What kind of mechanisms are controlling the escarpment retreat?

What role does weathering play and what role does mass movement play?
REGIONAL SETTING OF THE STUDY AREA

The Great Escarpment and the paleoplain

The Great Escarpment in South Africa is one of the most extreme escarpments in the world connected to passive margins (fig 2). This especially concerns the Natal Drakensberg (fig 3 & 4) with a relief exceeding 1000 m in places. An escarpment separates, in a distinct way, different geomorphological environments; paleoplain, escarpment and the highly dissected topography below.

In southern Africa the Great Escarpment is a well defined geomorphological feature, usually recognised by that name, but occasionally as the Main Escarpment. Certain parts of the escarpment has local names such as Drakensberg. Nevertheless, many workers have acknowledged a single major escarpment over extensive areas, suggesting the existents of a single “Great Escarpment” in southern Africa. Though not invariably an escarpment in the strict sense of the term, it always constitutes a sharp rise from the marginal parts of the country to the high interior plateau (King 1952).

In southern Africa the Great Escarpment approximately parallels the coast all the way from Namibia around the coast up through Transval. In the Natal area the Escarpment reaches an altitude of 3000 m and is unbroken.

The high surface of southern Africa, inland of the Great Escarpment, is a prominent geomorphological feature and has such names as the highveld or the interior plateau. It is an ancient erosion surface, here termed paleoplain. This paleoplain is by no means perfectly flat, but the relief is low compared to that of the Great Escarpment and its footslopes. The paleoplain is a somewhat modified landsurface that existed before the break-up of Gondwanaland and corresponds to older surfaces. In comparison with much greater erosion connected to the escarpment, the paleoplain is relatively stable (Ollier 1991).
The Natal Drakensberg escarpment

Geology

The Drakensberg is built up by sandstone, mudstone and volcanic rock of Mesozoic age. The volcanic rock overlying the sedimentary strata goes under the name Drakensberg Group. The sedimentary rock, beneath, goes under the name Stromberg Group. The Stromberg Group is composed of three major formations, the Molteno (in the bottom), the Elliot (in the middle) and the Clarens formation (on the top). The Drakensberg Group has got different layers of basalts with some Dolerit dikes (Dangle et al. 1983).
This study only concerns the Drakensberg Group and the Clarens Formation. The flat lying basalts of the Drakensberg Group extend from the highest peak at the altitude of 3480 m down to approximately 1800 m in the scarp. It was formed in the late Triassic to mid Jurassic. The underlying Triassic Clarens Formation is a sandstone of aolian desert origin. The basalts in the Drakensberg Group goes under the name the Stromberg basalts and the sandstone in the Clarens formation is formally known as the Cave sandstone because of its characteristic, deeply-pitted weathering surface (Dangle et al. 1983).

Structurally, the Drakensberg is one of the most uncomplicated of the world’s mountain ranges. There are no younger geological formations upon the basalt mass. It has always been the highest ground in Southern Africa (King 1974). The geomorphology of the Natal Drakensberg is structurally controlled with valleys developed in weakened zones and plateaus developed on more resistant layers in the bedrock.

**Topography**

The topography in the Natal Drakensberg and the Lesotho plateau is varied. The relative relief on the paleoplain is approximately 300 m consisting of rolling landscape with broad valleys and convex mountains. Some of the valley floors are flat and up to 2 km wide. The valleys show asymmetry on the Lesotho plateau. Climatically controlled asymmetrical valleys are associated particularly with periglacial areas (Meiklejohn 1992).

The altitude difference can be about 1000 m on a 3 km distance from the paleoplain to the base of the escarpment.

The upper part of the Great Escarpment consists of a 100 to 300 m high scarp which continues down into debris slopes and smaller scarps. These slopes continue down to V-shaped valleys or lower lying plates (Topographic maps).

Valleys are sometimes cut into the cliffs and are connected to a drainage from the paleoplain. These valleys normally continue down the escarpment and create broad V-shaped valleys further downstream.

Hills on the lower parts of the escarpment sometimes form plateaus, where more resistant, rock form caprock. The slopes on the lower part of the escarpment normally consist of straight debris covered slopes interrupted by ledges of resistant rock (fig 5).
Climate in the past, and today

The climate during the Natal Drakensberg history has been varied. Southern Africa had a significantly warmer climate during the Cretaceous compared to today and compared to the average climate since then. This is the fact even since southern Africa had a 14°C lower latitude in the Cretaceous. The water temperature was 7°C higher in the southern pacific during that time. There were high run-off rates with a high content of clay which indicates enhanced weathering. This is supported by onshore evidence of deep weathering (Partridge 1990).

The Tertiary was characterised by a pattern of stepward cooling. The climatic gradient was significantly less, in the middle of the Tertiary, compared to today. New warmer periods occurred in Eocene and again in the beginning and middle of Miocene. There was a global warming in the late Pliocene and it was followed by a decline in temperature 2.4 My ago (Partridge 1990).

The climate today in southern Africa is dominated by two subtropical anticyclones. The South Atlantic anticyclone fluctuates in position off the east coast; the cell withdraws in summer and advances in winter. This anticyclone controls the general airflow over Natal. Over the subcontinent an anticyclonic circulation is the predominant feature. This weakens in summer and moves south through a few degrees of latitude. The essential features of circulation in summer and winter are similar, yet the seasonal variations of climate with respect to rainfall and temperature are marked (Summer 1995).

Today the total rainfall in the Natal escarpment area is 1000 mm to 1500 mm. The summer month December-February gets approximately 200 mm/month while the rainfall in June and July is down to 10 to 20 mm/month. The mean monthly temperature in July varies between –0.5°C on top of the escarpment (3000 m) and 2°C down in the escarpment (1800 m). The mean monthly temperature in January varies between 11°C on top of the escarpment (3000 m) to 15°C in the escarpment (1800 m) (Summer 1995).
METODOLOGY

The study started by selecting interesting areas in the Drakensberg. This was done by analysing topographic maps and it was supervised by Ian Meiklejohn at University of Pretoria. Three areas were selected and are supposed to represent different geomorphological regions, the paleoplain, escarpment and footslope. The topographic maps that were used came from Government printer South Africa, at the scale of 1:50 000. The maps that were used are 2929AD Giant’s Castle 1986, 2929AB Champagne Castle 1978, 2929CB Sani Pass 1986, 2929CA Sani Pass (West) 1988. One area was selected on top of the escarpment, on the plateau, to represent the paleoplain, south of Sani pass (fig 4). Another area was picked out in the sandstone layers, Salt and Pepper, beneath the basalt (fig 4). The last area was selected in the escarpment, Bannermans pass, to study escarpment retreat and slope processes (fig 4).

The next step was to do geomorphological field mapping at the study sites. It was done during a two weeks period and done with the help of enlarged topographical maps (scale 1:10 000), compass and Altimeter (thommen). Field notes were made and the areas were photo documented. Deep weathered areas, outside the study areas, were also documented by notes and photos. Aerial photos were used after the field study to interpret larger areas and to get the right positions for the formations checked in field. Air photos from the South African government were used from air survey year 1996 and photos NR 3375 Kwa- Zulu Natal 985G 1: 30 000 21W over Bannermans pass and NR 1595 28W, 2594 27W over Hudsons peak and NR 1601 28W over Salt and Pepper. Hand drawn maps were made with air photos as a base and photos and notes interpreted into the maps. The hand drawn maps were then scanned and edited in Photo Shop. No attempt has been made to calculate optical errors in the air photos since I considered that kind of accuracy irrelevant for this study.

An elevation database from USGS has been used to make a profile of the region. This was made in the GIS program Idrisi.
RESULTS

The paleoplain near Sani Pass

Drainage pattern

Studies of aerial photos in the area between Sani pass and Pitsaneng pass (fig 8) show that almost all the drainage on the paleoplain runs directly from the escarpment towards the Oranje and the Atlantic Ocean. There are three areas with wetlands close to the escarpment which seem to form the water divide. At two places capture of this old drainage system is documented. The drainage pattern shows very little surface drainage towards the escarpment. The drainage pattern beneath the escarpment is denser than the drainage on the paleoplain.

The present drainage divide is situated close to the escarpment. Apart from some captures, very little surface water is getting drained from the paleoplain towards the escarpment. The dense drainage pattern, in the escarpment, could therefore come out of a ground water flow, from the paleoplain towards the escarpment. There are similar wetlands at water divides, at passive margins, around the world (Ollier 1991).

Mapping in the valley south of Sani pass

The mapped area lies within a valley west of Hudson’s peak, on the Lesotho plateau (fig 8 & 9). The valley is asymmetrical with steep south facing slopes and less steep north facing slopes. The drainage starts at the edge of the escarpment and flows down through the valley towards the Oranje river.

The valley is described in six smaller areas (fig 9).
1. South facing slope (fig 7).

The south facing slope runs straight in a west to east direction. The slope has three different levels with valley side tors. The valley tors probably correspond to layers in the basalt which are more resistant against weathering. The valley side tors are mainly round weathered but some parts are of sharper angular, which indicates falls. The area in-between the steeper parts are covered with grass slopes.

Fig. 7 South facing slope with valley side tors and grass slopes in-between.
Fig. 8 Map of the Sani pass area. Note how closely the drainage divide follows the escarpment.
Fig. 9 Map of Hudsons Peak with 6 smaller areas.
2. The valley floor.
There are two swamps at the bottom of the valley (eastern swamp at the centre of photo fig 10). Gully systems have cut down into the swamps. The swamps consist of up to two meters of peat (Marker and Whittington, 1971). The gullies have probably developed because cattle walk down to the creeks for a drink.

![Image](https://example.com/fig10.jpg)

*Fig. 10 The north facing slope with the western swamp beneath.*

3. The southwestern part of the valley.
The lower part of the north facing slope is covered with a thin layer of soil and there are valley side tor formations on the upper part (fig 10). There is a slide tongue in the western part of this area. The mountain peak has steep outcrops but most is covered by vegetation. Many terracets are found all along the lower part of the slope. They are normally less than 0.5 m high and 1 m wide and they indicate soilcreep.

4. The southeastern part of the valley.
This is an area with rock pediment slopes and round weathered formations at the peaks. A slides tongue starts beneath the peak. There are steep round weathered formations high up on the slopes. The upper part of the valley are rock pediment slopes. The valley side towards the eastern peak has a large amount of rock pediment areas and terracets that are less than 0.5 m high. There are also many drainage channels in this area. The eastern peak has an uncovered round weathered rock surface. Beneath the peak weathering has formed an overhang.

5. Cattle station area.
This is a rock pediment area and there are three cattle stations with huts in the area.

6. Flat valley which ends at the escarpment (fig 11).
The drainage towards the Oranje river starts at the edge of the escarpment.
The bottom of the valley is wide and flat. The north facing slope shows us rock pediment and mass movement. The south facing slope looks preserved with valley side tor and grass slopes in-between.

**The escarpment in Sani pass**

*Deepweathering in roadcuts*

There is only one road going through the Natal Drakensberg to Lesotho, it goes through Sani pass. Several roadcuts occur between 2500 and 2300 m a s l. Most of the road cuts show signs of deep weathering and some of the roadcuts consist entirely of core boulders set in a matrix of decomposed rock (to the left fig 12). One roadcut reveals angular boulders surrounded by soil. The debris beneath is rounded by weathering. One other roadcut shows a deep weathered bedrock profile. Further down the road there is one roadcut with well jointed unweathered basalt overlying a less resistant basalt which is deepweathered (to the right fig 12).

Roadcuts in the Sani pass reveal that some basalt layers in the escarpment is highly weathered, in some places into a saprolite with rounded core boulders. This zonal weathering
suggests that some layers are more permeable and hence weathering will proceed at a faster rate within these zones.

The footslopes of Sani pass

_Salt and Pepper_

The mapped area is situated in the Clarens formation at an altitude between 1800 to 1300 m a s l at the footslope of the escarpment. The morphology of the area can be divided into separate geomorphic units discussed below with reference to figures on the map (fig 13).

1. This area is characterised by a flat sandstone plateau with a thin regolith cover. The bare rock is shown in many places and there is a pan on the plateau with a water depth of 0.2-0.3 m (fig 14).

*Fig. 13 Map of Salt and Pepper, with four smaller areas.*
2. Salt and Pepper (fig 15) are two large sandstone towers. They are 3-4 m in diameter and approximately 5 m high. They are obviously remnants of a former sandstone plateau which have been dissected by erosion.

Weathering has created overhangs on the steep walls beneath the peak, south of Salt and Pepper (fig 15). There is a large amount of loose boulders indicating undermining, probably by weathering. Small scale weathering, such as polygonal cracking and differential weathering, are shown on boulders in the area.

3. Gentle inter fluvial slope with sandstone ledges, or terraces, surrounded by debris covered slopes, characterise the slope beneath the sandstone plateaus. The debris consist of silt. Some of the drainage pattern starts as pipes.

4. The lowermost unit consist of large debris covered terraces and one alluvial fan which characterise this area.

The sandstone area at the base of the escarpment consist of a landscape characterised by structurally controlled sandstone plateaus, which are being slowly dissected by fluvial processes. This is evidential by the alluvial deposits found in the lowermost units. The dissection and degradation of the plateaus are basically dependent on different weathering of
the sandstone. Enhanced basal weathering found on cliffs suggests that groundwater sapping may be a possible cause of cliff retreat in this area.

**The escarpment**

*Bannermans pass*

Bannermans Pass is a valley cut in to the main escarpment. There is a upper main escarpment and a lower escarpment. It is an area with a lot of deep weathering and massmovements (fig 17).

Some of the drainage channels leading to Bannermans pass are captured paleo channels which begin on the Lesotho plateau in the vicinity of the pass (fig 17) but most of the drainage starts at the base of the cliff and runs down to the Martjal eagle stream. One interesting thing, on the slopes beneath the cliffs, is that the drainage starts in outflows that look like piping. The drainage starts in deep weathered ridges were groundwater pours out of the slope.

There is one pan in the aerial photo documented area with no drainage channel attached to it.

*Fig. 16 Bannermans pass. The wall to the left is approximatly 300 m high. The drainage channel starts at the Paleoplain.*
Fig. 17 Map of Bannermans pass with 7 different areas.
The different geomorphic units will be discussed below with numbers referring to the map (fig 17).

1. The unit consists of the main drainage channel from Bannermans pass. The bed of the drainage channel is originally flat with rounded debris, but smaller drainage channels are cut into it (fig 18).

2. Waterfalls occur at different levels along a drainage channel which ends up in a ravine. Rock falls have developed a talus below a minor cliff. The talus is formed in between two ridges made up by in situ deep weathered basalt (to the left at fig 19).

3. Caves have been formed at the base of a cliff. Most of them are just small hollows but one is 5 m wide and 4 m high and 3 m deep and can be considered a real cave (fig 19). It looks like the joints have been subjected to deep weathering, in the back of the caves, parallel to the front wall.

4. The only tor formation in the mapped area. They look like fallen boulders from a distance but are in situ weathered basalt forming a ridge shaped tor (fig 20).
5. The upper escarpment is approximately 150 m high at this site. Below that there are terraces and cliffs 1 to 10 m high. The debris on these terraces consist of fine material. Further down is the largest slide tongue in the mapped area and there is another slide tongue nearby, to the west. There are also non-periglacial solifluction lobes east of the two slide tongues (fig 21).

6. Steep slope with minor slides. There is also a major rock fall in this area.
7. Ridges that are built up by deep weathered rock. You can see the structure of the weathered core boulder on the track that runs over the ridges. The ridges are dissected by small creeks.

As regards the process of cliff retreat, Bannermans pass seem to point at several interesting clues to its understanding. The water seepage at the base of the cliff suggests that ground water flow, encouraged by the extreme hydraulic gradient, set up in the escarpment promote subsurface weathering within certain basaltic layers. This in turn may lead to undermining of the cliff as suggested by the existence of basalt caves at one site. Rockfall and talus formation of the undermined cliff is then responsible for successive removal of this groundwater, weathering, rockfall system.
DISCUSSION

Drainage

The drainage pattern in the mapped areas are typical for that of a passive margin (Ollier and Marker 1985). This might not be strange since the Drakensberg seems to be one of the greater examples for how drainage patterns look at a passive margin. The main drainage divide follows the escarpment except at a few places (fig 8). This is where the drainage has captured the old drainage pattern on the paleoplain. These areas are relatively small which suggests that fluvial erosion does not play a major role in the escarpment retreat. If fluvial erosion would be of any significant importance much deeper valleys into the paleoplain would be expected.

Deepweathering

The deep weathering looks more extensive in the escarpment compared to the paleoplain. The documentation of the roadcuts in Sani pass, shows deep weathering at the altitude of 2500 m. There are deep weathered ridges down in the escarpment which you see nothing of at the field study sight up on the paleoplain.

The stripped rock slopes on the paleoplain, especially on the north facing slopes, show that transportation of material has been faster than the deep weathering processes. This is no proof of inactive deep weathering, but it shows less deep weathering compared to the escarpment.

One thing that could be of great importance for the retreat is that much water ought to go down as ground water and pour out in the escarpment. The altitude difference creates a steep hydraulic gradient which leads to effective groundwater flow which in turn may enhance deep weathering and slope processes (fig 22).

Since the escarpment retreat seems to be connected mainly with rock falls and since there are not that many angular boulders on the slopes beneath, large amount of the rock fall debris seems to round weather in the slopes. This together with the fact that there are deep weathered ridges in the escarpment make it seem like deep weathering has a lot to do with the possibility for material to be removed by creeks as finer material. Therefore the combination of running water and deep weathering seems to be the key for the escarpment retreat. The process of deep

Fig. 22 The ground water accumulates in some basalt layers and increases the weathering. The accumulation of water in some layers also generates solifluction.
weathering makes it possible for the short distance fast flowing creeks to remove large amounts of material.

**Debris origin**

The large amounts of fluvial debris in Bannermans pass can also have a connection to deep weathering. The different basalt layers can have different resistance to deep weathering as is shown in the Sani pass road cut (fig 15) and in the whole landscape with resistant rock forming at different levels. Basalt in underlying position weathers due to groundwater flow and is removed while the more resistant basalt falls down due to undermining. This means that debris that looks fluvially transported, far from the cliff, can come from a place very close to were it is now situated. The original position of a basalt boulder might be 200 m above present location but only 100 m up towards the escarpment (fig 23).

**Mass movement**

There is only one talus in the mapped areas, it is situated on the south slope of Bannermans pass. The debris slopes in-between the basalt layers are normally composed of finer material. This may suggest that weathering of the rock fall are faster than production of talus.

Mass movements such as slides, falls and non-periglacial solifluction are mapped in Bannermans pass. The solifluction in Bannermans pass might be associated with the ground water being stopped by the basalt layers. The soil on top of the basalt layer gets a large water content and solifluction occurs in the escarpment.

The same amount of mass movement and weathering are not seen up on the paleoplain. The large scale geomorphology with its flat wide valleys and low altitude difference of the paleoplain point at low geomorphic activity however valley asymmetry show signs of periglacial reshaping (Meiklejohn 1992).
CONCLUSIONS

The study demonstrates major differences between the landscape on the paleoplain and the escarpment.

The paleoplain shows a mixture of very old landforms and younger geomorphological features. The grand morphological appearance with low altitude differences and preserved drainage pattern originate in the Mesozoic era. This has been changed to some extent into valley asymmetry with rock pediment slopes on the north facing slopes. Not much has happened since then in a grand morphological sense and only minor slides and falls have occurred.

The escarpment on the other hand is undergoing rapid and extensive change in time. The whole lower part of the escarpment (footslope) is subjected to deep weathering enhanced by sapping of groundwater. The weathering processes makes it possible for running water to remove material from the footslopes. This in turn gives the opportunity for continuing mass movement to occur in the upper parts by undermining of the cliff. The mass movements in the upper parts of the escarpment are falls. Deep weathering occurs both in the bedrock and in the fallen debris.

Talus probably does not develop because the supply of debris from falls is slower than the weathering of the debris.

ACKNOWLEDGEMENT

I would like to thank my supervisor Mats Olvmo at University of Gothenburg, Department of Physical Geography, for the help during this study. I would also like to thank Ian Meiklejohn at University of Pretoria, Department of Geography and Environmental science, for the help during field studies and helping me with practical details at University of Pretoria. All photos in this paper was taken by the author in March 1998.
REFERENCES


Air photos. Chief Director of Survey and Mapping, Private Bag Mowbray. Printed by the Government printer, Private bag x 85 Pretoria.

Topographical maps. Published by the Chief Director of Surveys and Mapping, Private Bag Mowbray. Printed by the Government printer, Private bag x 85 Pretoria.