THE RIVER EVOLUTION AND THE REMNANTS OF THE TERTIARY SURFACES IN THE WESTERN LITTLE KAROO

By

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ABSTRACT

In this essay an attempt has been made to establish the relationship between surface evolution of landforms, regional and local geological structure, and the localisation of stream channels. The various remnants of stream sculpture, surfaces were mapped and correlated, and the nature of the deposits covering them were studied with the view to establish the climatic conditions which obtained during various epochs of the Tertiary Period. It was also attempted to establish the effects of epeirogenesis on stream rejuvenation in the area concerned and to present a reconstruction of the development of the Gouritz River System.

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CONTENTS

I LOCATION AND TOPOGRAPHY

The area investigated includes the magisterial districts of Touws River, Montagu, Swellendam, Laingsburg, Ladismith, Riversdale and Calitzdorp. It is situated in the Little Karroo and the Southern Folded Belt. The dominant feature of this area is the sub-parallel mountain ranges and the intermontane lowland belts which run approximately east-west, being gently arcuate to the south. In this area the northern range consists of the Witteberg and Elandsberg, backed, a few miles to the south, by the Swartberg Range. This range consists of the Aynsberg in the west, and the Klein Swartberg and the Great Swartberg in the east. This is by far the highest range in the area, rising to over 7,500 feet above sea level near Ladismith.

Between this range and the southernmost one—the Langeberg—there are a number of smaller, more or less isolated mountains. These are Touwsberg, Waboomsberg, Rooiberg (and the Gamka Hill) and the Warmwatersberg, rising from 2,000 to 4,000 feet above the surrounding country.

The Langeberg Range to the east of Gouritz Poort is locally known as the Attaquas Mountains. In the west this range, which trends east-west in the south, swings to the north-west and is joined to the Swartberg Range by the Waboomsberg and the north-east—south-west trending Couga and Nouga Mountains. This feature, together with the fact that the Rooiberg-Gamka Hills also make a slight angle with the southern range, gives the western portion of the area a canoe-shaped appearance. This is called the Ladismith Karroo, and the adjoining area to the east, bounded in the east by the Kamanassie Mountains, is termed the Oudtshoorn Basin.

II PROBLEM, METHODS AND ACKNOWLEDGEMENTS

In his book "A Glimpse of South Africa", Prof. M. S. Taljaard (1949) admits that the views he expresses regarding the drainage evolution in this area, are based on visual observations alone, and that more certainty can only be expected after an "exhaustive investigation and mapping programme has been completed". The writer has attempted this in the portion of the area outlined. He would here like to express his gratitude to Prof. Taljaard for his guidance and interest during the work. To Prof. D. L. Scholtz the writer is also indebted for help and advice. Of the many farmers in the area to whom thanks are due, the writer wishes to mention the late "Oom Jan" (J. J. M.) van Zyl and Mrs. van Zyl in particular for their kindness.

The solution to the problem of the drainage evolution clearly lies in determining the ages of the breachings of the mountains by the rivers. As a basis certain of the Tertiary surfaces were mapped and certain heights determined. The distribution and forms of the remnants of these surfaces were taken from aerial photographs, and in this connection the writer would like to thank the Director of the Trigonometrical Survey (Mowbray) for the use of a number of their photographs, and Mr. P. W. Thomas of that office, in particular, for his help.

The best topographic map of the area that could be obtained had a scale of 1 : 250,000 which proved to be inadequate. During 1949 and 1950 a considerable amount of work was done, using telescopic alidade and Paulin altimeter. However, the lack of tertiary triangulation beacons in a large part of the area made this method too slow and inaccurate. In 1952 a certain amount of the area was resurveyed with the aid of a barograph at base camp to check the altimeter. Readings were, wherever possible, confined to the mornings and within a radius of 10 miles of the base camp on the same side of the mountain, and checked against known beacons. By this method it is hoped that the possible error was reduced to less than 25 feet, although readings were taken to 5 feet. As Johnson (1944) has pointed out, the only reliable readings are those where the surface abuts against the mountains. Slumping and the fact that the remnants are nearly always discontinuous with the mountain, made accurate determination difficult. However, there are few surfaces in the area and thus correlation is, for the most part, relatively simple as the difference in elevation is usually a few hundred feet.

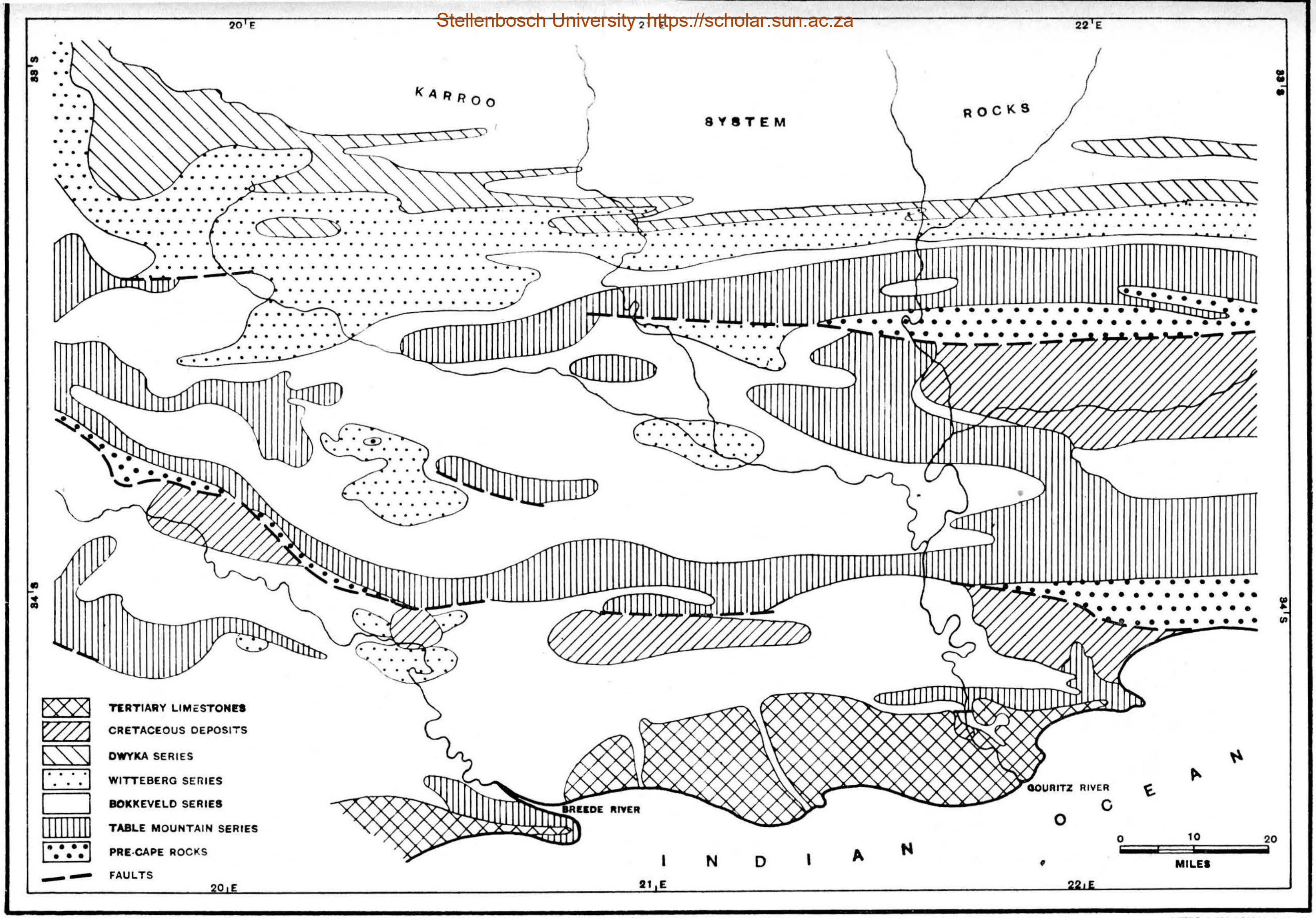
Because of the size of the area (50 × 115 sq. miles) it was impossible to study all the remnants of the surfaces thoroughly.

III STRATIGRAPHY, STRUCTURE AND HISTORY

The area displays part of the succession, conformable in the south, which stretches from the Palaeozoic into the Mesozoic era and has been divided into the trinal Cape System and the Karroo System (Fig. 1). These formations have been folded, intensely in the south and dying out towards the north. In the eroded syncline of the Oudtshoorn Basin, and to the south of the Langeberg, Cretaceous (Enon) rocks rest on steeply dipping Bokkeveld and Table Mountain Series, with a low dip to the north. To the north they are bounded by normal faults which have been instrumental in bringing pre-Cambrian sedimentary and granitic rocks to the surface. Melilite basalt has intruded the Enon deposits in the south. Resting almost horizontal over all these rocks are remnants of surfaces bearing deposits of Tertiary and younger epochs.

The sequence of the main events in the history of the Fold Belt is given below.

Planation of pre-Cape formations and deposition of Cape and lower Karroo Systems.	Ordovician. Devonian. Carboniferous.
Folding, in pulses (main pulse pre-Molteno).	Permian.
Continued deposition in north (Stormberg. Series).	
Erosion in south.	
Outpouring of Drakensberg Lavas.	Triassic
Erosion.	Jurassic.
Sagging, Crossfolding, Faulting and Deposition of the Enon Deposits.	Mid- } Cretaceous. Late- }
Differential uplift and melilite basalt injections.	
Formation of higher surface and deposits.	Tertiary (Eocene-Oligocene)
Warping (tilting and uplift).	Tertiary (Mio-Pliocene).
Formation of lower surface gravels.	
Further uplift.	
Recent fluctuation of sea level.	Quaternary.



AFTER GEOLOGICAL SURVEY

Figure 1. Geological Map

IV PRESENT-DAY CLIMATE, VEGETATION AND AGRICULTURE

The area may best be described as semi-arid although this is not strictly true. The temperatures in the lowland are never very low—slight frosts are sometimes experienced—but have a large dinural variation and high maximum (110°F.) In winter the mountain tops are often covered with snow, adding beauty to their grandeur. The rainfall varies from less than 5 inches in the open country to over 100 inches in the west against the mountains.

The effect of these climatic variations is seen in the vegetation. This includes the typical Karroo succulents and drought-resistant scrub in the open, while the kloofs in the mountains are well wooded. Aloes make vivid splashes of colour in the autumn.

Agriculture is confined to the narrow strips along the mountains and rivers where a supply of water is assured. Crops include grapes, tobacco, wheat, fruit, lucerne, etc. Sheep, goats and ostriches roam over the uncultivated parts.

V DRAINAGE

The area is drained by the Gouritz River System, all the major rivers of which are, for the most part, ephemeral; only the springs along the mountain fronts flow throughout the year. These streams derive their water from an accumulation of rain, mist and snow and are used for irrigation.

As a certain amount of confusion has been experienced regarding the names of rivers and poorts, the following description has been based on maps published by the Irrigation Department and the Trigonometrical Survey.

The drainage of the area can be divided into those rivers which rise to the north of the Langeberg Range and drain directly through them to the coastal plain to the south, and those which rise to the north of the Swartberg Range and, after flowing through the mountain and being joined by others rising in the area, flow through the Langeberg Range.

Of the first type there are three examples (the areas they drain are given to indicate their relative sizes):—

The Keisies-Appelkooskloof-Kingna Rivers which join near the town of Montagu before passing through Kogman's Kloof, drain an area of 71 sq. miles.

The Tradouws River flows eastward to the town of Barrydale and then turns south through the pass bearing the same name. It drains 125 sq. miles.

The Vette River, flowing through Garcia's Pass, drains about 9 sq. miles north of the mountain.

The second type, which display an apparent disregard for the high mountain chains, include the Touws, Buffels, Dwyka, Gamka en Olifants Rivers.

The headwaters of the Touws River lie to the north-west of the town of the same name. After flowing south-eastwards into the Little Karroo, the river is joined by tributaries from both the north and the south before it ultimately joins the Groot River. The total area drained by this system is 3,018 sq. miles, of which 793 sq. miles is north of the Couga Mountains.

The Buffels River has its source at the base of the Great Escarpment (Klein Roggeveld Mountains) and after flowing past Laingsburg, traverses the Witteberg Mountains at Leeukloof Poort and after crossing the intermontane area, cuts through the Klein Swartberg in Buffels River Poort. The trend of the course of the river within the mountain has been likened to an incised meander because for a distance of 1·4 miles it flows northward before turning and again flowing southwards through the mountain. From the mouth of the poort it is called the Groot River. Before it joins the Touws River, it is joined by the Knuy River which drains the Ladismith area. To its confluence with the Touws River, the area drained is 2,166 sq. miles of which 1,533 sq. miles is north of the Witteberg. After its confluence with the Touws River it keeps the name of Groot River, passes Vanwyksdorp from where it begins to twist and turn, to its confluence with the Gouritz River.

The Dwyka and Gamka Rivers also rise at the base of the Great Escarpment and meet just before passing through the Swartberg at Gamka Poort. On emerging from the mountain it, too, turns back on itself and flows northward for a short distance. Before it enters the Oudtshoorn Basin it is joined by the Huis River which drains Seven Weeks Poort. It then passes Calitzdorp and flows due south to Jagtberg where it is joined by the Olifants River and flows through the Rooiberg-Gamka Hills at Jagtberg Poort. (This poort has no name on the maps; the local inhabitants refer to it as "Olifantspoort" or "Badspoort". These names are unsatisfactory as the former may be confused with the well-known Transvaal poort and the latter is too specific: the "baths" being located at the mouth of the Olifants section of the poort.) On emerging from the mountain it is called the Gouritz River where, south of its confluence with the Groot River, it crosses the Langeberg Range at Gouritz Poort and after cutting the low Aasvoëlsberg, enters the sea a few miles to the west of the town of Mossel Bay. Up to Jagtberg Poort and excluding the Olifants basin, it drains an area of 4,865 sq. miles of which 4,308 sq. miles are north of the Swartberg.

The Olifants River has its headwaters to the north of the Great Swartberg as the Tarka River. Within the Oudtshoorn Basin it is joined by the Kamanassie River and then flows westward to the Jagtberg Poort. It drains an area of 3,760 sq. miles of which 406 sq. miles are north of the Swartberg.

In all, the catchment area behind the Gouritz Poort is just over 14,000 sq. miles of which a little over half is to the north of the Swartberg Range.

The pattern of the main drainage lines is simple. With the exceptions of the areas within a radius of about 15 miles north of Gouritz Poort, where incised (N + 1) cycle meanders occur and a dendritic pattern is noticeable, and the region to the north of the Swartberg Range, a marked trellis pattern is both expected and encountered. Where certain rivers cut through the mountains the pattern tends to become almost rectangular owing to adaptation to the structures of the rocks. To the north of the Swartberg Range the pattern is again dendritic with the tributaries showing decreasing signs of subsequence northwards.

The poorts which are a striking feature of the Fold Belt, will be described in more detail later.

VI PREVIOUS LITERATURE

Descriptions of the area, including the deposits under consideration, are to be found in the reports of the Cape of Good Hope Geological Commission, the Geological maps and in most text books.

Rogers (1903) in his paper "The Geological History of the Gouritz River System" traces the river history of the area. He shows the existence of longitudinal valleys prior to the deposition of the Cretaceous deposits (Uitenhage Series), and the improbability of an antecedent origin of the courses of the Gamka and other rivers in these words: "This absence of all traces of Pre-Uitenhage transverse valleys in the Zwartebergen and Langebergen together with the direct evidence of longitudinal valleys, which were eroded relatively more deeply than the present valleys, affords strong evidence against the view that the Gamka and other rivers from the Karroo were antecedent to the mountain ranges; in other words the rivers did not cut those valleys into rising mountains" (p. 379). He visualised the valleys as being filled with deposits derived from these mountains and the superimposition of the river courses from this surface. "We must thus look upon the river system south of the Karroo as a superimposed one as regards the folded country between the Karroo and the ocean; that is, it worked its way down from the surface (of Uitenhage Series) upon which the main streams were consequent, to a highly diversified surface . . . so that the rivers which thus maintained their courses came to have no direct relations to the structure of the country over which they ran after removal of the unconformable Uitenhage rocks" (p. 280). The Buffels River is suggested as having flowed over Garcia's Pass and having since been captured by the Gouritz River (p. 382). The gravels and deposits, he concludes, "record a past stage of the past development of the river system, during which the rivers had, in many parts of their courses, approached the limit of downward erosion . . ." (p. 383) and it was from this surface that the meanders in the lower reaches of the river were inherited.

Schwartz (1904) noted that the surface cut by the rivers was not a gradual one but stepped, because "behind each mountain chain there was an enforced period of base-leveling".

In his explanation of Cape Sheet 5, Rogers (1925) deals with the problem of the river evolution in this area once again. He argues (p. 9-10) that the unexpected course of the rivers through the mountains can be explained by one of three alternatives:—the rivers were antecedent to the mountain ranges; they were due to headward erosion (or as he says, consequent "on an original dip slope bordering the ocean"); or they were superimposed from a covering formation on which they were consequent. He reiterates his argument of 1903 that antecedency could not be the explanation, owing to the lack of evidence of pre-Cretaceous valleys through the mountains which would be expected. He then postulates the superimposition of the river on two points, namely the assumption that the Cretaceous deposits buried the mountain and have since been removed, and the form of the river which is like "a very deeply entrenched meander, shaped like that of a river flowing over flat ground". He dates this meandering as Early Tertiary or Later Cretaceous.

He quotes Prof. W. M. Davis (1906, ii), who favours the idea of extension by headward erosion and capture, "especially during earlier stages of whatever cycles of erosion the region has witnessed, for then the incision of valleys takes place most rapidly". Rogers rejects this possibility because of the bearing of the Uitenhage deposits, which are not preserved in the area which Davis saw, on the history of the river system.

Remnants of two erosion cycles are noted (p. 12)—the truncation of the Klein Swartberg at about 4,000 feet and the terraces at 2,600 feet on the northern flank of the Witteberg.

The conclusions reached by Rogers have had a profound influence on the later writers. Du Toit, for instance, suggests that the inauguration of the north-south drainage was a result of the crossfolding of late Cretaceous times (1939, p. 511). King (1942 and 1951) not only accepts without argument the postulate that the Buffels River once flowed through Garcia's Pass (p. 64 and 74), but also retains the hypothesis of superimposition for the origin of the major river courses. His views are presumably based directly on Rogers' conclusions as can be seen from the following quotation: "Thus a diversified pre-Cretaceous or early-Cretaceous topography seems to have been smothered until no more than the tops of the hills, if that, remained exposed" (1942, p. 309). Even after du Preez had shown that the Cretaceous beds were deposited in tectonic basins (the bulk of the Enon antedating the faulting and crossfolding,) and Taljaard had suggested that most of the poorts were due to headward erosion, King clings to the superimposed hypothesis. This can be seen from the following quotation: "A recrudescence of folding then tilted the Enon formations within the valley, and the huge faults which now border the southern faces of the main ranges came into being. Possibly before this time, when the valleys were filled with detritus, the rivers initiated those courses across the ranges by which they now escape from the Karroo, often through the narrowest of poorts (e.g. Meiring's Poort), to the sea" (1951, p. 310).

Du Preez's paper on "The Lithology, Structure and Mode of Deposition of the Cretaceous Deposits in the Oudtshoorn Area" (1944) throws more light on the earlier history of the area. He finds (p. 225) that prior to deposition the area must have had relatively steep slopes and high relief with a relatively low gradient surface in the valley. Differential depression then occurred (p. 226) which, although it did not delimitate the depositional basin, modified it considerably. Delimitation was accomplished by crossfolding and the basin was deepened by faulting, possibly starting at the same time as the folding although the former was shortlived (p. 232). In this structural and tectonic basin the Enon deposits collected. The date at which the faulting ceased, is indeterminable; there is proof, however, that subsequent movement of about 15 foot has occurred in some places. (Prof. Taljaard, personal communication).

Taljaard (1948, i, p. 13) shows that no part of the Gouritz-Gamka River System could have been superimposed. He visualises the headward extension of the lower Gouritz River which breached the low Outeniqua Range along joints, during upper Cretaceous times. The Gamka breach was caused by streamhead extension from the Cango fault-scarp face, while poorts such as Meiring's and Towerwater are "without doubt" incised along major joints.

In his book "A Glimpse of South Africa" (1949) he gives a detailed and accurate account of the rivers and landforms in the area together with their possible dates. He maintains that the Touws-Groot-Gouritz River is the oldest in the region and that it flowed from the highlands around the present town of that name, through Gouritz Poort to the south, during Cretaceous times (p. 136). He considers the Gamka River as a fault-scarp stream and here dates the poort as Mid- to Late-Cretaceous in age. The Traka River (Towerwaters Poort) is of similar age (p. 140), while the Buffels is later but earlier than Prins Poort (see fig., p. 130), which he dates as Late Tertiary (p. 128-129). The Kogmanskloof, Tradouws and Vette Rivers are also all headward extended along joint planes of younger age.

VII REMNANTS OF THE TERTIARY SURFACES

General. Before describing these remnants in particular, a few general characteristics may first be described. The flat-topped terrace remnants and the planed surfaces have been reflected in names such as Grootvlakte, Rooivlakte, Kareevlakte (all surfaces), Platrug, Platrand, Tafelberg, Long Mesa and Jakhalsplaat, while the local inhabitants refer to the terraces as "plate" (sheets) and "platos" (plateaux).

For the most part the terraces are confined to the flanks of the mountains, usually within 5 miles of the latter. They overlie with an angular unconformity older

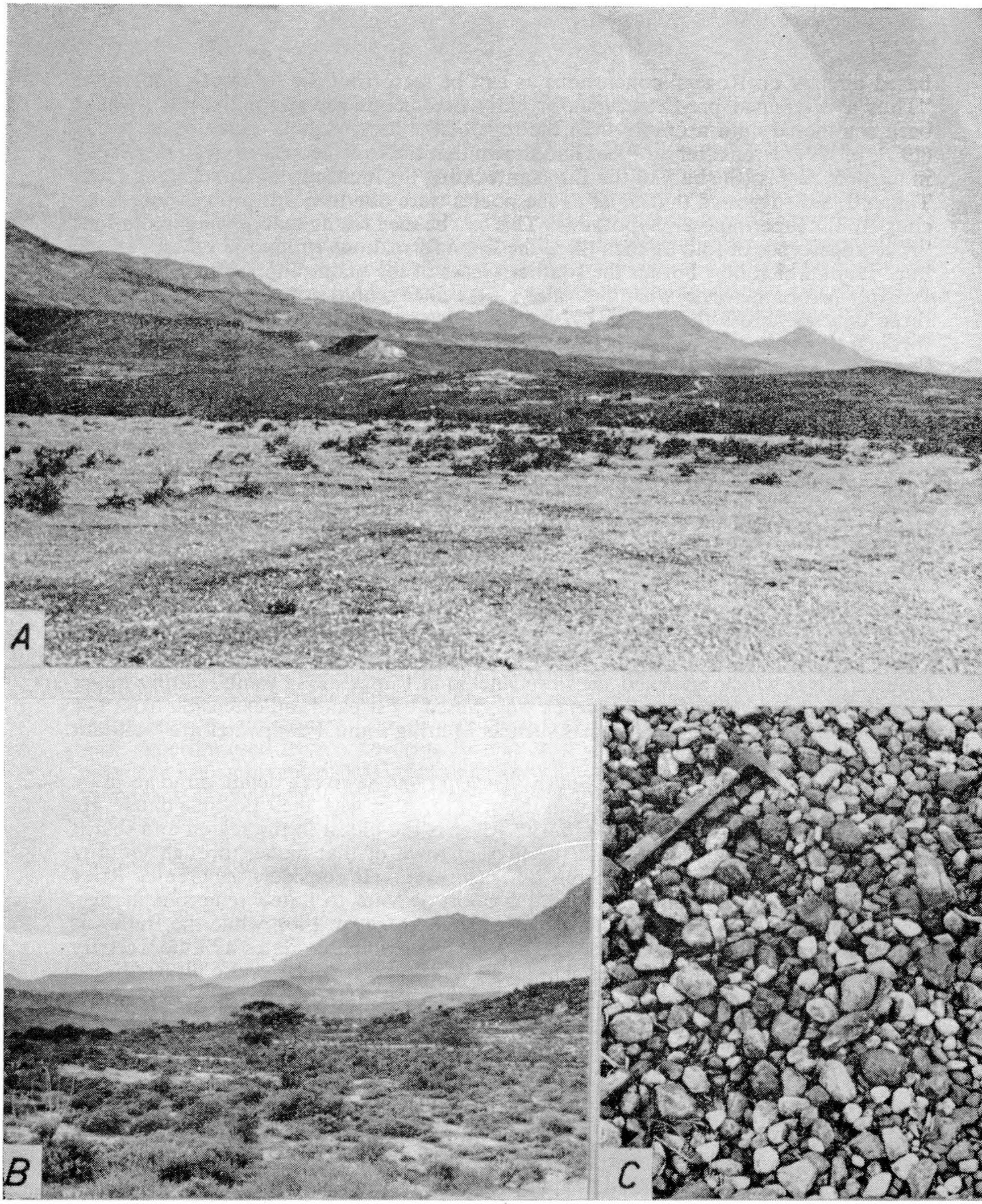


Plate I

(a) Consolidated gravels capping remnants of higher surface on northern flank of Langeberg, east of Garcia's Pass.

(b) Remnants in the Lemoenshoek area showing "stepped" upper surface on skyline, looking east.

(c) Pebble patch on a remnant's surface (Long Mesa).

rocks—in the western area those of the Cape System (usually Table Mountain and Bokkeveld Series, but where the faulting has brought the Witteberg Series close to the Table Mountain Series, they may overlie both); in the east, rocks of the younger Enon and older pre-Cape and granitic rocks; to the north, Witteberg, Dwyka and Ecca Series.

In some cases the terraces are contiguous with the mountains, but generally speaking those having consolidated deposits are isolated from them, and a bench, at a height continuous with that of the surface underlying the deposits, is often discernible on the flank of the mountains. However, both on low and high dipping strata the jointing and bedding planes produce a number of similar "benches" at various heights, and thus the use of this feature has been restricted to those which are in all probability a continuation of the surface. The terraces are usually diamond-shaped, having a maximum width some distance from the mountain.

The terraces occur in groups and any deposits resting on the surfaces, although varying considerably from place to place, are usually similar in neighbouring terraces. The thickest deposit measured (including recent scree) to the north of the Touwsberg, were 255 feet—the thickness increasing towards the mountain. Various degrees of cementation of the deposits have taken place, generally speaking confined to the lower 50 to 70 feet. Where the deposits overlie shales it is common for the latter to have been leached to clays of various colours.

As will be shown later, the surface is nearly everywhere overlain by gravels which in some cases have been cemented to form a conglomerate; the gravel consists of rounded boulders, cobbles, pebbles and granules (the size being smaller and the rounding better towards the valley, and regionally towards the south-east).

The Northern Slopes of the Langeberg. (See Fig. 2). The consolidated deposits stretch from Barrydale in the west to Gouritz Poort in the east. They occur in five groups: those in the vicinity of Lemoenshoek; Brand River; Long Mesa (including those to the west of Garcia's Pass); Sandkraal and those to the north of Gouritz Poort, but they are so similar that they will be described collectively. Their preservation must be attributed to their lithology which includes conglomerates and surface quartzites (silcretes). These terraces are often bounded by cliffs to the north but the southern ends are invariably covered with slump material.

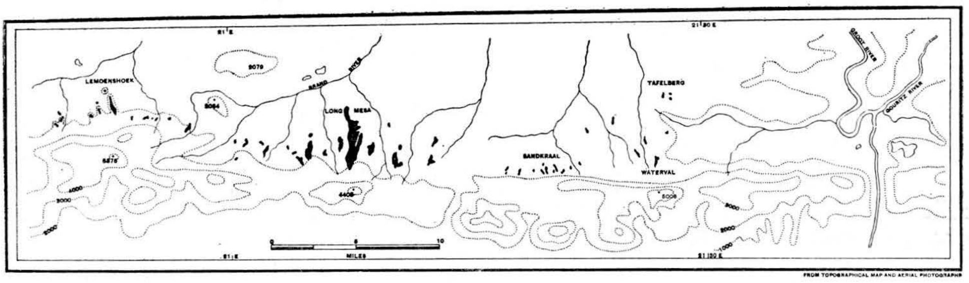


Figure 2.

Consolidated (solid) and unconsolidated (open) Gravels on the Northern flank of the Langeberg. From Lemoenshoek to Gouritz Poort.

The height of the surface underlying these deposits was measured in a number of places and from this the following calculations were made.

(i) Relative to the streams flowing near them, they show incision depths varying from 300 feet to 850 feet. Readings obtained at the northern edges of the terraces were as follows:

Gouritz Poort	872 feet
Sandkraal	305 feet
Garcia's Pass	300 feet
Lemoenshoek	515 feet

(ii) The surface appears to be concave in a valleyward direction. There is nearly always a sharp angle where it abuts against the mountain. The results of the measurements in this direction are:

Lemoenshoek. A fall of 110 feet over 0·75 mile or 146 feet per mile near mountain. followed valleywards by 135 feet over 1·00 mile or 135 feet per mile.

Long Mesa. A fall of 300 feet over 1·25 mile or 240 feet per mile near mountain.
followed by 60 feet over 0·5 mile or 120 feet per mile.
followed by 25 feet over 1·5 mile or 16 feet per mile.

Sandkraal. A fall of 75 feet over 0·25 mile or 300 feet per mile near mountain
followed by 80 feet over 0·5 mile or 160 feet per mile.

Waterval (S. of Sandkraal) 85 feet over 1·0 mile or 85 feet per mile
followed by 25 feet over 0·25 mile or 50 feet per mile
followed by 80 feet over 1·25 mile or 53 feet per mile
followed by 30 feet over 0·25 mile or 60 feet per mile.

(iii) The average of these 4 profiles is 106 feet per mile.

(iv) The southern edges of the remnants (or most southerly measurement in some cases) show a regional inclination to the east. In places, notably Muiskraal (north-west of Garcia's Pass) and Tafelberg, a slight back slope was measured amounting to 15′ and 10′ respectively. (These figures serve to indicate a measurable back slope rather than an accurate measurement.) The regional slope from west to east can be seen from the following list of heights. The reason why they appear irregular is that they are not all against the mountain.

Witkleikop (Lemoenshoek)	2,265 feet
Brand River	1,985 ,,
Long Mesa	1,872 ,,
Muiskraal	1,860 ,,
Sandkraal	1,655 ,,
Waterval	1,534 ,,
Poort	1,200? ,,

(v) The direct distance between the first and last readings above is about 50 miles and thus the average slopes is 20 feet/mile; along present-day drainage lines it is about 65 miles or 16 feet/mile.

Although the slope of the surface remnants is greater to the north than to the east, they must have flattened considerably valleyward, as the east-west striking ridges of Bokkeveld and Witteberg Series appear to have been planed to a common level. Some places show that they must have been higher than the surface; usually this occurs near the mountains and separates the groups. The best example is that between Lemoenshoek and Brand River where the beacons at heights 2,048 feet and 2,079 feet are well above the projected level of the surface. Similar phenomena can be seen between the groups in this and other regions.

The tops of the terraces are usually smooth and possess a valleyward slope of low inclination in the north, increasing gradually to the south. Some, however, appear stepped, that is, they have two surfaces at different heights as at Lemoenshoek. This can be seen from the terrace on the skyline in the photograph. (Plate I, B.)

Patches of small rounded pebbles occur on top of nearly all the remnant terraces, these being exceptionally well displayed on the largest (2·97 sq. miles) on which the beacon Long Mesa stands. They vary from 3 inches to less than 0·25 inches in length, and although all sizes occur, one average size of one patch usually differs from the next. They are purple, black or reddish-brown in colour interspersed with white quartzite and sandstone pebbles. Some of those of darker colour are undoubtedly weathered quartzite and sandstone, but that some have been derived from the ferricrete, cannot be ruled out.

The consolidated deposits resting on the surface show a certain similarity in succession, even over the large area, as can be seen from the table of sections in Fig. 3. The general succession they suggest is that the surface is nearly everywhere immediately overlain by a well-rounded pebble layer of varying thickness which is partially cemented and weathers easily. The pebbles are less than 1 foot in length and average between 3 inches and 6 inches in length. This layer grades upward into cobbles and boulders which are better cemented by silica and iron oxide. Above this, often without a sharp contact, rest the silcreted sands and pebble lenses (conglomerate). The pebbles are all well rounded and average a few inches in length. One fairly persistent band of conglomerate about 4 feet thick can be seen in the Sandkraal area. This is usually overlain by less well consolidated deposits—often a pebble or cobble ferricrete above which sand, soil and rubble derived from the mountains have accumulated. This scree may be over 100 feet thick near the mountain, but valleywards it is considerably less, if present at all.

Two interesting features of the succession near Derde River Beacon are that the deposits contain a sandstone horizon which has a white clay-like matrix and that this horizon also shows signs of cross-bedding.

Although a few of the remnant surfaces have no deposits other than a thin veneer of gravels, they are easily recognizable as they overlie dark shales and the gravels are composed of light-coloured quartzites and sandstones. Little attention was paid to these deposits, with the exception of the area to the north of Gouritz Poort. They lie at a lower level than the consolidated deposits in most cases, although in the Long Mesa area they appear to be the valleyward extension of the top of the terrace. Their distribution is along the present drainage lines and in the valley they are about 200 feet to 300 feet below the planed ridges. The occurrences of loose unconsolidated gravels in the Gouritz Poort area have already been mentioned. They occur on both the east and west banks of the river. Those on the left bank occupy a large flat expanse which has rounded edges covered with well rounded and chatter-marked boulders and pebbles. The height of the top of this plain is between 1,000 and 1,100 feet, and can be seen to be related to the change of slope shown by the poort (see later). On the right bank of the river, below the trigonometrical beacon at a height of 759 feet, 20 to 25 feet of gravel is seen. For the most part this is unconsolidated, showing a slight ferruginous cementation in the lower parts. The components of this gravel are all well rounded, and some of the larger boulders are extremely well chatter-marked on all sides.

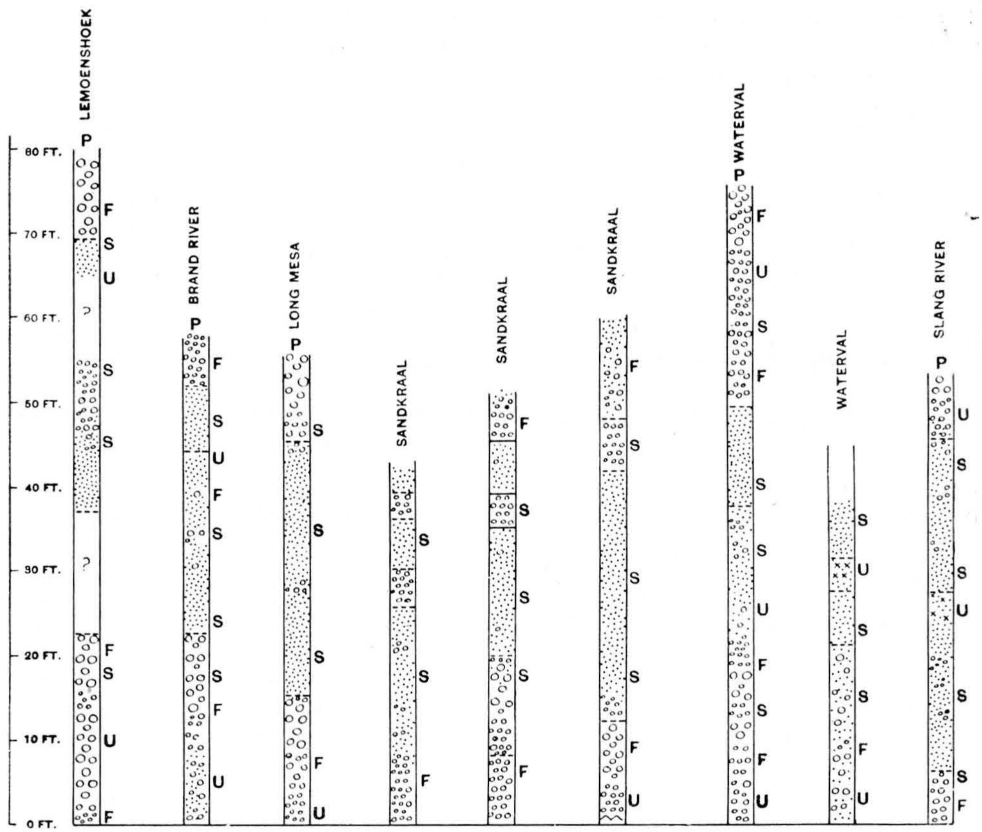


TABLE OF SECTIONS

Figure 3

Dots indicate sand
Small circles indicate pebbles
Large circles indicate boulders

F denotes mainly ferruginous cement
S denotes mainly siliceous cement
U unconsolidated
P denotes pebbles present on upper surface

The Warmwatersberg Area. On the southern side of this mountain a number of terraces occur at heights of about 1,750 feet. They are covered with a loose, unconsolidated layer of gravel. On the northern side two terraces were noted at heights around 2,000 feet, both covered with a thin veneer of gravels from 15 to 25 feet thick. They overlie Bokkeveld Series beds and the surface is remarkably smooth, being cut across the sandstones and shales alike. The sizes of the components of the gravel range from sand particles to 2-feet boulders near the base and up to 5 feet near the top. They are angular to sub-angular in shape and mainly composed of Table Mountain Series quartzites and sandstones.

To the south-east of Bellair Dam there are a few sporadic patches of gravel. These appear to have been reworked. To the south of this dam there is what appears to be a perched, disused narrow poort through the mountain. It is locally known as the "Valley of Desolation", and notwithstanding the legendary curse of the original Hottentot inhabitants, a more probable reason for the lack of vegetation and failure of crops is suggested by the fact that a borehole passed through 165 feet of sand and boulders without reaching bedrock.

The North-west. In the north-western portion of the Little Karroo, bounded by the Waboomsberge, Coega Mountains and the Anys-Witteberg Range, a large tract of the land has been planed to a smooth, though gently undulating surface. (See Plate II, A). This could be inferred from the name of the farm and the beacon in the area, namely Grootvlakte. The general height of this surface is about 2,500 feet. It rises towards the mountains and is covered in places by a thin sheet of gravel and soil. It slopes towards the Touws River from both north and south, and in the north the planing of hard and soft rocks is beautifully displayed (see Plate II, B). It can also be seen from the photograph that a lower surface exists at about 100 feet below the higher surface, below which the river has been entrenched.

Touws River Town Area. The country to the north-west of the Couga Mountains, to the west of the town of Touws River, is again very flat, at a height varying between 2,500 and 3,000 feet. Taljaard (1948, p. 77) has described relics of an older surface which cuts across rocks in the area about 1,000 feet higher than the above-mentioned surface, at heights of between 3,600 and 3,800 feet, reaching 4,000 feet at a maximum. This corresponds in height to the remnants of a surface mentioned by Rogers (1925, p. 12): "During the earlier of the two cycles there was produced the flat surface which truncates the anticlinal fold of the Klein Zwartberg". "The height of the remnants of the earlier formed plain is about 4,000 feet".

Anysberg. On the southern slopes of the Anysberg both the surfaces mentioned above are displayed. The lower surface appears in certain places to merge into the higher, and the deposits on the former consist of unconsolidated or weakly-consolidated rounded gravels with boulders of up to 3 feet, at a distance of 3 miles from the mountain. The slope of this surface was not measured, but it can be seen sloping towards the present river from the north, while in the south the present-day surface also slopes in the same direction, as at Karreevlakte.

The deposits of the higher surface are invariably cemented by iron oxides with some silica, the relative proportion of Fe to Si being 3 : 1 at Wilge River. This cements boulders and cobbles of Table Mountain Series and vein quartz.

The remnants to the south of Touwsberg are essentially similar, there being possibly a smaller proportion of consolidated gravels, and their general height is naturally lower (approximately 2,100 feet for the higher surface).

Touwsberg-Swartberg Intermontane Region. (Fig. 4.) The area to the north of the Touwsberg is more complex as regards the surfaces; the writer noting no less than five surfaces possibly all different, above the present river alluvium. However, owing to the position of the mountain in relation to the local erosion base, it is probable that these are contemporary surfaces which have been formed at different heights. Fortunately the highest two surfaces can be recognized fairly easily.

Midway between the ends of Touwsberg, and sloping away to the north, the higher surface is represented by a terrace which overlies T.M.S. and the Bokkeveld

Series to the second shale horizon. It carries an extremely thick covering of deposits, the base of which is 650 feet above the local stream and at an altitude of about 2,450 feet. The contact of this surface with the mountain appears to be a sharp one.

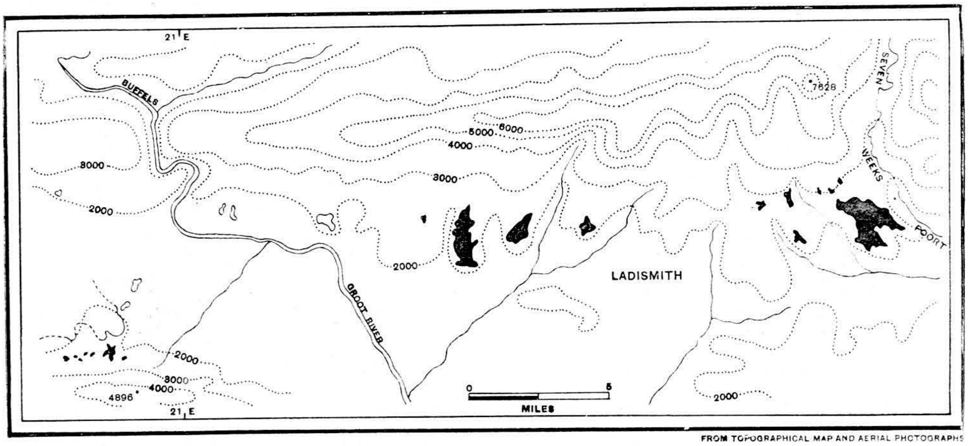


Figure 4

Higher (solid) and lower (open) surfaces on the Southern flank of the Klein Swartberg. From Buffels River Poort to Seven Weeks Poort. Touwsberg in south-west corner; Amalienstein in the east.

Resting on this surface is a layer of ill-sorted, more or less consolidated layer of pebbles, cobbles and boulders, between 50 and 80 feet thick. On the south-eastern edge of the terrace it is predominantly cemented by iron which weathers easily, forming caves and overhanging ledges, whereas to the north and west the silicious conglomerate is again encountered . . . this forms a hard cap and cliffs of about 30 to 40 feet high, below which blocks of conglomerate are littered over the hill slope. The jointing in this area passes both through and around the pebbles, depending on the degree of cementation. The size of the boulders in the cemented portion seldom exceeds 5 feet in length, but some of as much as 10 feet were seen near the mountain.

Above these deposits there is an accumulation of scree and soil containing huge pieces of angular quartzite up to 20 feet in length. The thickness measured was approximately 200 feet, but this must be exceeded further southward where debris is still accumulating.

Similar terraces, though none with the thick scree deposit, are found to the west of this terrace. To the east there are no remnants or even reliable benches. The surface dips to the north-west, the valleyward inclination near the mountain is 125 feet/mile and the westerly component is about 80 feet/mile.

To the north of the central terrace and about 100 feet below it, a second more extensive surface can be seen which is separated from the former terrace by about 75 yards. It stretches to the north and north-west at a general height of 2,000 feet (from 2,243 feet to 1,903 feet) with a slope averaging 120 feet/mile over 3 miles. It is covered with a gravel mantle in places, 10 to 20 feet thick and composed of well rounded rock fragments and soil, the former averaging a few inches, but also reaching up to a few

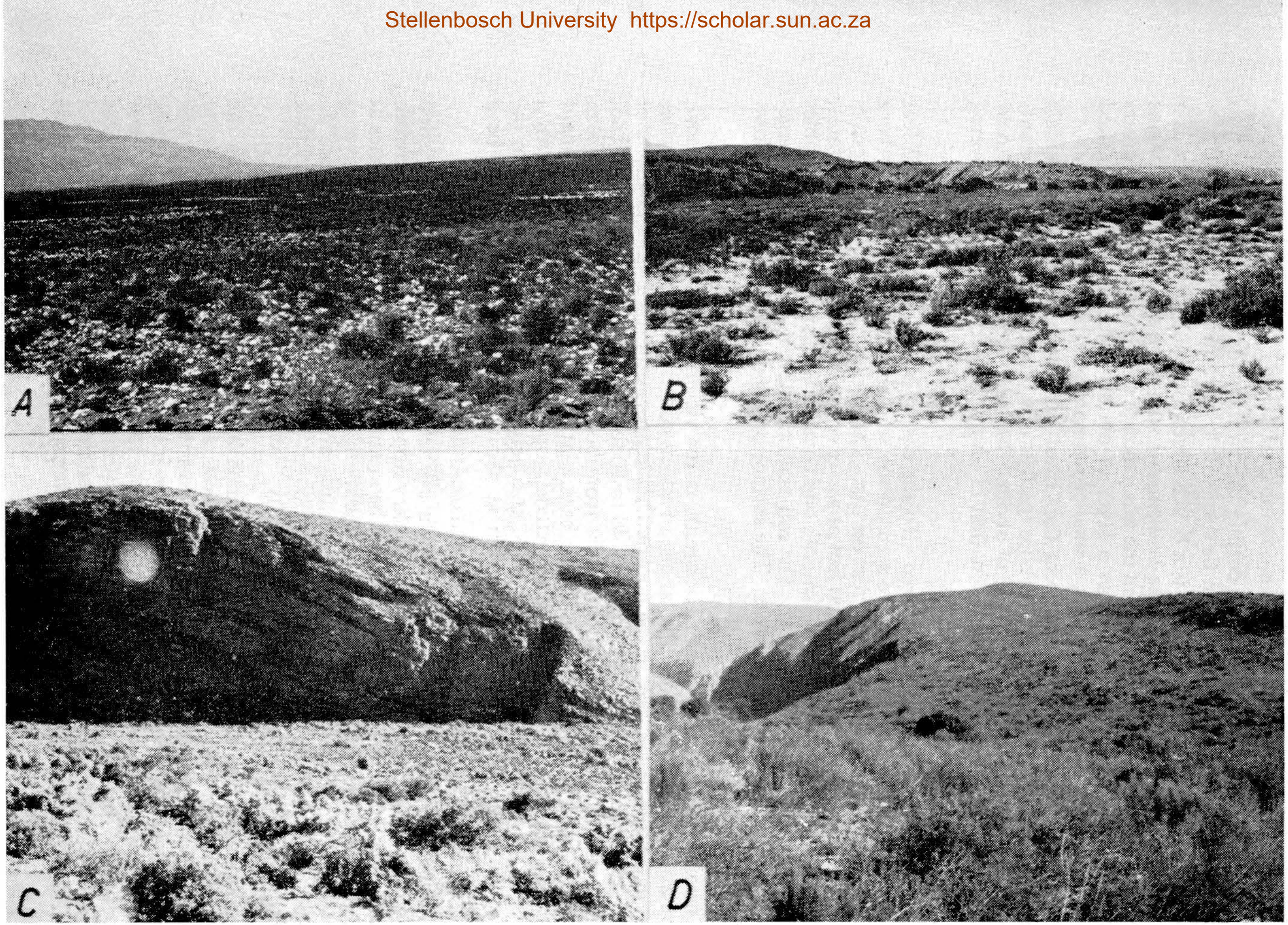


Plate II

(a) The surface near Grootvlakte looking N.E. (Anysberg left background).

(b) A bevelled remnant in the Bloutoring area with the Touws River in the foreground. Anysberg on the right. Taken from lower surface.

(c) Stream-cut bench on west side of Jagtberg looking S.W. over incised Gamka River. Oblique to strike.

(d) Structural bench on south side of Jagtberg. Confluence with Gamka River middle left. Olifants River incised on left.

feet in length. At a distance of 3 miles from the mountain they still attained a length of 2 to 2·5 feet.

In places a third surface is seen cutting this in the south, but they merge into one another in the north. A fourth can be seen still lower down.

On the farm Mierefontein there is a bench which is about the same height as a small remnant terrace to the east of the Ladismith-Laingsburg road, where it begins to ascend the mountain. It is situated on the watershed of the Groot and Touws Rivers at an altitude of 2,026 feet, and carries a layer of about 10 feet of unconsolidated gravels. To the east 120 feet below this, a smaller remnant occurs.

At a point due north of Touwsberg the Groot River emerges from the Buffels River Poort. Just to the east of the poort lies the first of a number of terrace remnants which stretch to Voorbaat at an altitude of about 1,700 feet—350 feet above the local river height. They have an easterly inclination of about 20 feet/mile and are covered with unconsolidated gravels.

The Dwars River (*Ladismith*) *Area*. To the east of these terraces and 675 feet higher, the higher surface remnants are seen on the southern flanks of the Swartberg at an altitude of approximately 2,400 feet on top. The surface on which the deposits rest is lower than this, and the lowest 50 feet or so are consolidated into conglomerates. The top of the deposits is remarkably smooth and covered with small rounded pebbles as described on the southern terraces. The soil and rainfall here is such that the vegetation is thicker than on other terraces. The surface on which the deposits rest shows an easterly slope of about 17 feet/mile.

Amalienstein. To the east of Ladismith, in the vicinity of Seven Week's Poort, there are a number of remnants, the largest of which covers an area of 2·21 sq. miles and is situated just to the west of the poort. This impressive terrace has a covering of about 35 feet of conglomerates overlain by 40 to 50 feet of scree, at the northern end. The conglomerate is again a mixture of sizes from boulders to sand which have been cemented by silica and iron oxides and the base is at about 2,806 feet. No remnant straddles the fault. The terraces have a westerly slope of 10 feet/mile. To the east a pronounced level occurs, cutting the T.M.S. at a height of about 3,000 feet. On the ridges in the valley reworked gravel occurs at about 2,000 feet which might be a reflection of the lower surfaces seen elsewhere.

Rooiberg. To the north of Rooiberg a few terraces were seen but not visited by the writer. From the topographic map they appear to be at heights of between 2,000 feet and 2,500 feet. The western end of the mountain has a number of benches at a height of about 2,000 feet, while the area to the south has a number of terraces covered with loose unconsolidated deposits at an altitude around 1,400 feet. There are no conspicuous terraces above these surface remnants, although it must be stated that this mountain (a simple anticline) is stepped by "benches".

The South-east. Only in the valley drained by the Slang River, between the Pogha and Gamka Hills, are consolidated gravels again found (Fig. 5). They are extensive and well preserved on the southern side of the valley where they overlie both T.M.S. and Bokkeveld Series, while on the northern slopes they generally overlie only the Table Mountain Series. They rise from heights of around 1,500 feet to well over 1,800 feet to the east. A remarkable fact of the deposits in this area is that they are less well cemented and show definite signs of crossbedding in the sandstones. A general section (a combination of three) shows the following succession (see Fig. 3). The surface is overlain by ferricrete or conglomerate of small pebbles which grade upward into cobbles and boulders. This varies from about 5 to 10 feet in thickness. On this, 8 to 20 feet of silcrete, sandstone with conglomerate and pebble lenses occur which in turn grade into the usual gravel and scree on the top. The tops of the remnants are flat and often covered with pebble patches.

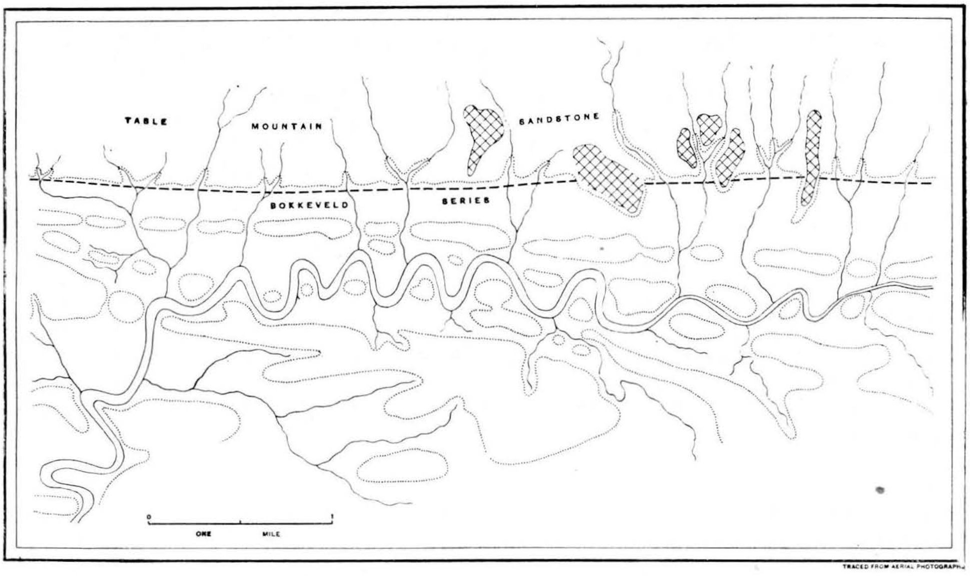


Figure 5

The Slang River Valley showing approximate Table Mountain and Bokkeveld Series contact (broken line), Eo-Oligocene consolidated gravels (cross-hatched) and more resistant ridges of Bokkeveld Series (dotted)

Terraces were also seen in the narrow valley of the Kamma River, a few miles south of the Slang River, and here too the remnants are confined mainly to the southern slopes.

The Oudtshoorn Basin. Although no measurements were taken in the Oudtshoorn basin itself, one or two observations must be included here. The "High Level Gravels" have been described by a number of authors. Du Preez (1944) refers to a lower surface sloping towards the Olifants River and cutting across the Enon deposits. In the Kamanassie Valley to the east, de Villiers (1938) finds that the two surfaces are 200 feet apart, the lower about 400 feet above the master stream. The lower surface is preserved on the southern side of the river only, while the higher has a maximum distribution on the northern side at an altitude of about 2,100 feet (topographic map). If this higher surface is correlated with the lone remnant a few miles to the north-west of Jagtberg Poort a regional slope of about 10 feet/mile is obtained. This latter remnant is at a height of about 1,760 feet.

In this western portion of the Oudtshoorn basin there are far fewer remnants than in the central and eastern portions. However, those at Armoed and Kerkrand dip towards the centre of the basin and not to the present more southerly position of the Olifants River. Benches are, however, seen everywhere against the mountains, occurring at various altitudes, none bearing gravels. One soil-covered bench is of special interest: it is cut into the west side of Jagtberg, parallel with the Gamka River at an altitude of just over 1,200 feet at a slight angle to the dip of the T.M.S. (Plate II, C). It stretches for a distance of about 0·75 mile from the T.M.S.-Bokkeveld contact to the south. Two chatter-marked boulders and a small piece of calcrete, containing rounded pebbles and embedded in the soil covering, provided the only positive evidence that the bench was formed by water action. This bench today slopes towards the present river to the west and to the south, and is the only water-cut bench which could be found. That on the southern side, parallel to the Olifants River, is a structural bench (Plate II, D), and the general height of the shoulders and benches on the southern side of the river suggests a slope to the east. No higher benches were seen.

Swartberg-Witteberg Intermontane Region. In the whole of the intermontane area between the Swartberg and the Witteberg only a few patches of unconsolidated gravels were seen, near the Buffels River and the Klein Swartberg River. They occur at a height of just over 2,000 feet. An investigation of aerial photographs showed no other occurrences. Considering present-day stream activity to the north and south of the Klein Swartberg, the absence of the higher surface cannot be ascribed to more active weathering and stream-cutting in the intermontane region. In fact, the reverse is true as, owing to the higher precipitation, the streams on the southern flank are more active.

The Area South of Laingsburg. North of the Witteberg a number of terraces occur. These have been described and studied by both South African and overseas geologists.

No less than three surfaces were seen in this area (Fig. 6) and Strydom (1950, p. 268) mentions "two or three" river terraces below these. The most extensive surface is found on both sides of Leeukloof Poort, sloping towards the poort (80 feet/mile from the east) at an altitude of about 2,550 feet, but it has larger remnants on the western side where the largest terrace covers an area of 4·64 sq. miles. This huge terrace stretches for about 4 miles northward from the mountain and at its broadest point is about 3 miles wide. Near the mountain it both grades into and abuts, with a 130-foot scarp, against a higher surface. Where the two grade into one another the slope is more than 300 feet/mile, while the northward gradient is merely 140 feet/mile. Where the two surfaces are separated by a scarp, they are situated to the south of a ridge of Dwyka tillite which has been planed down to the level of the terrace to the west. The surfaces grade into one another to the west of this point. The width and slopes of the gap, however, suggest that it was in all probability in existence when the upper surface was formed, as the latter also slopes in this direction (10 feet in 200 feet).

The upper surface can also be seen further to the west, where it is preserved behind more resistant ridges of the Witteberg Series quartzite.

The ridges composed of the Karroo System rocks to the north all present the appearance that they have been planed to a common level at just over 3,000 feet, with some resistant parts protruding above this.

A stream has cut into a large remnant at a distance of about two miles from the mountain, exposing the shales and tillites of the Dwyka Series. Here it has cut a definite bench about 25 feet below the higher surface. In a downstream direction the difference between the two surfaces increases to about 75 feet. A similar feature may be seen to the east of this point.

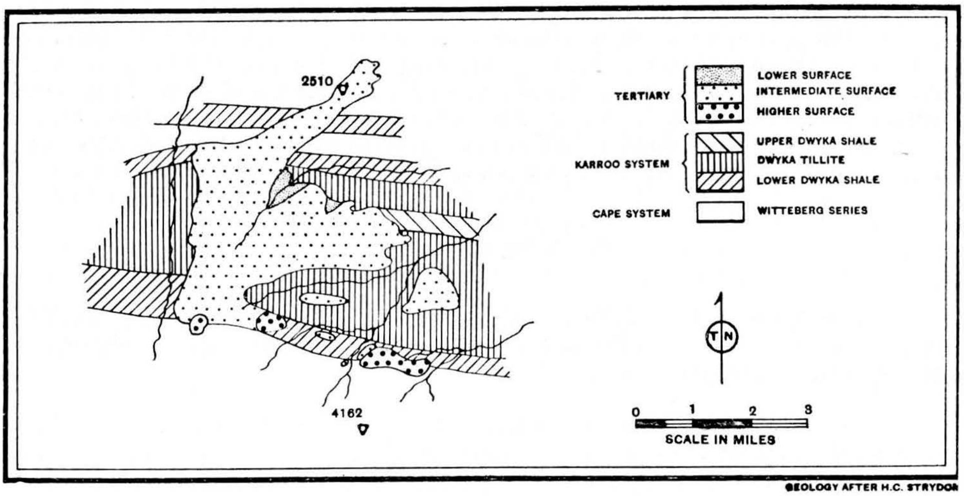


Figure 6

Sketch Map showing Geology and surfaces on Northern flank of the Witteberg, south of Laingsburg.

The components of the unconsolidated layer of gravels overlying the large surface are remarkably constant, varying from boulders to sand, the size of the largest boulders being about 10 feet near the mountain but decreasing to about 3 feet within the first mile and virtually remaining this size right up to the northern end of the terrace. The average size, however, decreases considerably to a foot or less. Throughout the larger boulders have percussion marks, and the smaller ones show some degree of rounding. They are undoubtedly Witteberg quartzite derived from the mountain to the south. The northern edge of the terrace was measured to be 355 feet above the Buffels River.

Terraces were also noted on the watershed between Hartebeestspruit and Kerk River to the east of this group, i.e. between the Doekberg and the Elandsberg, at about 3,000 feet (topographical map). They appear to be covered with unconsolidated gravels.

Die Hel. The intermontane valley in the Swartberg, known as 'die Hel,' also shows from a stereoscopic investigation terraces on the southern side of the valley, and the Bokkeveld ridges appear to have been planed down to about the same level as this surface.

Other Drainage Basins. The only other areas of importance are those which are drained by short rivers rising north of the Langeberg and flowing directly out of the Little Karroo. In these areas the only gravel patch which was found was on the Droogte River in the Kogmanskloof drainage basin, a few feet above the local stream and about 50 feet above the master stream.

On the watershed between the Tradouws and Kingna Rivers a few loose T.M.S. boulders were seen. These were lower than shoulders and benches seen all along the mountain range to the south, which suggests the former existence of a surface rising to about 3,000 feet in the Montagu region.

The Area South of Gouritz Poort. This area was visited briefly to compare the nature and heights of the Tertiary "Silcretes, Ferricrete, and Older Gravels" described in the Explanation to Sheet 201 (Haughton, etc., 1937 (i)) with those north of the Langeberg. They occur at about 1,100 feet both to the east and west of the poort. They are inclined towards the present river and drop to just under 500 feet north of Aasvoëlberg, an average slope of 38 feet/mile. It must be remembered that the warp axis to the south of Riversdale may extend and influence this figure (see later).

VIII PETROLOGY

A certain number of specimens were collected in the field from various localities and horizons, but the types differ so little both in hand specimen and in thin section, that they will be described collectively.

Ferricrete. Samples from Wilge River (near Anysberg Post Office), Touwsberg, and from the area to the north of the Langeberg were examined. They consist of T.M.S. pebbles, usually well rounded, together with quartz grains which have been cemented by a dominantly ferruginous material, giving them a deep red or brown colour. On weathering the matrix is usually removed first, sometimes resulting in a pitted or "honeycomb" effect as in the Slang River valley.

Calcrete. Only one sample of this was found on the bench at Jagtberg. It contained a few well rounded pebbles and quartz grains cemented by lime carbonate.

Silcrete. This type is confined to the areas to the south and east, samples being collected at Lemoenshoek (not pure), Long Mesa, Sandkraal and Tafelberg. It is a greyish-white rock, often streaked with brown staining and containing small cavities. It usually contains a number of small, well rounded pebbles, but in its more pure form, as seen at Tafelberg, is composed of subangular, angular and slightly rounded sand-sized grains of quartz. (Wentworth scale is used throughout as the rocks were studied both in hand specimen and thin section.) Its fracture is sub-conchoidal to splintery and it weathers along cracks or exfoliates. When struck with a hammer it produces a metallic "ring". In thin section it is seen to consist mainly of granules and sand particles composed of quartz and cemented by chalcedony. Zircons are the most abundant of the accessory minerals. They are rounded but their size and abundance appear to vary unpredictably.

Other accessory minerals that were noted, were muscovite, tourmaline, hematite and limonite. The quartz grains are separated from one another and nearly all show signs of strain (undulatory and columnar extinction). The matrix may comprise as much as 65% by volume, but is usually between 40% and 50%. Vague colloform structures were observed, as were differences in the amount of iron staining. A few of the grains have fretted outlines.

Conglomerate. There is a continuous transition between this type of rock and a silcrete containing pebbles. The conglomerate here may be said to consist of cobbles, pebbles, granules and grains (in some cases even boulders) of T.M.S. quartzite and vein quartz set in a matrix of silica and iron oxides. Excluding the particles larger than granules, the ratio of cement to allogenic material, is about 1 : 1, although this proportion is not by any means constant. Usually the cement is such that the conglomerate breaks through pebbles and matrix alike, but where the cementation is weaker, it breaks round the pebbles. In places abundant colloform structures and rhythmic layering were seen, varying in size from 0·6 cm. to 0·2 cm. (see Fig. 7), presumably where silicious and ferruginous material have been coagulated together. (See Frankel and Kent, 1937). A peculiarity of some of the conglomerates is the occurrence of what appear to be silcrete "pebbles". These have a much higher iron staining which increases towards the edge of the pebble, but the proportion of grains to matrix is lower than the purest silcrete found. (See Fig. 7.) In the conglomerates some of the grains of quartz have fretted outlines. Zircons and other accessory minerals are also present in small quantities in the matrix. In places the conglomerate developes a jointing normal to the bedding and at the edges of the terraces large blocks can be seen lying on the slopes below the deposits.

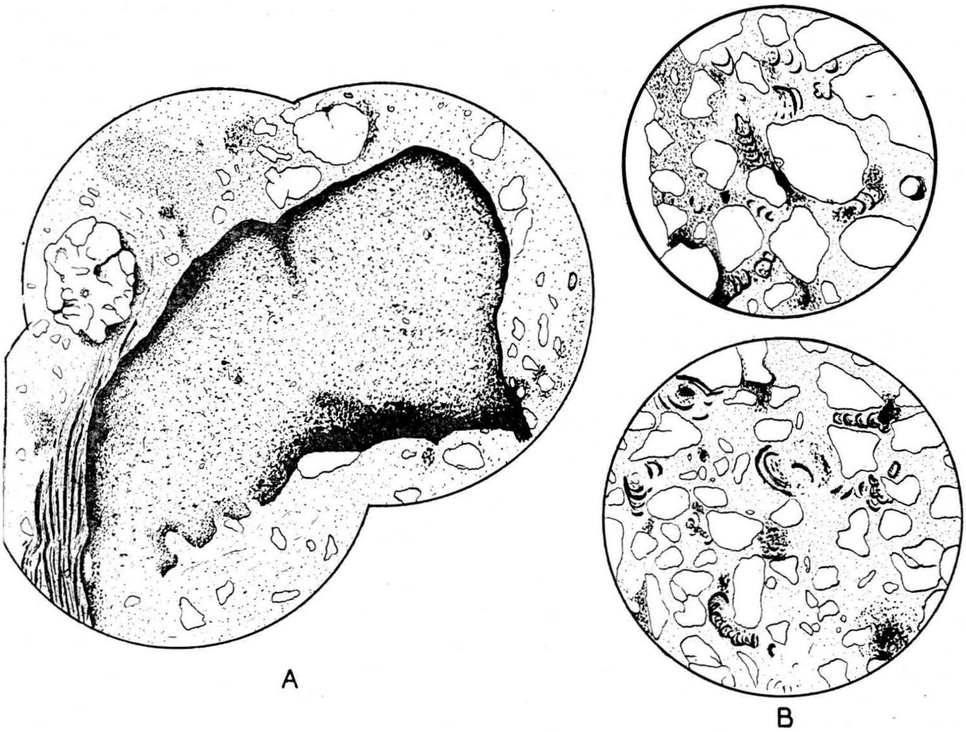


Figure 7

A. Silcrete (?) Pebble and Rhythmic Layering in Conglomerate.
B. Colloform Structures in Conglomerate.

IX POORTS IN GENERAL

Because of the significance attached to the gorges or "water gaps" in determining the history of this area, special attention will be paid to these striking and beautiful features of the Cape Fold Belt. A poort is a relatively narrow, steep-walled opening cutting almost perpendicularly across a topographic barrier, through which the more open areas on either side are connected, usually by a river.

Five major types can be recognised, namely, consequent, antecedent, subsequent, inherited and superimposed poorts.

A consequent poort is one which has developed in response to the inequalities of a newly formed surface. They may develop on coastal plains for instance (see von Engeln, 1942, p. 121).

An antecedent poort is one which results from an uninterrupted flow of a river, across which the barrier is formed. A necessary but not essential condition for this type of poort is, that the age of the structure succeeds that of the establishment of the river.

A subsequent poort is one which is developed along a relatively weaker part of the barrier by a headward eroding stream.

An inherited poort is one in which the stream responsible for the formation of the poort has been imposed from a higher level having the same governing structure.

A superimposed poort may be considered a special type of inherited poort, as has been shown to be the case with rivers (Maske, 1951). It is a poort which owes its existence to the letting down of a stream from a foreign structure with which it was in harmony, the stream maintaining that course in the lower structure. A necessary, but again not sufficient, condition for this type of poort is, that the downcutting stream must pass through an unconformity.

For three of the above types poort formation may take place when a river has reached any stage of development; but for subsequent and consequent river-poorts youth is essential.

It is impossible, for obvious reasons, to draw up criteria for the recognition of the different types of river-poorts listed above. The type can only be decided after taking into account the history of the area, the physiographic age of the area and rivers and the form of the poort.

However, subsequent poorts in similar climatic regimes, traversing similar geological formations and structures, and in regions of physiographical stages of development similar to those displayed in this area, make an interesting study. The relationship between their age, degree of adaptation to structure, valley slopes and trend of their courses will be traced in general, drawing on examples displayed in the area.

As this type of poort has its origin in the headward erosion of a stream, it is characteristically controlled by the structure and lithology of the rocks.

In youth the poort is a narrow twisting defile with the river channel parallel to the directions of the major joint and bedding planes. The walls of the poort are steep and often vertical. One of the many examples of subsequent poorts of this age is that of Seven Weeks Poort. Some idea of the winding pattern of the river course can be seen from Fig. 4. The total relief can be pictured when it is realized that the highest point of the Swartberg Range in this area (7,628 feet) lies 2·5 miles to the west of the poort and the river flows at a level of around 3,000 feet. Kogmanskloof, Tradouws Pass and Prins Poort are all examples of similar origin and age in the area.

As maturity is approached the river tends to straighten its course as a result of the increased gradient through the poort and a lessening in the degree of structural adaptation. Side streams reduce the precipitous slopes of the walls to a smoother gradient. Control by the minor structural features is lost, although the general trend of the course may still reflect the major structural lines. This stage of development is displayed by such poorts as Gamka, Jagtberg and Buffels Poorts. That of late-maturity, by Gouritz Poort.

Old age may be presumed to have been attained when the river's course is not influenced by the structural features and the walls of the poort have become low in gradient and comparable to those of the mountains through which it passes.

It must be emphasised that nearly all poorts in this area have been inherited, and as a result of the rejuvenation youthful features are nearly always seen.

X RECONSTRUCTION OF THE DRAINAGE LINES

As has been previously mentioned, the key to the river evolution lies in dating the breaching of the mountains. Associated with this is the problem of the origin of the poorts. With the first point in mind, an attempt will be made to reconstruct the drainage lines by correlating the various surfaces, the latter on grounds of lithology, their altitudes and their mutual relationship. Possible dates of the surfaces will be discussed later.

Setting a date to the Gouritz Poort is relatively easy, as the highest surface, with its covering of conglomerates, silcretes and gravels, is preserved on both sides of the poort at a height of approximately 1,200 feet to the north and approximately 1,100 feet to the south. Additional evidence is afforded by the cross-section and the trend of the river within the poort. The walls of the gorge slope gently to a point almost level with the higher bench and gravels to the west and east of the poort at a height of 1,200 feet. Below this point the slope becomes steeper, to a point corresponding to the height of the lower (approximately 750 feet) semi-consolidated gravels. Below this it becomes almost vertical for about 520 feet. The course of the river within the mountain is relatively straight, with only very minor and youthful adaptation to structure. This seems to suggest that the river, before its inheritance, had developed a relatively straight course through the mountain and that the surfaces to the north and south of the mountain are of similar age. With uplift the slopes receded sufficiently to reflect the lower stance, before a continuation of the downcutting.

What of the earlier erosion base of the river between the Langeberg and Swartberg? During the late-Cretaceous times deposits collected in the area to the south-east and north of the poort. The Mossel Bay patch (to the south-east of the poort) is bounded by a normal fault to the north, which has tilted the formations to angles of about 20° (see Potgieter, 1950). The lithology of this patch of Cretaceous deposits has not been described in detail, but it is interesting to note that in his description of the area, Haughton (1935) shows that some of the components of the deposits are derived from a northern provenance. Thus, where they lie in contact with Pre-Cambrian rocks, boulders of granite, gneiss and slate are found (p. 16-17). However, "on Hemelrood (A 2) the conglomerates near the village of Herbertsdale dip at angles up to 20° to the north. On the west bank of the river the deposits are silicious, with pebbles and boulders of quartzite set in a ferruginous sandy matrix that imparts a red colour to the cliffs; but on the road leading north from the village, the conglomerates consist almost entirely of muffin-shaped pebbles of Bokkeveld shale in a greenish argillaceous matrix". If the provenance of a part of these deposits also lay to the north, it would seem that a certain significance could be attached to the above description, as the area immediately to the north is composed almost entirely of arenaceous material which is not reflected to the extent one would expect. If, however, the Gouritz Poort was in existence at this time, or the provenance was entirely from the south and west, then the presence of the shale pebbles and the argillaceous matrix could more easily be accounted for. However, with the lack of detail and the possibility that the material was derived from other parts of the basin rim, the writer feels that no positive evidence can be gained from the above, but considers that the lithology does not contradict the postulate that the poort existed during this period.

Evidence from the Cretaceous deposits north of the Langeberg is confined to the Oudtshoorn basin and to the area around the town of Touws River. This latter area reflects a surface which must have existed during that time. The former area presumably had an eastward slope which was basined by compressive cross-folding in the east disintegrating the drainage (see du Preez, 1944). No evidence is led by du Preez to postulate a similar compressive cross-folding in the west and thus the axis shown on his map, running north-south through Zandberg and Rooiberg, must rather represent a monoclinal axis, to the east of which faulting reached a maximum, deepening the already existing trough. Thus no dismemberment of the river systems is indicated in this region by this "cross-folding", and the river which occupied the valley to the west may have continued to flow into the Oudtshoorn basin. There appears to be no evidence of this either from the deposits in the basin or relic surfaces, and thus the river, in all probability, flowed through the Langeberg.

The Gouritz Poort is definitely not a superimposed river-poort, as Taljaard has pointed out (1948, p. 13). His reasoning is that the only possible surfaces from which it could be superimposed, after the folding of the Cape and Karroo Systems, are the Cretaceous and the "Jura" surfaces. The former, we know, never covered the area, as the deposits were laid down in disconnected "sag-and-fault basins", while the Triassic lavas preserved in the Suurberg area show that erosion had already begun to etch out valleys before the "Jura" surface was developed. The origin of the poort can thus be best postulated as being analogous to the many others in the area, i.e. as a subsequent poort of late-Cretaceous age.

Well established drainage lines must have existed in a region of mature valley sculpture during the formation of the higher surface to the north of Gouritz Poort, as from both the Slang River area to the east (1,800 feet) and from Sandkraal (1,500 feet), Brand River (1,950 feet) and Lemoenshoek (2,200 feet) in the west, the surface underlying the deposits slopes regionally toward the poort. The fact that "back-slopes" are encountered, and the existence of ridges dividing the groups of remnants, raise the problem of the nature of the surface near the mountain. Two possible explanations readily suggest themselves; that the primary surface was flat and that the "back-slopes" were caused by later movement, or that the original surface was gently undulating while being reduced to a number of local stream levels. The fact that the present divides parallel those existing previously, is not significant; but the fact that ridges did exist near the mountains at least (e.g. Lemoenshoek-Brand River), on either side of which surfaces and deposits formed, suggests that low "watersheds" are the more likely.

Presumably the higher surface was not so well developed in the Barrydale-Montagu area as in other parts, but that some development had taken place is shown by shoulders on the mountain slopes rising to over 3,000 feet in the Montagu area. Remnants to the south of Anysberg and the country around Groot Vlakte beacon show that the higher surface was formed at about 2,500 feet and the lower surface a few hundred feet below this. The relatively flat country around Touws River town which existed earlier must also be considered as having been lowered to its present height (2,600 to 2,700 feet) by the rivers during the formation of the higher surface. Little subsequent incision has taken place from this surface.

Before discussing the age of the Buffels River Poort, one statement must be stressed: it is only in a region of mature valley sculpture, with suitable gradients, that the formation and preservation of stream-cut benches, and of river-lain gravels on the benches, can take place. Neither in youth nor in old age can such a feature be formed and preserved.

The fact that neither benches nor gravels, corresponding to the higher surface, could be found in the region between the Klein Swartberg and the Witteberg, and that today the region shows many features of youth, strongly suggests that during the earlier period it was in a youthful stage of development. Remnants of the lower surface are found near the Buffels River at a height of about 2,000 feet, which can be correlated with the larger terraces to the south of Laingsburg on the northern flank of the Witteberg (2,500 feet). As has been stated earlier, this intermontane area is more suitable for the preservation of any remnants had they been formed, than the area to the south of the Klein Swartberg where they are preserved.

It seems from the above, therefore, that breaching of the mountain took place between the two periods during which surfaces were formed. Further confirmation of this may be gained from an examination of the cross-section of the poort. The lower 300 to 400 feet of the walls are almost vertical and above this point, which corresponds to that of the lower surface to the south of the poort, the slope of the walls decreases sharply. A further decrease in slope at a height comparable with that of the higher surface, such as is displayed by the section of Gouritz Poort, is not apparent. With regard to the course of the river within the mountain, which resembles that of a meander flowing over flat ground, it must be considered as an anomaly. A result of accepting the date above is that the poort must be subsequent. The direction of the tributaries, which are presumably strongly controlled by the structure of the rocks, is parallel to those of the main stream. The turns in the centre of the mountain display slip-off and under-cut slopes at heights near those of the remnants of the lower surface to the south. This phenomenon is significantly situated near the anticlinal axial plane. An explanation of the apparent anomaly may thus lie in its relation to the position of the axial plane, the joint pattern, the resistance of the rocks and the nature of the entrenchment. The latter was presumably slow enough to permit the formation of slip-off slopes in the beginning and must have been followed by rapid incision. This cannot be considered a meander as the structure determines the form. This last incision has produced a number of discordant valleys.

There is no evidence of drainage during the earlier period in the area to the north of the Witteberg (3,000 feet), if this is represented by the highest surface in the area. It is interesting to note that the lowest present-day watershed to the east is situated between 2,500 feet and 2,750 feet (topographical map), just north of the Doekberg: the divide of the Hartebeestspruit and Jakhals River.

The Ladismith region up to and including Amalienstein (3,000 feet) and Vaartwel (3,100 feet) presumably drained to the west, if the higher surface is undisturbed. Seven Week's Poort must have attained considerable development by this time if the evidence of the slopes of the walls at the exit of the poort is to be believed. They are as low as 20° to 30°, below which they steepen abruptly. However, stereoscopic investigation of the upper reaches suggests that the present-day lines were inherited from the upper surface with little modification and there are no gravel remnants. The lower surface is not developed to any extent in this area, but it may be represented by a few shoulders and the tops of the ridges, which have a slight gravel covering. If, as is suggested above, the drainage was originally to the west, capture of the rivers in this area by the Huis River must since have taken place.

The terraces and benches around the north and west of Rooiberg show that the fall was to the west in the north (2,500 feet to 2,000 feet), but the group of terraces on the southern flank must be considered to be the remnants of the lower surface because of their heights (1,404 feet at Vanwyksdorp and 1,100 feet in the east near Jagtberg Poort) and their unconsolidated nature. The same applies to the bench along the left bank of the Gamka River in Jagtberg Poort (approximately 1,200 feet). Of interest is the fact that this bench is only developed along the Gamka River and that the portion occupied by the present Olifants River, above their confluence, shows no equivalent development, save possibly a smooth structural bench 200 feet above that on the other "fork" which dips in an opposite direction to the present river. The regional slope of the shoulders on the southern bank opposite the bench mentioned above, also appears to be to the east. It seems probable, therefore, that the course occupied by the Olifants River between Jagtberg and Gamka Hill, above its confluence with the Gamka River, is of more recent origin, i.e. post-lower surface. The course of the Gamka River between the Rooiberg and Jagtberg-Gamka Hill must be of pre-higher surface age, as is shown by the fact that the surface is well developed both to north and south of the poort.

From the height of the remnant to the north-west of the poort this higher surface must have crossed the range at a height of about 1,600 to 1,700 feet, and the valleyward dips that can be seen, at Kerkrand for example, suggest a more northerly course of the Olifants River. The slope during the beginning of the Cretaceous deposition in this area was eastward and after the cross-folding, centroclinal, thus proving that the Jagtberg (Gamka portion) breaching must have occurred between the late-Cretaceous and the higher surface periods. This may be associated with the cessation of the deposition in the area.

A similar date can be ascribed to Gamka Poort through the Swartberg-Gamkasberg.

All the remaining poorts in the area, namely Prins Poort, Kogmanskloof, Tradouw and Garcia's Pass, suggest that their breachings occurred later than the lower surface, with the possible exception of Kogmanskloof which may have been slightly earlier.

The breaching of Aasvoëlberg, the ridge to the south of the Albertinia-Mossel Bay road, may be considered here, even though it falls outside of the area investigated. The fact that the remnant terraces, covered with consolidated deposits, dip towards the present river must be interpreted to mean that the river afforded a local base level during the formation of the surface, and that it drained through the ridge during this period. The deposits of Enon to both north and south prove that during that time a disintegrated drainage also existed in this area, and thus the breaching must best be regarded as similar in age and origin to that of the Gamka Poort, i.e. a fault scarp stream of post-late-Cretaceous, pre-Eocene age.

Summing up, the writer finds that all the poorts in the Western Little Karroo are presumably of subsequent origin, that is, they developed by headward extension, and that their dates of breaching can be tabulated as follows: (Dates of surfaces, see later).

One result of this dating shows that the deduction of Rogers, that the Buffels River once flowed over Garcia's Pass, falls away because the earliest possible date for such a course must have been during the Cretaceous age, as is shown by the higher surface. At that time the Buffels River did not exist.

Quaternary	Recent		
	Pleistocene		Prins, Garcia's, Tradouws, Jagtberg (Olifants, portion), etc.
Tertiary	Pliocene	Lower Surface	Kogmanskloof?
	Miocene		Buffels
	Oligocene	Higher Surface	
	Eocene		Aasvoëlberg, Gamka and Jagtberg (Gamka, portion).
Cretaceous	Late	Enon deposits	Gouritz.

XI THE SURFACES AND OVERLYING DEPOSITS

Higher Surface usually with consolidated deposits.

The remnants of this surface in the western and north-western parts of the area (Grootvlakte and Touws River), which have no resistant protective covering, have been reworked and lowered subsequent to formation. In the central and eastern parts of the area, however, remnants flank the mountains and the original surface has been preserved under consolidated deposits in a number of places.

This surface, in a valleyward direction, is concave, as has been shown by the measurements in the areas near Lemoenshoek, Long Mesa, Sandkraal, Waaikraal, and north of the Touwsberg. They vary between 300 feet/mile near the mountain, to 50 feet/mile towards the valley. There is little doubt, however, that towards the valley the surface had an even lower gradient comparable with the longitudinal inclination (16 to 20 feet/mile, Lemoenshoek-Gourtiz Poort and 10 feet/mile Oudtshoorn basin).

Near the mountain, tongues of the relatively flat surface extended to the mountain front, divided by watersheds. How far these divides extended valleywards above the average height of the surface cannot be stated with certainty, but they may, as in the case of the Lemoenshoek-Brand River divide, have stretched a matter of miles from the mountain range. The surface towards the valley was thus undulatory in transverse profile, to at least this distance.

The deposits which rest on the remnants of this surface, with the exception of the talus which makes an angle with the surface, have a stratification which is roughly parallel to the surface. The nature of the deposits immediately overlying the surface shows that they are foreign to the underlying rocks and thus must have been transported. The rounding of the larger particles (boulders, pebbles, etc.), and the occasional percussion mark, suggest a fluviatile origin. The thickness of the deposits, where overlain by talus but not including it, varies from 25 to 110 feet, averaging about 55 feet throughout the area. The upward gradation from small, rounded pebbles to larger, less well rounded boulders shows an increase in competency. Above this the sand, with its pebble bands and lenses, suggests a decrease and fluctuation in competency, probably brought about by climatic changes.

All these factors indicate that the surface originated under fluviatile conditions and was reduced to the level of the master stream and the tributaries by processes including lateral planation, weathering, rain wash, rill wash and sheet flood. The deposits represent those of aggrading rivers in a mature stage of development with a pattern similar to those of today and in an area which experienced climatic changes. The talus is regarded as of later date—presumably the result of incision of the streams into and below these deposits.

Consolidation of the deposits by silicious and ferruginous cements occurred under conditions of a fluctuating water table in the subsoil, as has been shown by Frankel and Kent (1937). In a valley containing deposits, the area adjacent to the river will experience little or no change of the ground water table, and thus little cementation. Immediately next to the mountain similar conditions will result, as the movement of water is due to seepage and evaporation and not a fluctuation of the water table. The maximum fluctuation, and thus maximum cementation, will take place near the mountain although a short distance from it. The shape and position of the remnants bear this out: even where they overlie rocks of similar resistance, they are seldom contiguous with the mountain, and show a maximum width some distance from it. Had the cementation been uniform, the opposite effect would have resulted: the maximum width of the remnants would be adjacent to, and contiguous with, the mountain. Another result would have been that the deposits near, and possibly within, the poorts would have been cemented.

The climatic phases postulated above are not out of keeping with the views of other authors (see for example, du Toit, 1939, p. 507). Frankel and Kent (1937) find that in the Grahamstown area "all the original deposits, whether the peneplain is of fluviatile or marine origin, seem to have been removed by unknown agencies, probably aeolian, and the peneplain subsequently weathered for a long period under subaerial conditions, resulting in the formation of incoherent residual deposits" (p. 38). The cementation which then took place in the subsoil, was interrupted on several occasions: "These alternating periods of silification and non-silification are probably ascribed to climatic variation—it has been shown that a seasonal fluctuating water table is essential for the formation of silcretes" (p. 39).

The Lower Surface.

Although this surface was not studied in detail, from the few remnants visited some conclusions can be drawn. The planation of this surface was not as well developed as that of the higher, and the thickness of the unconsolidated gravel mantle seldom exceeds 25 feet. The constituents of the gravel are, as in the case of the higher surface, mainly transported material which have a fluviatile origin, as is shown by the chattermarks. Davis (1906, i, p. 397) wrote of the remnants to the north of the Witteberg as follows: "The reduction of the surface to a plain must have been largely aided by the general wasting down of the minor ridges as well as lateral swinging of the streams. The distribution of the coarse cobbles over the plain seems to have been the work of sheet-floods, such as become peculiarly effective in the later stages of a cycle of erosion, particularly in a region where occasional heavy downpours of rain occur". The writer suggests that the above mode of formation of the surface and the gravels applies to the other parts of the area equally well.

XII AGES OF THE SURFACES

No evidence for accurately fixing dates to either of the surfaces was found in the area under discussion. As they cut across the tilted Enon deposits in the Oudtshoorn basin, they must be at least of post-late-Cretaceous age.

Dates have, however, been ascribed to the higher surface to the south of the Langeberg by various authors, who usually relate it to the Bredasdorp-Alexandria beds, found nearer the coast. Some suggest they were contemporaneous (e.g. du Toit and Haughton) while others consider that the terrestrial deposits were later than (Potgieter), or younger than (Wybergh) the marine. In passing it should be noted that the age of the Bredasdorp-Alexandria beds, on the European time scale, cannot be fixed with any certainty, being found to be similar to the Eocene (Haughton and Chapman) and the Mio-Pliocene (Newton). (See du Toit, 1939, p. 401).

King (1951) has attempted to correlate cycles of erosion related to a base level. This has resulted in surfaces separated by 5,000 feet belonging to the same "cycle" p. 191 and p. 256). Also a surface of erosion overlying a surface of erosion and deposition, is considered as belonging to the same "cycle" (p. 248). These surfaces may have been formed in different geological Periods. With regard to the higher surface in this area he tentatively suggests that it falls in the "African" cycle (p. 311). This was "initiated in the earliest Cretaceous" (map at end). However, this surface "appears between 2,000 feet and 3,000 feet near the sea, and 3,000 to 4,000 feet in the interior" (p. 251) and in the south of this area it lies at about 1,000 feet and, adjacent to Aasvoëlberg at less than 500 feet.

In an attempt to date the surfaces, the writer assumes that the coastal limestone deposits south of Aasvoëlberg are of Mio-Pliocene age, and that the 20-foot marine benches and terrestrial terraces are of Pleistocene age.

Wybergh (1919, p. 51) states: "It would appear, therefore, from the wide distribution of the pebbles and their peculiar mode of occurrence that they were probably already distributed over the surface of the area upon which the Bredasdorp beds were laid down, but were 'worked over' again and incorporated with the latter, receiving at the same time the marine shells which they contain. The pebbles themselves probably date back to a much earlier period".

Basing the argument on the assumption above and Wybergh's conclusions, it would appear that the surface underlying the higher, consolidated deposits extends under the Bredasdorp beds in this area. This must date it as pre-Miocene and, from its attitude to the Enon beds, post-late-Cretaceous, i.e. Eo-Oligocene. The lower surface was thus, in all probability, the result of the incursion of the sea, and thus of Mio-Pliocene age.

XIII NATURE OF THE UPLIFT

During the Tertiary period many parts of the sub-continent experienced differential uplift. Du Toit has indicated the regions of depression and the axes of uplift (1933). Those of the coastal regions are possibly associated with continental sliding and the origin of submarine canyons (1940).

In the Baviaanskloof area, de Villiers (1942, p. 144) has shown the existence of an east-west trending axis of upwarping of post-Eocene age, situated in the Couga Mountains. He suggests that a similar type of uplift occurred in the Kamanassie Valley, but does not suggest any locality.

To the south of the Langeberg, Taljaard (1949, p. 78) has shown the existence of another axis which he has followed from a position south of Swellendam to east of Riversdale. The warping was so intense that a back-slope has been produced in some places.

Evidence from the area to the north of the Langeberge which also suggests warping is fivefold:—

1. The relatively narrow valleys of the Slang River, the Kamma River, the Hell and those between the Touwsberg and the Swartberg, all have a maximum distri-

bution of remnants of the Eo-Oligocene surface to the south of the centre of the valley. They have been completely removed to the north in some cases. A similar condition is displayed by the Mio-Pliocene surface between the Touwsberg and the Swartberg.

2. In the more open valleys, such as that between the Langeberg and the Rooiberg, that between the Warmwatersberg and the Anys-Touwsberg, and the Oudtshoorn Basin, the rivers have a tendency to flow either to the north (first two) or the south (Olifants River) of the centre of the valley. The same may be said of the Slang River, the Groot River (between the Touwsberg and the Swartberg), and other rivers in the area which are situated to the north of the centre of the valleys.

3. The depth of incision, too, may be an indication of the tilting nature of the uplift. In the area to the north of the Langeberg, for example, the incision from the Eocene surface is between 300 and 500 feet, whereas in the region to the south of the Swartberg it is considerably more, varying from 600 to 900 feet. The area around Jagtberg shows incision of about 800 feet from the higher surface. From the lower surface to the present-day rivers there is a variation in the figures obtained from the different parts of the area. Almost everywhere it is about 300 feet, but in the area near Gouritz Poort, the Rooiberg and Jagtberg Poort it is between 500 and 600 feet. When considering these figures it must be remembered that the present rivers have not attained the low gradient possessed by those of the earlier periods.

4. The differences in elevation between the two surfaces, too, suggest that warping has taken place in certain areas. Between the Touwsberg and the Swartberg, for example, the difference in elevation in the south is about 100 feet, while in the north the difference is over 600 feet. It has already been mentioned that near Long Mesa the "lower" surface appears to be above the "higher".

5. The meanders displayed by some of the rivers of the Gouritz River System around Gouritz Poort may be suggestive of unequal uplift.

These points evince that warping has occurred in this area. The exact position of the hinge lines and the date at which they were formed are still vague, but some idea of these may be gained from an examination of the diagrammatical sections of certain of the valleys (Fig. 8). These are based on points 1 and 2 above; they are not drawn to scale.

The section from Touwsberg to the Swartberg (A-B on the map) appears to be very similar to that of the lower portion (up to the Eo-Oligocene surface) of the Baviaanskloof (I-J on the map. From de Villiers, 1938, Fig. 16). It has been suggested by de Villiers (1938, p. 143) that the Baviaanskloof experienced two successive periods of surface formation, each followed by a northward tilting of the area and incision of the rivers. A similar sequence of events may be postulated here. The variation in the difference in elevation between the higher and lower surfaces (point 4 above) may be explained by the movement of the local erosion base and possibly also by the breaching of Buffels River Poort.

The valleys of the Hell, Slang River and Kamma River (sections C-D) suggest that they too were tilted at some period after the formation of the Eo-Oligocene surface. The lower surface was not studied in these areas.

From the positions of the areas described above it seems reasonable to suggest that if one axis of uplift is postulated, it lies to the south of the Langeberg. This, however, is contradicted by the amount of subsequent incision, for where the greater uplift occurs, i.e. in the southern parts, the greater incision must result, provided the rivers have similar gradients. The remnants against the northern flank of the Langeberg, for example, are some 10 miles nearer the common erosion base than those

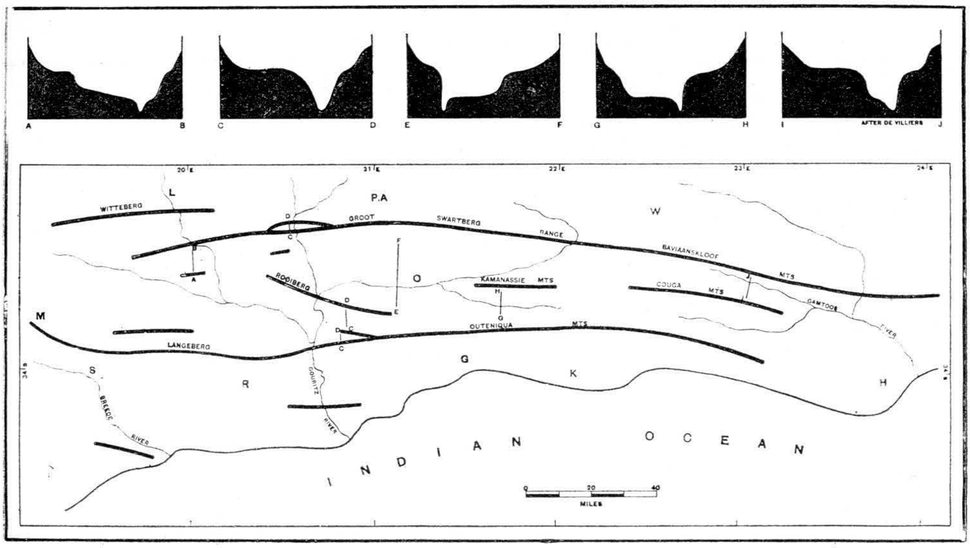


Figure 8

Diagrammatic Valley Sections.

G = George. H = Humansdorp. K = Knysna. L = Laingsburg. M = Montagu. O = Oudtshoorn. P. A = Prins Albert. R = Riversdale. S = Swellendam. W = Willowmore.

against the southern flank of the Swartberg. The total incision from the higher surface, however, is greater in the north than in the south: against the Langeberg it is 870 feet (Gouritz Poort), approximately 400 feet (Long Mesa), against Rooiberg about 800 feet (Jagtberg Poort), to the north of the Touwsberg about 650 feet and to the south of the Swartberg 800 to 900 feet. [The corresponding figures for the lower surface are 512 feet (Gouritz Poort), 400 feet (Long Mesa), 600 feet (Vanwyksdorp), 350 feet (Touwsberg) and 300 feet (Voorbaat)].

It seems likely, therefore, that at least two separate warpings have occurred (post-Eo-Oligocene surface and post-Mio-Pliocene surface). Presumably they did not have the same axis. The amount of uplift along each axis may have been differential.

The key to the problem seems to lie in the Kamanassie Valley. In this area de Villiers (1936) found that the higher surface has a maximum distribution on the northern side and the lower surface on the southern side of the river (see section G-H, Fig. 8). This would suggest that uplift after the formation of the higher surface resulted in a southerly migration of the river, while the movement succeeding the lower surface caused the rivers to migrate in the opposite direction, that is, northwards.

A possible explanation of the movements in the area to the west of the Kamanassie Valley, may be as follows: After the formation of the Eo-Oligocene surface, warping occurred. This warping was an extension of, although not necessarily continuous with, the line of warping which affected the Baviaanskloof and Kamanassie areas. In these areas the rivers were caused to migrate to north and south respectively, removing the deposits in those directions. This hinge-line in all probability caused the

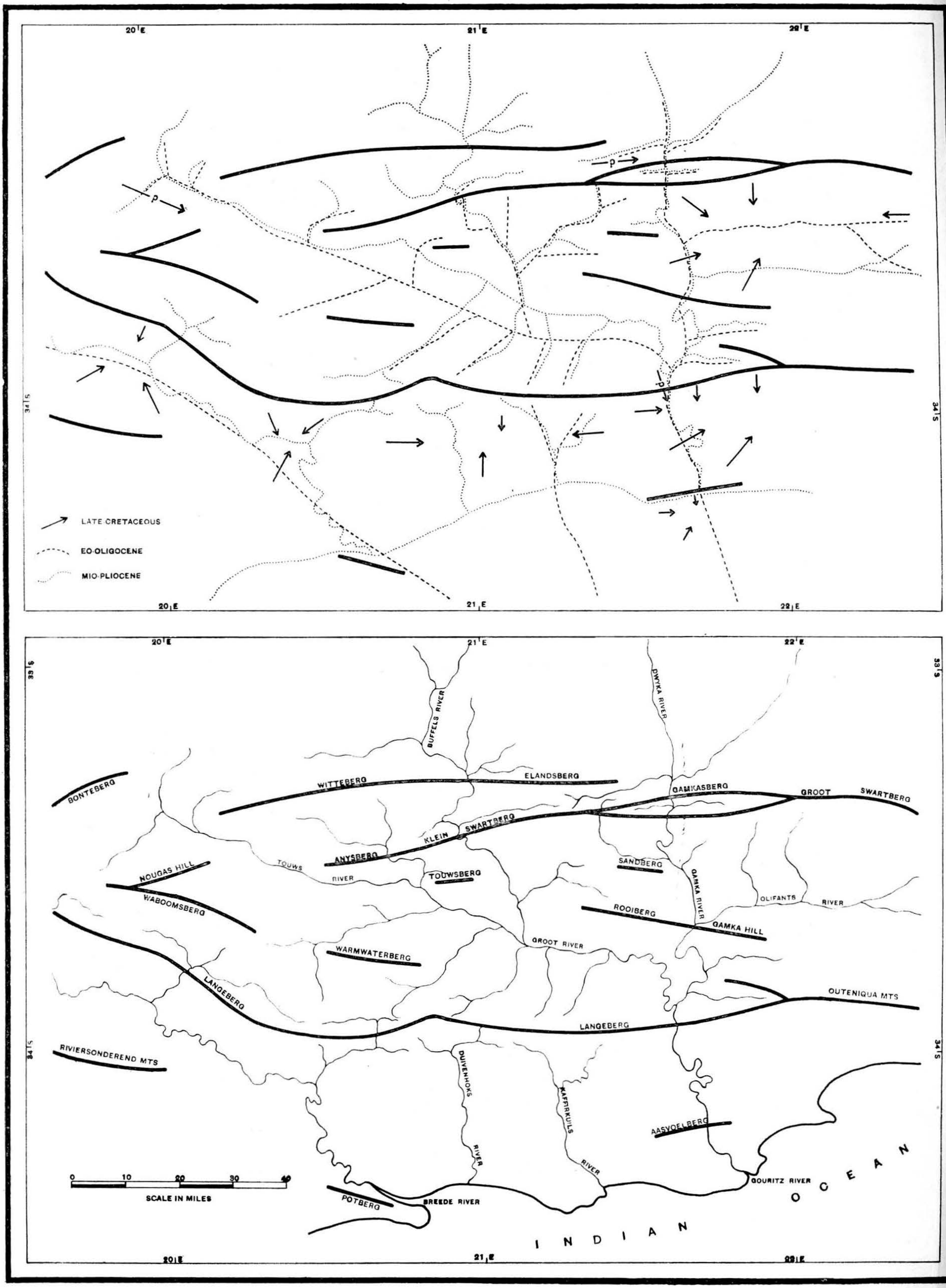


Figure 9

Above: Drainage Development. (Late-Cretaceous to Mio-Pliocene)
Below: Presentday Drainage.

Olifants River to migrate southwards in the Oudtshoorn basin and the Groot River to migrate northwards in the area north of Touwsberg, again removing the gravels in those directions. The area to the south remained relatively unaffected by these movements; they were in all probability elevated reasonably evenly. The second (post-Mio-Pliocene) tilting presumably then caused the Groot-Touws and Kamanassie Rivers to migrate to the north. The Slang and Kamma Rivers which had remained virtually unaffected as regards position by the first movement, then moved northward. This second axis must lie to the south of the Langeberg and may have coincided with that traced to the south of the towns of Swellendam and Riversdale. Another result of this later warping was the formation of the meanders displayed by the rivers for some 30 miles north of the warping axis. They were subsequently entrenched to approximately their present position. The Gouritz River shows abnormally large entrenched meanders north of an extrapolation of the warp axis, and to the south a remarkably straight course.

Another point which may be noted is that the rivers to the north of the Swartberg have been relatively unaffected by the tilting in the Buffels River Basin, while a number of the subsequent tributaries of the Gamka Basin have asymmetrical valleys.

The Olifants River has remained near the southern range. This may be due to the nature and attitude of the Enon deposits over which it flows.

XIV THE DRAINAGE EVOLUTION OF THE GOURITZ RIVER SYSTEM

(*Based on du Toit* (1939), *du Preez* (1944), *de Villiers* (1942), *Taljaard* (1949) *and the present paper.*)

The birth of the major drainage lines in the Southern Cape Fold Belt occurred at the beginning of the Mesozoic Era. Very little is known of the direction of the drainage before this time, but it was, in all probability, northwards from this area. Even though the evidence from the time of inauguration is very sketchy, there seems to be little doubt that an east-west trending drainage existed prior to the Triassic Period. This is suggested by the attitude of the "Suurberg lavas" in the Uitenhage area, which rest in an eroded, structural valley. It is very doubtful whether the surface attributed to the late-Jurassic Period has any relics in this area, and thus it may be presumed that it did not obliterate the strike ridges of the folded formations.

Before the late-Cretaceous Period these valleys had been excavated, so that in the intermontane valleys, such as the Oudtshoorn area, a high relief must have existed. At about this time a regional, differential, small scale submergence of the continent occurred and the sea-board moved south-westwards. In the interior this movement consisted of a basining of the valleys. This was accomplished by sagging and cross-folding, followed by normal faulting. In these centroclinal, structural and tectonic basins deposits began to accumulate. Certain parts of the surface which existed at this time were thus buried, while the remainder were eroded. Today reflections of this latter part of the surface can be seen around Touws River town, on the Klein Swartberg, and on the northern flank of the Swartberg to the west of Gamka Poort. The climate suggested by the nature of the deposits must have been similar to that of the Oudtshoorn area, namely semi-arid. The drainage at this time was thus disintegrated, flowing into various basins, and there is a possibility that Gouritz Poort came into being at about this time. (See Fig. 9 for drainage lines). (Du Toit has suggested that the separation of originally continuous deposits occurred. The above sequence of events, as suggested by du Preez, seems to be more likely.) The sea-shore at this time must have been somewhere to the south and east in the present Indian Ocean.

Uplift, presumably of a differential nature, then followed, elevating the marine deposits, and causing a change in the position of the sea-board. At this time, possibly associated with the movement, basaltic magma was injected into the crust (melilite basalt and kimberlite). The increase in the erosive power that the rivers experienced as a result of the uplift, may have been the reason for the breachings of Aasvoëlberg, Rooiberg-Gamka Hills and the Swartberg which occurred at this time. The major rivers and tributaries reduced their gradients considerably, until a mature stage of valley development was attained in the area. A possible scheme of the drainage lines can be seen on the accompanying map. On the flood-plains of these streams, deposits accumulated to considerable depths. These deposits reflect climatic conditions very similar to those of the earlier period of deposition, namely a predominantly semi-arid climate with phase variations. It is possible that at least two of the later phases were such that a seasonally fluctuating ground-water table was produced. Under these conditions colloidal silica and iron oxides were leached from the underlying formations and cemented the overlying deposits.

Uplift along an axis then occurred which in this area is shown by the nature and relationship of the remnants of the surfaces in the area between Touwsberg and the Swartberg. The river in this area, the Groot, most probably succeeded in breaching the mountains to the north and formed Buffels River and Leeukloof Poorts at this time.

At the same time the sea advanced as far as Aasvoëlberg. It reworked the river deposits and then covered them with a considerable thickness of shelly limestone deposits. These are suggested as being of Mio-Pliocene age. (The fact that the underlying gravels show no signs of cementation and that no pebbles of silcrete have been found in the flood deposits in the marine beds, suggests that the cementation had not taken place by this time.)

In the hinterland the Eo-Oligocene Epoch surface became dissected and scree began to accumulate on many parts of the surface which was not kept cleared by the streams. To this new base-level the rivers cut a new surface which carried a thin mantle of gravels. The drainage lines at this time can be seen on the accompanying map.

Once again uplift occurred, again of a warping nature. To the north of the axis the rivers were dammed up and forced to meander, or if they already possessed meanders, these were enlarged. To the south, as a result of the increased gradient, they tended to straighten their courses. As the strand line had moved further south by this time, the rivers were extended in consequent manner over this newly-formed surface. Doubtless as a result of the uplift and subsequent increase in erosive power, certain rivers breached the Langeberg (Tradouws and Garcia's Passes.) The breachings at Kogmanskloof and Prins Poort may have occurred at about this period, but the occasional gravel in their drainage basins to the north of the mountains suggests a slightly earlier date. The drainage lines thus became very similar to those seen today (see Fig. 9).

XV BIBLIOGRAPHY

Davis, W. M., 1906 i. Observations in South Africa. Bull. geol. Soc. Amer., Vol. 17.

Davis, W. M., 1906 ii. The Mountains of Southernmost Africa. Bull. geogr. Soc. Amer., Vol. 30.

De Villiers, J., 1938. The Geology and Morphology of Portion of the Long Kloof and Kamanassie Valley. Abstract Trans. geol. Soc. S. Afr., Vol. 41.

De Villiers, J., 1942. The Geology of the Baviaans Kloof and Surrounding Area. Trans. geol. Soc. S. Afr. (Abstract). Vol. 44. A Review of the Cape Orogeny. Ann. Univ. Stellenbosch. Vol. 22. (1944.)

Du Preez, J. W., 1944. Lithology, Structure and Mode of Deposition of the Cretaceous Deposits in the Oudtshoorn Area. Ann. Univ. Stellenbosch. Vol. 22.

Du Toit, A. L., 1933. Crustal Movement as a factor in the Geographical Evolution of South Africa. S. Afr. geogr. J. Vol. 16.

Du Toit, A. L., 1939. Geology of South Africa. Oliver and Boyd, Edinburgh.

Du Toit, A. L., 1940. An Hypothesis of Submarine Canyons. Geol. Mag. Lond. Vol. 77.

Frankel, J. J. and Kent, L. E., 1937. The Grahamstown Surface Quartzites (Silcretes). Trans. geol. Soc. S. Afr. Vol. 40.

Haughton, S. H., 1925. The Tertiary Deposits of the South East Districts of the Cape Province. Trans. geol. Soc. S. Afr. Vol. 28.

Haughton, S. H., 1928. The Geology of the Country between Grahamstown and Port Elizabeth. Explanation Cape Sheet 9.

Haughton, S. H., 1935. The Geology of Portion of the Country East of Steytlerville. Explanation of Sheet 150.

Haughton, S. H., Frommurze, H. F. and Visser, D. J. L., 1937. i. The Geology of the Country around Mossel Bay, C.P. Explanation Sheet 201. ii. The Geology of Portion of the Coastal Belt near the Gamtoos Valley, C.P. Explanation Sheet 151.

Johnson, D., 1944. Problems of Terrace Correlation. Bull. geol. Soc. Amer. Vol. 55.

King, L. C., 1942. South African Scenery. A Textbook of Geomorphology.

King, L. C., 1951. South African Scenery. A Textbook of Geomorphology. Second Edition. (Revised.) Oliver and Boyd, Edinburgh.

Mahard, R. H., 1942. The Origin and Significance of Entrenched Meanders. J. Geomorph. Vol. 5.

Maske, S., 1951. A Review of Superimposed and Antecedent Rivers in Southern Africa. Ann Univ. Stellenbosch, Vol. 33, Sect. A, 1957.

Potgieter, C. T., 1950. The Structure and Petrology of the George Granite Plutons and Invaded Pre-Cape Sedimentary Rocks. Ann. Univ. Stellenbosch. Vol. 26.

Rogers, A. W., 1903. The Geological History of the Gouritz River System. Trans. S. Afr. phil. Soc. Vol. 14.

Rogers, A. W., 1925. The Geology of the Country near Laingsburg. Explanation Cape Sheet 5.

Schwartz, E. H. L., 1904. The High Level Gravels of the Cape and the Problem of the Karroo Gold. Trans. S. Afr. phil. Soc. Vol. 15.

Strydom, H. C., 1950. The Geology and Chemistry of the Laingsburg Phosphorite. Ann. Univ. Stellenbosch. Vol. 26.

Taljaard, M. S., 1948. On some Concepts in Geomorphology. S. Afr. geogr. J. Vol. 31.

Taljaard, M. S., 1949. A Glimpse of South Africa. University Publishers, Stellenbosch.

Von Engelen, O. D., 1942. Geomorphology. Macmillan, New York.

Wybergh, W., 1919. The Coastal Limestones of the Cape Province. Trans. geol. Soc. S. Afr. Vol. 27.