

UNION OF SOUTH AFRICA.

DEPARTMENT OF MINES AND INDUSTRIES ·

GEOLOGICAL SURVEY

THE GEOLOGY

OF THE

NORTH-EASTERN PART OF THE SPRINGBOK FLATS AND SURROUNDING COUNTRY

An Explanation of Sheet 17 (Springbok Flats)

ΒY

PERCY A. WAGNER, D.Sc., D.Eng., F.G.S.

WITH AN INTRODUCTION BY A. W. ROGERS, D.Sc., F.R.S. (Director)

Printed by authority of the Honourable the Minister of Mines and Industries

Price: Two Shillings and Sixpence (2|6) [COPYRIGHT]

PRETORIA

THE GOVERNMENT PRINTING AND STATIONERY OFFICE



- 7 ACT 07

The Geology of the North-Eastern Part of the Springbok Flats and Surrounding Country.

I.—THE AREA AND THE SPRINGBOK FLATS.

The area represented by Sheet No. 17 embraces the north-eastern, north-western, southern, and south-eastern portions respectively of the Pretoria, Middelburg, Potgietersrust, and Waterberg Districts of the Transvaal, while the southern corner of the Pietersburg District just enters it. The greater part belongs to the Potgietersrust and Waterberg Districts.

It is drained by the Olifants and Nyl Rivers and a number of their tributaries.

The village of Naboomspruit, the only considerable centre of European population, is situated near its eastern margin on the Pretoria-Pietersburg railway, which traverses the area from north to south. The Mutue-Fides Tin Mine, situated in its east-central portion, has for nearly ten years been an important source of that metal.

The area takes in the whole of the north-eastern part of the Springbok Flats. The Sheet thus completes the map of that remarkable geographical region which may here be reviewed in its entirety in order to remove some misapprehensions that are prevalent about it. It is represented in Fig. 1, which is a geological sketch map prepared by the writer for Mr. E. E. Galpin's botanical survey memoir on the Springbok Flats. This shows that the tract of country, popularly known as the Flats, marks the position of a tectonic basin filled with sedimentary and igneous rocks of the Karroo System, which, as a result of folding and denudation, has been broken up into two minor basins of practically the same size. The main basin, which occupies the central part of the Bushveld Basin, is of irregular oval outline and some fifty miles in greatest length, its longer axis trending north-east south-west. The two minor basins are also of irregular oval outline and rather similar in shape. Their longer axes trend east-north-east to west-south-west. They are occupied by basaltic lavas belonging to the Stormberg Series underlain by Bushveld Sandstone. The latter also forms a broad belt separating them, being disposed here in the form of a low anticline.



Fig. 1.

The Stormberg volcanics, identical with those which in Natal and Basutoland build the stupendous escarpments of the Drakensberg and Maluti Mountains, have been reduced in the area under review to fairly level plains. The lava plains, for the most part covered with a thick mantle of soil, constitute the Flats proper. Those marking the position of the northern minor basin are known as the Northern Flats, and those marking the position of the southern basin as the Southern Flats. The intervening sandstone gives rise to a broad swelling comparatively elevated sandy belt known as the Central Sand Bult. Similar sandy bults mark the position of the outcrops of the Bushveld Sandstone along the southern and eastern margins of the Flats. Here the Bushveld Sandstone is underlain by mudstones also belonging to the upper division of the Stormberg Series, and these in turn are unconformably underlain by the shales, coal measures, and grits of the Ecca Series of the Karroo System.

The Karroo beds rest on an uneven floor composed of older rocks belonging to the Transvaal and Waterberg Systems and the Igneous Complex of the Bushveld. These rocks rim the main basin of the Springbok Flats and in places project, island-like, from the younger Karroo beds. It will be noted that they occupy very considerable areas of the north-western and eastern portions of the map. That in its north-western portion includes the hilly country east and southeast of Nylstroom, itself situated about six miles west of its western margin, and farther north part of the lesser plateau encircling the main Waterberg Plateau and forming part of the eastern rim of the main Waterberg basin.

The tract of pre-Karroo rocks taking in the whole of the eastern part of the area embraced by the present description includes the comparatively low-lying granite country occupying the valley of the Olifants River and bordering it, the plateau and hill country occupied by the Rooiberg beds north-west of the confluence of the Olifants and Elands Rivers, and the area occupied by rocks belonging to the Transvaal System in the south-eastern corner of the map.

II.—PHYSICAL FEATURES AND GEOLOGICAL STRUCTURE.

The area presents a great diversity of physical feature, and, there being throughout a very close relation between physiography and geology, it may for convenience in description be sub-divided on a geological basis into the following more or less clearly defined natural regions :---

- (I) The tract of pre-Karroo rocks in its north-western portion.
- (2) The tracts occupied by Bushveld Granite and allied rocks in its eastern and south-eastern portions.
- (3) The tract occupied by the Rooiberg beds and associated igneous rocks.
- (4) The tract occupied by the Dolomite and Pretoria Series in its south-eastern corner.
- (5) The tract occupied by Ecca and Stormberg beds south and east of the Springbok Flats.
- (6) The Springbok Flats.

It will be noted from the map that over the greater part of the area the dominant structural and physiographic trend or grain is east-north-east west-south-west. In its western portion a number of younger north-east south-west trend lines have been superimposed on this grain. In the south-eastern and extreme eastern portion of the map the grain is north-north-east south-south-west.

The most elevated portion of the area is situated along its eastern margin in the tract of pre-Karroo rocks above referred to, the altitude at at least two points exceeding 4,900 feet above sea-level. This elevated country, as will be shown later, descends more or less abruptly to the level of the Springbok Flats. These range in altitude from 3,650 to 3,350 feet and slope south-eastward and eastward to the valleys of the Elands and Olifants Rivers. The latter includes the lowest lying part of the area, the level of the bed of the river where it crosses the eastern margin of the map on Rietvallei No. 534 being about 2,700 feet above sea-level. The extreme range in altitude is thus roughly 2,200 feet. Further particulars in regard to the levels of different parts of the area will be found on the map and in the following pages.

The mean annual rainfall over the western half of the area is 25 inches. For the eastern half no records are available, but here the rainfall appears to be considerably lower.

We proceed to describe the several natural divisions.

1. The Tract of pre-Karroo Rocks in the North-western Portion of the Country mapped.

The greater portion of this comparatively elevated tract has been described in detail by Mellor.* It takes in part of the eastern margin of the main Waterberg basin and the eastern portion of the subsidiary basin by which this is bordered on the south-east.

* Report Geol. Survey of the Transvaal, 1908, p. 27, and 1909, p. 41.

Structurally the tract is remarkable for the degree of folding shown by the Waterberg sedimentaries and the underlying felsites. Its southern portion includes, as previously stated, the hilly area east and south-east of Nylstroom which projects like a peninsula into the low country of the Springbok Flats. It marks the position of the eastern end of the Nylstroom Syncline, a broad synclinal basin occupied by rocks belonging to the Waterberg System. The main part of the syncline has an east and west axis, but in the portion included in the present map the axis trends east-north-east west-south-west. The dips along the northern and southern limbs of the syncline are variable. Near the western margin of the map they are steep, the inclination of the strata being frequently as high as 70 degrees. Farther east they are much lower. The easternmost exposure of the Waterberg beds belonging to the syncline is on Nyls Vly No. 1738, about two miles west of the Nyl.

The Waterberg sediments give rise at the surface to a number of low east-north-east west-south-west trending ridges, increasing steadily in altitude toward the west, where they merge into the elevated country north and south of Nylstroom. From afar these ridges show smooth rounded outlines, but close at hand they present a rough appearance, and during the winter months a characteristic brownish-purple colour. They are sparsely but uniformly covered with small trees and scrub. The two main ridges are separated by the broad flat-bottomed sandy valley of the Nyl, from which there stands out in **bold** relief southsouth-west of Middelfontein Station the remarkable isolated eminence known as Kranskop. This is built of massively bedded Waterberg sandstone and grits lying practically horizontally on the axis of the Nylstroom Syncline, to which fact it clearly owes its preservation and prominence. Its frowning scarped crest, about 1,000 yards in length, with an elevation of nearly 800 feet above the valley at its feet, is one of the most conspicuous landmarks of the entire area.

It is of interest to record that Kranskop bears the sinister but at the same time picturesque native name of *Modimohle*, literally "God has eaten," the precipices on its eastern and western sides having been the scene, prior to the advent of the white man, of numerous propitiatory human offerings by the chiefs of this part of the Waterberg District.

South of the hilly tract with which we have been dealing is an extensive area of flat country deeply covered with sand. This is underlain by Waterberg and Bushveld Sandstone and felsite. Patches of felsite project from it in the north-eastern corner of Middelplaats No. 596 and on the boundary between that farm and Maroelesfontein No. 1130.

Felsite and Waterberg Sandstone conglomerate also make their appearance in a conspicuous faulted ridge extending in a north-east south-west direction across the farms Leeuwdoorns No. 1182, Syferfontein No. 1133, Haakdoornpoort No. 1139, and Varkenskuil No. 978. The ridge is bounded on the east by a powerful dislocation along which the felsite and Waterberg sediments have been faulted against Bushveld Amygdaloid and Sandstone. The fault is one of the series of north-eastward trending normal faults of post-Karroo age, traversing the south-eastern part of the Waterberg District, and cutting across the older east-north-east west-south-west structure lines of that area. They all have downthrows toward the south-east.

On Mooifontein No. 883 and Roosterlaagte No. 889, an isolated outlier of Waterberg sandstone and conglomerate projects from the main belt of the Bushveld Sandstone, to be presently referred to, in the form of a low ridge with smooth rounded outlines. The Waterberg sedimentaries are much disturbed, the dip, which is to the south, ranging from 20 degrees to 48 degrees.

The Nylstroom Syncline is succeeded on the north by the broad westward-pitching Zwagershoek Anticline, only a small portion of which, however, enters the present area. It is occupied mainly by felsite, but on Doornhoek No. 896, situated in the north-western corner of the map, Red Bushveld Granite appears from below the felsite along the axis of the anticline and occupies portions of the farms Eerste Geluk No. 378, Nooitgedacht No. 1117, Vischgat No. 1091, and Buffelskloof No. 704. The felsite builds lofty ridges and plateaux along the eastern margin of the map, these constituting, as already indicated, the most elevated portion of the entire area. The highest points actually are the hill superimposed on the felsite plateau west of the main Nylstroom-Naboomspruit road in the eastern part of Groenfontein No. 309 and the prominence, situated near the middle of the north-eastern boundary of Naauwpoort No. 798, and carrying a conspicuous beacon. Both attain an elevation of over 4,900 feet above sea-level. From this elevated area the outcrop of the southern rim of the anticline falls gradually to the level of the Springbok Flats, on the margin of which it is crossed by the railway on Boekenhout-fontein No. 805. The felsite ridges and bults, as elsewhere, present smooth and rounded outlines, but the apparently smooth slopes are always covered uniformly with angular sharp-edged fragments of the rock which render them difficult and laborious to traverse.

A characteristic feature of the eastern part of the felsite tract are the remarkably deep steep-sided cañon-like kloofs cut by the streams flowing south-eastward toward the Nyl. A very fine example is to be seen in the central part of Naauwpoort No. 798. It is incised to a depth of over 250 feet below the surrounding surface.

The felsite country is well grassed, but in contradistinction to that occupied by the Waterberg beds, largely devoid of trees and bush. This applies particularly to the elevated plateau tract along the western margin of the map which has been aptly likened by Mellor* to English moorland.

Reference has already been made to the Red Granite appearing from below the felsite on Doornhoek No. 896, Eerste Geluk No. 378, and Nooitgedacht No. 1117. On the two last-named farms and on Rietfontein No. 3 an ancient peneplain cut in the granite is covered by a fairly thick sheet of Bushveld Sandstone. This gives rise to an almost level plateau with an elevation of some 600 feet above the Springbok Flats. The plateau is covered with deep yellow sand, from which the Bushveld Sandstone occasionally rises in the peculiar

* Report Geol. Survey of the Transvaal, 1909, p. 44.

whale-backed surfaces and piled up kopjes so characteristic of this formation. Small detached portions of the sandstone plateau form the conspicuous flat-topped hills west of the railway at Naboomspruit.

Toward the east this plateau tract drops rapidly to the level of the Springbok Flats, which are bordered on Buffelskloof No. 704 and Nooitgedacht No. 1117 by precipitous granite and sandstone escarpments. The rapid drop is due to an exceptionally clearly defined fault with a maximum throw of about 400 feet and striking northeast south-west, which has brought the Bushveld Sandstone into juxtaposition with Red Granite on the farms named. The fault does not coincide with the edge of the escarpments above referred to, but lies a short distance east of them, the original fault scarp having been eaten back by erosion.

The position of the fault is, however, marked on Vlakfontein No. 1106 by a line of low bush-clad kopjes built of a hard quartzitic phase of the Bushveld Sandstone. This owes its origin to the silicification of that rock by solutions that welled up along the fault. The latter and the minor dislocations by which it is paralleled are occupied by veins of white cherty quartz. The main fault splits up on Vlakfontein No. 1106, Nooitgedacht No. 1117, and Vischgat No. 1091 into two branches, between which is situated on the last-named farm the isolated sandstone-capped hill known as Loskop. The two branches reunite on Vischgat, but in the central part of that farm the fault again bifurcates, sending off a branch toward the southeast. A hot spring issues on Vischgat along the northern branch.

2. The Areas occupied by Bushveld Granite and Allied Rocks.

The Granite Country bordering the Olifants River.—The Olifants River flows in a broad open valley across the eastern part of the mapped area in a general north-north-east south-south-west direction. The river is, as a rule, bordered by steep silt terraces from 25 to 30 feet in height, dotted over with magnificent shady camel-thorn trees, many of them clearly of great antiquity. These terraces are bordered in places by higher gravel terraces. The granite country along the river is somewhat variable in character.

That lying *east* of the river in the northern part or the area has been described by A. L. Hall*. He states that it has an average elevation of about 3,000 feet above sea-level and exhibits the familiar characteristics of a granite tract long exposed to denudation under sub-tropical conditions. It consists of great monotonous stretches of sandy veld dotted with kopjes and ridges built of big spheroidal masses of "ball-granite" carrying a luxuriant bushy vegetation of which the elegant *Euphorbia candelabra* is a constant feature.

The same type of flat granite country with isolated rugged kopjes is developed east of the river in the south-eastern corner of the map.

In between is a very rough hilly tract with innumerable picturesque kopjes of every conceivable shape. This is typically developed on Vlakspruit No. 360, Lola Montes No. 387, Mooihoek No. 403, Roodekopje No. 404, Rietvlei No. 413, and Welgelegen No. 186. Just east

* Report Geol. Survey of the Transvaal, 1909, p. 367.

of the river in the southern part of Hindustan No. 362, a hill built of greyish granite veined by granite-porphyry stands out prominently from the surrounding flat country.

The northern part of the granite country west of the Olifants is, like that across the river, flat and featureless. South, however, of Latitude $24^{\circ} 40'$ it becomes more rugged and is made up of low wooded ridges with a prevalent east and west trend, alternating with flatbottomed depressions.

The granophyre overlying the granite to the north of the Makeckaan Plateau gives rise to similar country, the east and west ridges becoming progressively higher as one proceeds southward. Toward the east and north-east the ridges die out and the granitegranophyre tract merges imperceptibly into the flat country occupied by the Ecca beds along the borders of the Springbok Flats.

East of the Makeckaan Plateau and separating it from the Olifants is a tract of flat granite country broken on Schuinsdraai No. 424 by groups of picturesque hills.

The Granite Country bordering the Elands River and lying West of it.—This is in the form of an irregular elongated belt occupying part of the Elands River Valley on the farms Kwaggafontein No. 531, Rietfontein No. 394, Uyskraal No. 228, and Elandsdrift No. 483, and thence extending westward and south-westward through Dronkiontein No. 734, Claremont No. 543, Rhenosterfontein No. 885, Spoedwell No. 358, Bultfontein No. 511, Makeepsvlei No. 1134, and Zamenkomst No. 1218 to Witfontein No 350, on the southern margin of the map. In the Elands River Valley where it borders on the north and north-west an area occupied by soda-syenite and allied rocks, and on Claremont No. 543 and Dronkfontein No. 734, it gives rise to monotonous flat country with occasional hummocky and whaleback-shaped outcrops. Much of it is covered with impenetrable thorn-scrub (*Acacia detinens*). This is establishing itself, thereby affording a natural sanctuary to the surviving remnants of the great herds of game that at one time occupied this part of the Transvaal.

The granite encloses numerous detached masses of quartzite and shale belonging to the Pretoria Series. These build low ridges or give rise to prominent outcrops standing out above the general level of the surrounding country. The biggest and most conspicuous of the ridges is that in the northern part of Scherp Arabie No. 367, formerly crossed by the main road to Pietersburg in the gap known as Israel's Nek. The western and south-western parts of the granite belt are made up of alternations of wooded bults and broad sandy laagtes. It is quite clear that much of this country has only recently been stripped of its covering of Karroo beds.

3. The Area occupied by the Rooiberg Beds and Associated Igneous Rocks.

This is situated north and north-west of the confluence of the Elands and Olifants Rivers. It is of irregular triangular shape and is deeply embayed on its western side by broad tongues of Coalmeasure grit and sandstone. The area is made up of two distinct portions, namely, (a) a northern plateau tract and (b) a southern hill tract. In the plateau tract the Rooiberg beds are comparatively undisturbed and dip at low angles to the south or south-west. In the hill tract, on the other hand there is abundant evidence of diastrophism, the beds being folded and intricately faulted. This will be apparent from the map and from Fig. 2 which shows a section across the hill tract and the country south-east of it.

(a) The Plateau Tract.—The most important physiographic element of this tract is the Makeckaan Plateau occupying portions of the farm Roodewal No. 532, Tambootieboom No. 677, Stavoren No. 470, Kwarriehoek No. 400, Rooibok No. 387, Palmietfontein No. 393, and Salie Sloot No. 396. It attains its greatest elevation on Rooibok No. 387, where it is capped with a sheet of silicified nodular felsite. The plateau is most clearly defined at its eastern end. It here rises abruptly to a height of nearly 700 feet above the level of the granite flats separating it from the Olifants River. Toward the south the descent is more gentle, the sedimentary and igneous rocks giving rise to extensive dip slopes with an average inclination of about 10 degrees. The northern edge of the plateau is deeply dissected by one of the minor tributaries of the Olifants River, a quartzite hill of rounded outline partly detached from it by this water-course near the northern boundary of Tambootieboom No. 677 forming a conspicuous landmark for many miles around. The plateau is uniformly timbered with trees averaging between 15 and 20 feet in height, from which big isolated morulas stand out in relief. The commonest trees are the rooibos (Combretum holosericeum), the dikbast (Dombeya rotundifolia), and Diplorrhyncus mozambicensis. A feature of the arboreal vegetation is the entire absence of acacias.

Towards the west the plateau tract merges into undulating bush country made up of broad swelling ridges separated by flat-bottomed valleys. It is typically developed in the western part of Palmietfontein No. 393 and on Vlakpan No. 517, Saxonia No. 433, and Ubique No. 431.

On the farms Ameland No. 421, Buitenpost No. 466, Sedan No. 413, and Delftzyl No. 467, situated north-west of the main area occupied by the Rooiberg beds, are further occurrences of these rocks separated from the tract just described by a strip of Coal-measure grits and sandstones. They give rise to exactly the same type of undulating bushveld.

(b) The Hill Tract is situated south and south-west of the plateau tract. The principal topographical feature in it is a bold range of hills with curiously smooth rounded outlines extending in a north-easterly direction from the central part of Rietfontein No. 394 to the northern part of Swartkop No. 475. This bears the native name of Thaba Sot, pronounced Taba Schow, meaning the White Hills. It attains its greatest elevation on Kwaggafontein No. 531 in a small knoll superimposed on the biggest of the hills. This carries the trigonometrical survey beacon "Quaggafontein," $_{3,739}$ feet above sea-level and roughly 1,000 feet above the junction of the Elands and Olifants Rivers. The Thaba Sot hills are throughout uniformly



dotted over with the characteristic vegetation of small trees (Diplorrhyncus mozambicensis) and green bushes.

North-west of these hills on Vlakfontein No. 409 is a conspicuous plateau capped with white quartzite and east of this a flat-topped ridge built of alternations of sedimentary and igneous rocks (Fig. 5). Between the latter and the southern slopes of the Makeckaan Plateau is a scarped ridge, also built of igneous and sedimentary rocks, the crest of which extends in an east-north-east direction along the northern boundary of Riffontein No. 406 into Salie Sloot No. 396. Lower ridges built of quartzite and altered felsite flank the plateau on Kwarriehoek No. 400 and Tambootieboom No. 677.

The geological structure of the hill tract is, as previously indicated, very complicated; faults are numerous and in places there is a veritable fault mosaic. One of the most important faults is that bounding the Thaba Sot range on the north. It can be traced from Vlakfontein No. 409 to Tambootieboom No. 877, being displaced at several points by minor faults. It is a thrust fault along which the White Quartzite of the Rooiberg beds, to be presently referred to, and the rocks associated with it have at several localities been overtilted toward the north-west, evidently by tangential pressure from the south-east. The overtilted White Quartzite gives rise on Riffontein No. 406 to a great wall-like feature which is one of the most conspicuous objects in this part of the hill tract. The quartzite and quartzitic pebbly grits building the Thaba Sot hills are throughout considerably folded. It is practically certain that the Thaba Sot range is also bordered on the south side by a powerful fault. This is nowhere actually exposed, but a number of springs issue along its presumed course.

The area occupied by the Rooiberg beds terminates toward the west in a low ridge of indurated felspathic quartzite on Dronkfontein No. 734, of which the quartzite outlier on Haringbult No. 674 clearly represents the continuation. The quartzite building this ridge strikes almost at right angles to that of the Thaba Sot range at its southwestern extremity, and the dip is to the north-east at 20 degrees. This abrupt change in strike and dip which takes place in the central part of Rietfontein No. 394 is due to the combined influence of a north-eastward pitching anticline in the Rooiberg beds and a fault, with a downthrow toward the south, which intersects the anticline along its axis.

The Rooiberg beds form part of the original roof of the Bushveld Complex, which, in the Makeckaan Plateau, is probably in much the same position as it occupied originally. The granitic and granophyric rocks on which the lowest exposed Rooiberg sediments everywhere rest represent the uppermost portion of the great composite lopolith. The Pretoria Beds and Dolomite exposed south-east of the Thaba Sot hills are part of the metamorphosed floor of the complex. The area under review is thus one of the very few where the original roof and floor of the complex are found in close proximity to one another. Separating the outcrops of the two groups of rocks at the surface are extensive sandy flats, in part occupied by Coal-measure grit. The flats, like the granite country to the west, are densly covered

with thorn-scrub, on which Acacia detinens is the outstanding feature. Very fine examples of Boscia rehmanniana, some of them of great size and obviously of great antiquity, are also much in evidence.

Quartz Veins.—In the eastern part of the area occupied by the Rooiberg beds and the granite country north and north-east of it, the outcrops of great veins of white quartz are at many localities conspicuous features of the landscape. Their strike ranges from north and south to north-east south-west. The biggest of the veins, which is up to 150 yards in thickness, can be traced for a distance of twelve miles in a general south-south-westerly direction from Van der Merwe's Kraal No. 533 across Krokodelkop No. 395, Elandskraal No. 407, and Roodewal No. 532. Near the southern boundary of the last named the strike changes abruptly to north and south, and in the northern part of Tambootieboom No. 877 it joins up with a great north-north-eastward trending vein which traverses that farm and comes to an end in the north-eastern part of Kwarriehoek No. 400.

The main vein builds a long prominent hog-back known as Krokodelkop, situated on the farm of that name on the west bank of the Crocodile River, and the conspicuous bush-clad ridge on which the eastern beacon of Gaasterland No. 474 stands. The vein is vertical and clearly occupies a fault with a fairly considerable downthrow toward the east. Another very conspicuous vein extends from the southern part of Hinloopen No. 456 across Gaasterland No. 474 and Roodewal No. 532. In the southern part of that farm it splits into two branches, one of which can be followed for over four miles in a general south-westerly direction across the eastern corner of Stavoren No. 470 and thence across Kwarriehoek No. 400. It will be noted that the veins are especially numerous on the eastern part of the Makeckaan Plateau. It is not improbable therefore that the latter owes its prominence to the reinforcement it has received from these highly resistant wall-like bodies of guartz.

4. The Area occupied by the Dolomite and Lower Part of the Pretoria Series.

This embraces portions of the farms Swartkop No. 475, Roodeboschplaat No. 477, Scherp Arabie No. 367, Rooibokkop No. 491, Rondavel No. 86, Marble Hall No. 248, Elandslaagte No. 269, and Uyskraal No. 228, in the south-eastern part of the map. The occurrence of Pretoria Beds and Dolomite here in the heart of the Bushveld Complex is remarkable, and is due to an anticlinal fold which has caused part of the metamorphosed floor of the Complex to protrude from the surrounding Red Granite. The Swartkop-Marble Hall anticline, as it may be termed, strikes north-north-east south-southwest and pitches to the north-north-east. The general relations between the sedimentary rocks involved in it and the Red Granite indicate that the intrusion of the latter and the folding were contemporaneous and thus probably related events.

The greater part of the area occupied by the altered sediments is flat bushveld from which the outcrops of the harder rocks project

as tree-clad ridges. Its outstanding topographical features are two parallel quartzite ranges which extend in a general south by west direction along its eastern margin from Swartkop No. 475 to about six miles beyond the southern limit of the map. The quartzites and altered shales of which they are built form part of the eastern limb of the anticline. Both present fairly steep escarpments to the west and more gentle dip slopes to the east. They are thinly timbered with low trees and scrub. The commonest tree on them is Diplorrhyncus mozambicensis. The more westerly of the ridges, apart from the breach made by the Elands River and a minor gap on the farm Moses Riviersmond No. 134, shows an unbroken crest line throughout its entire length. It has an average elevation of about 300 feet above the flat country along the Olifants River. The eastern ridge is more broken and attains its greatest elevation in Rooibokkop, situated on the farm of that name east of the now abandoned police post. The ridges built by these quartzites along the apex of the anticline are much lower and do not in general rise to a greater height than 30 feet above the level of the surrounding country.

The area underlain by the dolomite and associated marbles is flat and featureless. The several marble quarries opened up on Marble Hall and Scherp Arabie prove, however, that the apparently level surface is karsted and reveal a typical karst topography with numerous dolinas and solution fissures, for the most part filled with reddish-brown and chocolate-coloured soil.

Reverting to the geological structure of this tract of country, it will be noted from the map that the rocks forming the eastern limb of the anticline dip regularly to the east-south-east and are undisturbed by faults. Along its apex where the dip is to the east, north-northeast, or north, there are a number of radial faults, but the structure is comparatively simple. On Roodeboschplaats No. 477, the Pretoria beds and underlying Dolomite strike regularly a little south of west. In the centre of the farm they are unconformably overlain by Coalmeasure grits, which also overlie the Red Granite by which they are abruptly replaced in the south-western part of the farm as a result of faulting. South of this all regularity ceases, the western limb of the anticline having been entirely destroyed by faulting and the intrusive action of the Red Granite and the soda-syenites, already referred to; so that instead of continuous areas of Dolomite and Pretoria beds there are found big detached masses of these rocks engulfed in the granite and syenite. The structure is in places almost incredibly complex. This applies particularly to the farm Scherp Arabie No. 367, where, while the main mass of the Dolomite is disposed in the form of a compressed overturned anticline, detached bodies of dolomite and of the immediately overlying rocks have been torn from it and twisted and broken up in a most remarkable manner. The hard chert pseudo-conglomerate at the top of the Dolomite, which will be presently referred to, forms here an admirable horizon marker. Had it not been for it the structure of this tract of country could never have been unravelled.

It will be noted that faults are exceedingly numerous within it. Brief reference can only be here made to some of them.

The most important is the one extending first in a general southsouth-westerly and then in a general south-south-easterly direction from Rooibok No. 387 to Scherp Arabie No. 367. Its throw is variable, but in the central part of Roodeboschplaat cannot be less than 4,000 feet. It is apparently cut off toward the south by a fault running along the south side of the Elands River on the last-named farm. The relation of the fault to the soda-syenites north of the Elands River suggests that the diastrophism to which it was due and the intrusion of the igneous rocks were contemporaneous. Another powerful fault is that responsible for the duplication of the pseudoconglomerate and associated rocks on Roodeboschplaat No. 477. It will be noted that on Scherp Arabie No. 367 the outcrop of the pseudo-conglomerate has been quadrupled by a series of north-northeastward trending faults.

The area of complication, with which we have been dealing, evidently does not extend south of Scherp Arabie as on Marble Hall the compressed overtilted and faulted anticline above referred to passes into a normal open anticline, but slightly disturbed by faulting. South of Marble Hall on Klein Klipput No. 596 and Elandslaagte No. 269, situated beyond the southern limits of the map, a minor west-north-west east-south-east trending anticline which gives rise to a conspicuous quartzite ridge appears to be superimposed on the north-north-east south-south-west trending Swartkop-Marble Hall anticline. The Dolomite and Pretoria beds are, however, here in great part hidden by a thin covering of Coal-measure grits and the precise relation between the two anticlines remains to be ascertained by detailed mapping.

5. The Areas occupied by the Ecca Beds and by the Mudstones of the Stormberg Series South-East and East of the Springbok Flats.

As a preliminary to the description of these areas, it will be useful briefly to refer to the structural relations of the several members of the Karroo System. Reference to the coloured section on the map will show that the Bushveld Sandstone and Amygdaloid are disposed in gentle undulations, the main axes of folding trending east-northeast west-south-west. They thus coincide in direction with the predominant structures in the pre-Karroo rocks which points to the recurrence of tectonic movements along old-established fold-lines of very much earlier date. The effects of a system of minor folds trending north-north-west south-south-east are also seen in places ; thus on Roodepoort No. 1004 on the Northern Flats and Byzonder No. 945 on the Southern. The dips, except for purely local disturbances, are very low throughout. They range from I degree 30 minutes to I0 degrees.

The mudstones of the Stormberg Series appear to be similarly disposed to the Bushveld Sandstone, while the Ecca beds along the south-eastern and eastern margins of the Flats are apparently in the form of a great monocline, the dip along the flanks of which ranges

from 2 degrees to 4 degrees. But until more information has been gathered from boreholes about the behaviour of the Ecca beds and mudstones beneath the Southern and Northern Flats it will not be possible to say anything definite about their disposition. It is worth recording that, whereas at least three faults of post-Karroo age are known in the western part of the area, none has been located so far in its eastern part.

Adverting once more to the main area occupied by the Ecca beds, it will be seen that this is of considerable extent and stretches across the map from north to south. It includes several distinct types of country. The sandstones and grits of the series give rise to typical undulating sandy bushveld, made up of alternations of broad tree-clad bults and laagtes. The commonest trees on the bults are seringa (Burkea africana), vaalbosch (Terminalia sericea), and morula (Sclerocarya caffra), while in some of the laagtes are found fine examples of tambootie (Spirostachis africanus).

The shales give rise to extensive grass-covered flats with a thin sprinkling of trees, occasional lime-bults covered with calcareous tufa probably marking the position of outcrops or sub-outcrops of the thin limestones commonly interbedded with the Upper Ecca shales.

The Stormberg mudstones, which occupy a tapering belt of country on the eastern margin of the Flats, give rise to absolutely flat featureless bushveld covered with brownish sandy loam. This type of country may be seen on Kromdraai No. 887, Middeldoorn No. 884, and adjoining farms. It somewhat resembles portions of the Springbok Flats proper, the main difference being in the nature of the arboreal vegetation, which consists mainly of different species of the genus Combretum.

The area occupied by the Ecca beds includes on the farms Klavervalley No. 492, Frascate No. 427, and Pax Intratibus No. 426 an elongated strip of felsite and felsite tuff. The felsite country only differs from that occupied by the Karroo rocks in that the soil is less sandy and encloses angular fragments of felsite. On Ubique No. 431 a smaller inlier of felsite protrudes from the Ecca beds.

6. The Springbok Flats.

Four main physiographic elements enter into the constitution of the sector of the Springbok Flats falling within the area represented by the map. They are :—

- (a) The Northern Flats, of which it includes the southern half.
- (b) The Southern Flats, the north-eastern part of which it embraces.
- (c) The Sand Bults separating the Northern and Southern Flats and bordering them on the east.

(d) The Valley of the Nyl, which traverses the Northern Flats. The Flats proper are characterized by their level nature, the absence over great areas of trees and scrub, the paucity of rock outcrops, the almost entire lack of well-defined water-courses, and their peculiar black and red soils. They are made up of great expanses of apparently level grassland and tree-steppe which alternate and merge toward the margins of the two tracts into more typical bushveld. The grassland, speaking generally, marks the position of areas occupied by black turf soil, to be presently referred to. It is normally devoid of trees, but supports an abundant growth of dwarf, bush-like acacias (A. permixta and A. natalitia). In places, however, the tracts of black turf are traversed by belts or rows of graceful trees (A. litakonensis, A. spirocarpoides, and A. benthami).

While the Flats appear from afar to be quite level, it is found on closer investigation that their surface is varied by broad and gentle undulations. Dead-level stretches are, however, met with here and there, and in many areas which are not absolutely flat it is impossible without accurate levelling to say which way water would flow or where culverts should be placed. This the engineers who built the Tuinplaats railway learnt to their cost, for after the line was completed there were numerous washaways in places where they had been least expected.

In some localities the general level is broken by low bults capped with surface limestone. A good example is to be seen on Schiedam No. 1049.

Rock outcrops are, as already stated, few and far between. In places, however, big bare surfaces of basalt, either flush with the surface or projecting slightly above it, are in evidence. Such are in evidence on Vlaklaagte No. 646, situated on the Northern Flats.

Perhaps the most striking features of these remarkable tracts of country are the almost entire absence of water-courses and dongas, and the complete absence of pans that are so widely distributed in other areas occupied by flat-dipping Karroo rocks.

The recognizable drainage lines take the form of broad, shallow depressions or laagtes barely perceptibly sunk below the general level of the surrounding surface, and only carrying water for short periods after exceptionally heavy rains.

The absence of pans is the more remarkable as they are fairly common on the sand-bults. It is generally assumed that they came into existence as a result of wind erosion* during the arid period that immediately preceded the present climatic period. That there are none on the Flats may possibly be due to the nature of the soils with which these presumably have always been covered. They are, as we shall learn, heavy clays rich in colloids which, when once properly wetted, dry with extreme slowness and, in drying, cake. The dry soil when exposed to wind action thus resists disintegration by deflation, whereas the sandy soils of the bults when dry are incoherent, and thus at the mercy of the wind. This is well seen north of the Mission Station on Schildpadfontein, where the destruction, as a result of overstocking, of the original grass cover of a tract of sandveld has led to the formation of several big shifting sand dunes, one of which has overwhelmed a small house.

* Cf. Wagner, P. A., "The Pretoria Salt Pan: A Soda Caldera." Memoir No. 20, Geol. Surv. Union of South Africa, 1922. Also Econ. Geol. 1924, pp. 664-665; Rogers, A. W., "Post-Cretaceous Climates in South Africa," S.A. Jl. Sci., 1922, pp. 1-38; also "The Geological Structure of the Union: An explanation of the Geological Map of the Union of South Africa, on the Scale of One to a Million," p. 7. Of the great herds of springbok which at one time occupied the Flats and gave them their name, practically nothing remains. During the whole time the writer spent in the area he only saw about half a dozen of these graceful animals.

(a) The Northern Flats have an area of 1,480 square miles, of which, as previously stated, roughly one-half falls within the limits of the present map. They range in elevation from 3,650 to 3,400 feet. They have a general slope to the east towards the Olifants River. This is interrupted by the Valley of the Nyl, but not influenced in any other way by that remarkable feature. We have thus the unique phenomenon of a peneplain, for such the Flats undoubtedly are, traversed by an obviously very ancient river, but graded with respect to a more vigorous stream situated beyond its limits.

The Northern Flats are, as already pointed out, bounded on the west by a powerful fault which has let down relative to the rocks building the plateau tract to the west those by which they are underlain. The western portion of the Northern Flats thus represents a sunken area. It is possible that the subsidence may still be in progress, as the fault is evidently a comparatively recent one and earthquake shocks are occasionally felt in this and the Nylstroom area. The fault, as previously stated, has a maximum throw of about 400 feet to the west of Naboomspruit. Towards the south-west the throw appears rapidly to diminish, and toward the north-east the fault comes to an end a short distance north of the northern margin of the map.

It will be noted on the farms Roodepoort No. 1004, Mooihoeks Poort No. 1013, Gruisfontein No. 1023, and Vogelstruispan No. 888 a triangular-shaped area of Bushveld Sandstone projects east-northeastward into the Flats. It marks the position of a minor eastnorth-eastward plunging anticline, the axis of which coincides with that of the much older Nylstroom syncline. On the north side of the anticline the dip of the Bushveld Sandstone, as determined from borehole records, is 3 degrees.

The isolated areas of sandstone north-west of this anticline represent layers and lenses interbedded with the basalt; the biggest of them on Rotterdam No. 553, gives rise to a broad sandy bult covered with fine morula trees.

Of the sub-surface geology of the Northern Flats far less is known than of that of the Southern, as no deep boreholes have so far been put down on them. It is not even known whether or not they are underlain by the Ecca beds.

(b) The Southern Flats have an area of 1,420 square miles. Only a relatively small portion of this area falls within the limits of the present description. It will be noticed that their eastern end is of irregular outline. The irregularities are due to the minor folds previously referred to.

As to their sub-surface geology the only information at present available is that afforded by several deep boreholes put down for water. These indicate that the basin which they occupy is fairly deep. Thus one of the boreholes situated in the north-west corner of Diepsloot No. 772 passed through 588 feet of Bushveld Amygdaloid and 645 feet of Bushveld Sandstone, and at a depth of 1,233 feet entered hard white quartzite presumably belonging to the Pretoria Series. Another hole on Ludlow No. 1296, situated just west of the western margin of the map, went through 996 feet of basalt, 600 feet of sandstone, and 185 feet of red, purplish, and green mudstones, in which it was stopped. It is quite probable that the mudstones are themselves here underlain by a considerable thickness of Ecca beds.

Topographically the Southern Flats show somewhat greater relief than the Northern, being traversed by several big bults. One of them is crossed by the railway between Sibis and Tuinplaats.

(c) The Sand Bults.—The sandstone belts separating the Northern and Southern Flats and bordering them on the east give rise, as previously stated, to broad swelling timbered bults rising from 50 to 180 feet above the level of the adjacent plains. They are deeply covered with fine yellow sand from which there stand out here and there great hummocks and fantastically shaped, steep-sided kopjes and ridges of red or grey sandstone. These consist, as a rule, of huge blocks bounded by vertical joints and piled irregularly on top of one another or on a base of solid sandstone. They are never of great height, 80 feet being about the maximum, but, owing to the level nature of the surrounding country, form prominent landmarks, their peculiarity of outline being accentuated when seen from afar by the mirages which are of such frequent occurrence in this area. Such kopjes are greatly in evidence on the south side of the sand-bult between the Northern and Southern Flats, but there are also several striking examples in the wedge-shaped tract of sandstone projecting into the former, the twin hills constituting Tweelingskop on Gruisfontin No. 1023 being among the best-known landmarks of the entire area. On the flanks of some of the kopjes the weathering of the sandstone has given rise to shallow caves; one such is to be seen on the north side of the more easterly of the Tweelingskop twins.

Another characteristic feature of the sandstone bults are pans, sometines of considerable size, which hold water during the rainy season. A fine example is the Elephant Pan near the southern boundary of Roodepoort No. 1004.

The bults, as already indicated, are well timbered, supporting a characteristic vegetation of seringa, vaalbosch, dikbast, and morula trees. On the bult east of the Flats stately kameeldoorns (Acacia giraffa) are, however, very common, and fine examples of A. burkei are found in the wedge-shaped sandstone tract projecting into the Northern Flats. The sandstone kopjes are also covered with bushes and trees, among which special mention must be made of a wild fig which sends its roots for great distances over the sandstone ledges in search of water.

The bult bordering the Flats on the south-east can be followed from their southern margin about 5½ miles north of Pienaars River Station all the way to Zebediela's Location, being joined on Grasplaats No. 1216 and adjoining farms by the bult separating the Northern and Southern Flats. There are only two gaps in it. One of them

on Goedvoer No. 294 and adjoining farms will be presently referred to. The other is on Locatie No. 1215 and Krugerskraal No. 790, where the stream that once flowed eastward from Kalkfontein No. 1030, and of which more will be said hereafter, has cut a broad open valley through it.

(d) The Valley of the Nyl.—This is without doubt one of the most remarkable topographic features of the area. Down to the confluence on Doorndraai No. 1011, a short distance below Nylstroom, of the Great Nyl with its main tributary the Little Nyl, it presents the ordinary features of a river valley in the Waterberg area, namely, a broad flat-bottomed grass-covered depression, at the lowest part of which is a narrow reed-fringed water-course bordered by low terraces of gravel and silt. Below this the central part of the valley begins to assume the character of a shallow vlei or marsh, in which there is, however, still a fairly well-defined main water channel. At the same time the valleys of the streams tributary to the Nyl also assume a vlei-like character as the main valley is approached. This is well seen in De Wets Loop, which joins the Nyl on Nyls Vly No. 1738. North of Weltevreden No. 380, the Nyl Valley itself, practically the whole of which has now the character of a vlei, becomes less and less clearly defined, and on the farms Grootvalley No. 977, Zyferkraal No. 999, and Du Toit's Kraal No. 972 it loses all semblance to an ordinary river valley. It is barely perceptibly incised below the level of the surrounding country, and it is thus impossible to say where it begins or where it ends. At the same time clumps of trees and scrub make their appearance, thereby increasing its lack of definition. There is no longer any well-marked water-course, this being replaced by a succession of marshes, except after heavy rain, when nearly the whole of the vlei, here over 11 mile wide, is transformed into an enormous sheet of sluggishly-moving shallow water. This is the nature of the Nyl Vlei from the farms named to Vaalkop No. 722, situated some distance north of the northern margin of the map, a distance of nearly 20 miles. The gradient of the viei is extremely low, the total fall from where it is crossed by the light railway to Singlewood to Vaalkop is said to be only 4 feet, but this remains to be confirmed by accurate levelling. North of Vaalkop the vlei decreases very considerably in width, and near Moorddrift, situated some 6 miles to the north, it once more assumes the character of a normal mature river valley.

It has already been pointed out that the Nyl Vlei south-east and east of Naboomspruit is barely differentiated from the surrounding country. Some idea of the actual configuration of the valley and of the Flats east of it may be had from a line of levels run by the engineers of the Irrigation Department from the lowest part of the vlei in the northern portion of Leeuwkuil No. 1041 parallel with the north-eastern boundary of that farm, across it and the adjoining farms Schiedam No. 1049 and Vogelstruispan No. 888, a total distance of just over 7 miles. It was found that for the first 9,000 feet the ground rises uniformly until it is 7 feet above the bed of the vlei; the surface then remains at this level for the next 12,000 feet. Beyond this level tract, constituting the watershed between the Nyl and the Olifants Rivers, the ground for the next 12,000 feet drops gradually to a level of 7 feet below the level of the Nyl Vlei. It continues to fall in the next 2,000 feet, and rises very slightly in the following 2,000. It then drops fairly rapidly until the open Flats on Geluk No. 1053 and Zandfonteinsoog No. 801 are reached. These lie considerably below the level of the vlei.

It will be clear from these figures that a canal taken out of the Nyl at Leeuwkuil, or farther north, would command a very extensive area of the Springbok Flats.

Three causes have probably contributed to the remarkable behaviour of the portion of the Nyl with which we have been dealing,

First in importance among them the writer would put the letting down along the fault, west of the Northern Flats, of a strip of country athwart the course of the river. In support of this contention it may be pointed out that the sector within which the Nyl Vlei attains its greatest width and most typical development coincides with that within which the throw of fault is greatest west and south-west of Naboomspruit, it having already been pointed out that the throw diminishes rapidly toward the south-east, and that the fault dies out altogether toward the north-west.

The hypothesis, however, necessarily presupposes that the Nyl was in existence before the faulting occurred or came into being while it was in progress, and of this there is no proof.

If it should be correct, it is evident that the subsidence within the area traversed by the Nyl must have been very much less than that along the fault, and also that it must have taken place very slowly; otherwise the river would certainly have changed its course. Probably the only effect of the faulting, so far as the Nyl was concerned, would have been slightly to depress this part of its course relatively to that farther downstream. The river evidently managed to keep pace with the subsidence by cutting down its bed at the northern end of the area affected.

The second of the presumed causes is the broad belt of soft, easily disintegrated Bushveld Sandstone which the Nyl traverses in the upper part of the vlei tract. This no doubt led to the stream being overloaded with sand. Judging, however, by the behaviour of other streams that traverse areas of Bushveld Sandstone, such overloading is incapable in itself of giving rise to a feature like the Nyl Vlei.

The third cause lay beyond the limits of the map: on Vaalkop No. 722, situated some miles south of Moorddrift. Here the Nyl leaves the Karroo rocks and enters an area of far more resistant norite. This has only recently been stripped of its covering of Karroo beds on which the river originally flowed. It is quite evident that when in the process of incising its channel the Nyl reached the norite beneath the Karroo beds, the down-cutting velocity of the stream was checked relatively to that further upstream, leading to a further lessening of the grade within that sector.

At the present time the erosion along the Nyl Vlei is practically nil. If the postulated subsidence should still be in progress, or if there should be a renewal of it, this might thus easily lead to the water that now finds its way downstream to Moorddrift seeking a new course eastward across the Northern Flats.

Drainage.

The principal rivers of the area have already been enumerated. Mention should also be made of the Sterk, a tributary of the Magalakwin as the Nyl is called below Potgietersrust, which cuts across the north-eastern corner of the map, and of the Moos and Gompies, important tributaries of the Olifants. The former joins that stream in the south-eastern corner of the map, and the latter just east of its eastern margin.

The Olifants, one of the most important rivers in the Transvaal, flows, as previously indicated, in a broad open valley. Within the area embraced by the map the river bed has been accurately levelled by the Irrigation Department.* The fall between the inflows of the Moos and Elands Rivers was found to be 119 feet in 13 miles, or 9 feet per mile. From the inflow of the Elands to the farm Hindustan, a distance of 9 miles, the fall is 46 feet or $5 \cdot 15$ feet per mile. Below this the gradient becomes very low, only averaging $3 \cdot 5$ feet per mile for the next 68 miles. According to Hurley, who made the survey, a masonry weir across the river on Klipspruit No. 161 would enable 22,000 acres of land bordering it to be irrigated. Owing to the inaccessibility of the area, the scheme at the time when the survey was made in 1921 was not, however, considered sufficiently promising to justify the heavy expenditure that its execution would entail.

The Elands, the most important tributary of the Olifants in this part of the Transvaal, also flows in a broad open valley across the south-eastern part of the area, first in a north-easterly and then in a west to east direction until it encounters the main quartzite ridge, previously referred to, in the eastern corner of Scherp Arabie No. 367. It cuts across it in a picturesque gorge, and then swings sharply to the north, joining the Olifants on the northern boundary of Rooibokkop No. 491.

The Elands and the Moos are perennial streams except during exceptional periods of drought, when they have both been known to dry up temporarily.

The Gompies or Zebediela River, which cuts across the northeastern corner of the map, is dry throughout the greater part of the year, but carries an underflow which is here and there forced to the surface by outcrops of hard rocks across its course; thus, for instance, by the dolerite dyke that crosses it at Byl Drift. It should be stated that this river has its source in the high ground south of Pietersburg, west of one of the big spurs of the Strydpoort Mountain. It has developed a well-marked valley across the Northern Flats, flowing in a wide sandy bed bordered by low terraces which support here and there a growth of fine trees.

The only other flowing water on the Flats proper is a small stream fed by a spring in the western corner of Kalkfontein No. 1030,

* Hurley, F. A.: "Report on the Reconnaissance of the Great Olifants River." Transvaal Irrigation and Water Supply Department, Pretoria, 1907. on the southern margin of the Northern Flats. The spring issues along a minor fault in the Bushveld Sandstone. The stream flows for some miles eastward across Kalkfontein in a reed-choked channel before it finally disappears. It, no doubt, at one time carried more water, as its bed can be traced across the main sand-bult east of the Flats, through which it has carved a broad, flat-bottomed valley, and thence as far as Klavervalley No, 492, where it joins the great nameless laagte draining the area between the sand-bult and the Olifants. The last part of its course is, however, very poorly defined.

As to the laagte itself, this is a broad, grass-covered depression without any definite water-channel, being of exactly the same nature as the *Omiramba* of the north-eastern Kalahari. It only carries water of exceptionally heavy rains, which convert it into a broad shallow stream. It is dammed at two localities below the Mutue Fides Mine, but the dams are as often dry as not. It eventually joins the Olifants immediately south of Krokodel Kop on the farm of that name.

Several lesser laagtes to the north can be traced across the sandbult, but disappear in the area occupied by the Ecca beds.

In the same way a number of laagtes draining the sand-bult between the Northern and Southern Flats disappear on the latter.

Evidence of Climatic Change.

The behaviour of these laagtes and of the stream that originally flowed eastward from Kalkfontein, and finally the occurrence of beds of gravel beneath the grass-covered surfaces of some of the laagtes that now hardly ever carry water, might be interpreted as indicating a progressive desiccation of the area. A more comprehensive view of the facts points, however, to the opposite conclusion, namely, that in recent times, at least, there has been an increase in humidity.

It has already been pointed out that there is clear proof in other parts of the Transvaal that the present climatic period was preceded by an arid period, and this in turn by a period characterized by more abundant rainfall or a much lower average temperature. So far as the area under review is concerned, every valley in the elevated tract in its north-western portion tells the same story of (a) vigorous erosion succeeded by (b) an arid period when the streams were overloaded with sediment which led to their valleys being aggraded with fine silt, leaving them probably in the condition of the laagtes with which we have been dealing*; and finally, (c) renewed vigorous erosion by the present streams which have cut down through the fine silt to bedrock or to the coarse gravel with which the valleys are floored.

That this rejuvenation of the streams is not due to a steepening of grade as a result of down-cutting at their lower extremity is proved by the fact that on approaching the Nyl they spread out, as previously stated, into broad flat-bottomed vleis barely differentiated from the surrounding country.

The valley of Tobias Spruit which enters the Nyl a few miles north of the northern margin of the map is a good illustration. In

* The great accumulations of sand on the outcrops of the arenaceous rocks of the area are also evidence of this period of aridity.

the hill tract the stream flows in a steep-sided valley, being bordered by terraces which prospecting operations for platinum have proved to consist of from 20 to 25 feet of fine sandy clay overlying a thickness of from 6 to 18 feet of coarse gravel. The stream itself has cut down to the gravel or to the granite underlying it. As the valley approaches the Nyl, its character changes completely, and where crossed by the railway it is barely perceptibly incised below the level of the adjacent plains.

The arboreal vegetation of the Springbok Flats and area to the east of them corroborates the evidence of these valleys. Trees like the camelthorn (*Acacia giraffae*) and various species of Boscia which are characteristic of arid regions such as the Kalahari are clearly dying out, while moisture-loving trees such as *Acacia karroo* and *Spirostachis africanus* are establishing themselves. The invasion of the Flats by *A. karroo* is particularly evident along the northern margin of the Southern Flats on Byzonder No. 828 and adjoining farms.

The Springbok Flats area may thus be said to afford strong support of the contention of Rogers* that there are no grounds for the widely held view that South Africa is drying up.

Ethnology.

Ethnologically the area is of great interest, as evidencing amongst other things the extraordinary extent of the migrations of some of our native tribes within the last 150 years.

The original inhabitants, within comparatively recent times at any rate, were Bapedi, who are still found at numerous localities in its southern and eastern portions.

In the east-central part of the area are a number of small communities of N'Debele who remained behind when the great hordes belonging to this and allied tribes from the borders of Zululand swept across this part of the Transvaal.

The natives occupying the populous locations at Schildpadfontein and to the west of it are Bakathla, whose original home was on the shores of Lake Ngami, and who are still subject to Chief Ifano Pilang They trekked into the Transvaal and settled at Schildpadfontein between 100 and 150 years ago. In 1837 they fled at the approach of the N'Debele, but after the defeat and dispersal of the latter by the Boers, returned to Schildpadfontein, which is known to them as *Marogane*, literally the "Land of the Little Bones," referring to the buried remains of their ancestors.

In the Thaba Sot hills are found numerous kraals, enclosures, and walls built of rough undressed stone. These are similar to those found at many localities in Southern Rhodesia, where they are generally attributed to the Makaranga. In the present instance the stone walls are said to have been built some twelve generations back by Mahläbogoane, a petty chief from the borders of Zululand, who, with his followers, resided in these hills for some time before founding what is now Zebediela's Location.

* S.A. Jour. Sci., 1922, pp. 1-38.

In all the poorts of these hills and of the hills paralleling the Olifants south of its confluence with the Elands are found cairns, up to 5 feet in height, built up of loose stones ranging up to 9 inches in greatest length. These cairns are also attributed to Mahlabogoane and his followers, male and female, each of whom was required on traversing one of the poorts to pick up a stone and deposit it on one of the heaps with the object of propitiating the gods. One of the largest cairns is to be seen in the poort by which the most westerly of the Thaba Sot hills is separated from the main range.

Stone Implements.—No account of the geology of the Springbok Flats would be complete without some reference to the crude palaeolithic stone implements, including bouchers, points, scrapers, rude knives, and arrow-heads, which are of extraordinarily wide-spread occurrence in the superficial deposits of the area.

On the Flats proper, where they are found mostly lying on the surface, it is impossible after a little practice to go for more than a few yards in any direction without coming across one or more of them; the ubiquity of such palaeoliths being not the least remarkable feature of these very interesting areas. They are particularly conspicuous and easy to find in areas occupied by the black turf soil to be presently referred to. They appear to be more numerous on the Southern Flats than on the Northern.

According to a rough estimate made by the writer, there is at least one implement to every fifty square yards of the former. Taking the average, however, at one to every hundred square yards, then, since the Southern Flats have an area of 1,420 square miles, the number of implements on them would be 43,985,920, a truly amazing total. In view, however, of their extraordinary abundance in many localities, the estimate errs, if anything, on the low side.

The implements are clearly the hunting equipment of Bushmen and more primitive peoples who roamed the Flats at a time when they teemed with game of every description. Their extraordinary profusion indicates that these ancient hunters must have followed their occupation for tens of thousands and perhaps hundreds of thousands of years. The weathered condition of many of the implements also indicates that they are of considerable antiquity. This is likewise proved by the conditions in which they are occasionally found. Thus, in a pit on Bultfontein No. 1904, small bouchers and scrapers were found resting on Ecca Shale beneath a layer of calcareous tufa, two feet thick, itself overlain by three feet of sandy loam.

The implements are mainly red and brownish red felsite and of quartzite. More delicately fashioned implements of opal and chalcedony were, however, also found.

Felsite implement "factory sites" were located on the farms Frascati No. 427 and Klavervalley No. 492, and Ameland 60. 421; also on Kromdraai No. 459 situated some distance south of the southern margin of the map. Very extensive "workshops" for quartzite implements existed on the west side of Makeeps Vlei on the farm of that name, where there is a prominent outcrop of hard, glassy Rooiberg Quartzite. Here there is an extraordinary profusion of stone implements, obviously mainly rejects. Makeeps Vlei then, as now, was probably the only open water for many miles around and would thus have been a rendezvous for hunters from far and wide. Less important quartzite and felsite factory sites were also located on Ameland No. 421. The hard, pink quartzitic phase of the sandstone outcropping in the northern part of Weltevreden has been successfully used here in the piers of a bridge across one of the tributaries of the Nyl.

On Hoogbult No. 936, pale purplish-pink Bushveld Sandstone has been used with good effect for building houses and a cattle-dip.

Some of the Coal-measure sandstones are also well adapted for building purposes.

That rough-dressed granophyre makes a handsome building stone is evident from a house built of that rock above the now abandoned Union Tin Mine.

Excellent road metal in the form of more or less decomposed basalt is obtainable anywhere on the Northern and Southern Springbok Flats at a depth of from 2 to 10 feet below the surface. This does not seem to be generally realized by either road or railway engineers.

Water Supply.—Though traversed by a number of perennial streams, the area as a whole is poorly off as regards surface water. The best watered section is the elevated tract in its north-western portion, where small streams carrying water all the year round are found in most of the deeper valleys.

As regards the Springbok Flats, the only open water on them prior to their occupation were a few isolated springs. The Northern Flats, in particular, were very poorly supplied, and on this account acquired a rather sinister reputation But while surface water is so scarce, there appears to be no difficulty in tapping fairly good underground supplies at moderate depth almost anywhere either in the basalts or in the sandstones. The basalts in particular rarely fail to yield water at or near the bottom of the zone of weathering, which lies at anything from ro to 80 feet below the surface, the average being about 60 feet. The water is contained in the pores of the decomposed rock, in vesicles from which the zeolites have been leached out, and finally in the joints which are everywhere in evidence.

The underground water over considerable areas of the Flats appears to be stagnant owing, no doubt, to the absence of surface relief. It is in consequence heavily charged with calcium carbonate and other salts, but only one instance is known to the writer where these salts are so abundant as to render the water unfit for consumption.

In the sandstones the underground water-table also stands from 5 to 80 feet below the surface. Exceptionally, however, it is much lower.

The most unsatisfactory rocks so far as underground water supplies are concerned are the Stormberg mudstones underlying the Bushveld Sandstone. Along the eastern border of the Flats where, as previously stated, these rocks attain a fairly considerable thickness and cover wide areas, a number of boreholes have been put down to depths of 200 and even 300 feet, either without yielding any water at all or only quite unimportant quantities. This is doubtless a consequence of the impermeable nature of these rocks and the absence of joints in them. Hopes were at one time freely entertained of striking artesian water beneath the Flats. All that can be said on the question is that the structural conditions are favourable to the occurrence of artesian supplies, and that the Bushveld Sandstone is one of the few really permeable rocks found in South Africa. These, however, are only two of the requisite factors and, judging by the results obtained from the deep boreholes previously referred to, some of the other conditions are not present.