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DEPARTMENT OF AGRICULTURE.

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GEOLOGICAL SURVEY OF PARTS OF VRYBURG, KURUMAN, HAY, AND GORDONIA.

By A. W. ROGERS.

surface. The salt crust is divided up into polygonal areas, analogous to the areas enclosed by cracks on dry mud flats. The cracks in the salt crust are filled with salt, whiter and containing less impurities than the crust itself. This very white salt forms low ridges, up to half an inch high, over the cracks, and it is evidently deposited by water rising along the cracks and evaporating at the surface. The pan is nearly three miles long, and about a mile wide at the broadest part. The salt crust extends almost to the edge of the pan. There is no apparent explanation of the large amount of salt in this pan, the only one on the west of the Hygap which contains much. It does not seem to receive water from a larger area than, for instance, Haakschein Vley. Another salt pan called Matsiman exists to the east of the Hygap in this region, but I have not seen it.

Analyses were made of the salt from the two pans by Dr. C. F. Juritz, Senior Government Analyst; the figures are:—

	No. 1.	No. 2.
Calcium sulphate	Very faint trace.	Very faint trace.
Magnesium sulphate	Trace.	Trace.
Sodium sulphate	.48	.62
Sodium chloride (common salt)	98.55	98.31
Moisture	.01	.29
Sand (insoluble matter, estimated by difference ...	.96	.78
	100.00	100.00

No. 1 is the salt from Rautenbach's Pan; No. 2 that from Matsiman Pan. The resemblance between them is very striking, and so is the percentage of sodium chloride. The Matsiman sample was obtained from a native at Wit Krantz, on the Kuruman River, who had recently come from the pan. The other sample was taken from the crust on Rautenbach's Pan. It cannot represent the composition of all the salts held in solution by the water which deposited it, for water was found three inches below the surface, so the most soluble constituents were probably still in the water. The very small amount of calcium sulphate, a substance of wide distribution in pans and in the soil of areas without efficient drainage, is probably to be accounted for by the facts that the deposit at this pan is thick, very likely thicker than the salt crust taken out, and the calcium sulphate is much less soluble than common salt, and would have been deposited earlier, in the black sand or below it.

Water Supply.

The country described in the previous pages is probably on the whole the worst watered area in the Colony, so far as water for domestic purposes and stock is concerned. The actual rain-

fall is not known, except at Upington (8.67 inches a year, an average of 9 years before 1894)[1] on the southern border; since 1894 the rainfall does not seem to have reached 5 inches. The country generally seems to be remarkably well covered with grass and bush, but this abundant vegetation is confined to the sand; on the hard ground near the German border, along the Orange River, and in the small areas found amongst the sand, the vegetation is of the Karroo type, short, sparsely scattered bush with drought-resisting leaves. The explanation of the difference probably is that in the sand-veld there is a thick layer of damp sand, the depth of which changes but slightly from year to year, and which supplies the trees throughout the year with water, possibly the grass also. In the hard veld there is no such damp zone at a moderate depth; the ground seems to be dry generally to a considerable depth, and then there is the layer of ground water which supplies wells when tapped.

From inquiries made on the journey, the usual experience of those who dig for water in the sand-veld is that damp sand is met with at a depth of 8 or 10 feet below the surface; but the water is never in sufficient quantity to collect in a well; after passing through many feet of damp sand, dry sand is again encountered, and usually no further water is found, even though the well be sunk to bed-rock.

The sand of the sand-veld allows rain water to penetrate the ground rapidly, and yet is not coarse enough to let the moderate or small quantity received run through to bed-rock or a less pervious layer; the water is thus held in the sand by capillarity.

The only successful wells met with west of the Langeberg-Korannaberg range were sunk in the river beds or in the hard ground near the German border. It is probable that water in moderate quantities could be obtained anywhere along the Kuruman River below Dikgathlon, at depths of less than 100 feet. The existing wells, except that of Wit Draai (80 feet) are not deep enough. The Witkrantz and Matlapaning wells at the time of my visit gave a few buckets of water a day, not enough for a small team of oxen, and the Lower Dikgathlon well was very weak; if these wells were deepened, they would very probably yield much more water than they now do.

The conditions in the Molopo above its confluence with the Nossob seem to be more favourable than those of the Kuruman bed, for water at a few feet below the surface is got between Kolingkwani and Kuis. Both in the Molopo and Kuruman Rivers the reason why deep wells have not been made probably is that the well sinker would have no security of tenure; otherwise the value of the water for stock and its sale to users of these routes to the German border would certainly have induced people to make satisfactory wells.

Both the Dwyka and the Zwart Modder beds afford water in

[1] A. Buchan: A Discussion of the Rainfall of South Africa, etc., 1897.

the country near the German border; the wells are, of course, sunk on the patches of hard ground; those seen by me were less than 100 feet deep. The water from the Zwart Modder beds is generally less brak than that from the Dwyka. There seems to be little difficulty in getting moderate supplies of water in the hard veld; west of the Hygap the country has a very small slope, and in spite of the scanty vegetation, the amount of water which runs off is probably small in proportion to that which evaporates at the surface or sinks underground along joints. It is likely that the conditions are more favourable along the German border than east of the Hygap, where the patches of hard ground are few and surrounded by thick sand, for the latter to a great extent prevents the rain-water from reaching the solid rocks from which it might be obtained by wells.

The sand-veld holds water in a way that is favourable to vegetation, but not to the supply of wells, and in the case of the hard-veld the conditions are reversed.

of its cover of sand in the way which Lamplugh[1] has suggested in discussing the silcrete deposits of the Zambezi Basin.

Many of the quartzites are certainly of considerable antiquity, but the formation of similar rocks may be still going on at the present day.

VII. The Development of the Physical Features of the Area.

Passarge has dealt very fully with the question of the origin of the physical features of the Kalahari, and has brought forward a great number of facts pointing to considerable climatic changes in the past.

Much of his description applies to the area under consideration, but the inferences which I have drawn as regards the development of the area and the climatic variation differ to a certain extent from those of Dr. Passarge.

As already remarked, the area shows that peculiar type of landscape termed "*Inselberg-landschaft*," the origin of which has been fully discussed by Passarge.[2]

There is some uncertainty, however, in this area as to whether the features had not been developed to a considerable degree in Pre-Dwyka times. The chain of hills north-west of Morokwen possesses beautifully smoothed and rounded outlines which recall most strikingly the Griqua Town hills between Griqua Town and Prieska, where the covering of Dwyka tillite has been recently removed. The discovery of Dwyka tillite by Mr. Rogers[3] on the Molopo near Kolingkwani, and by Mr. Molyneux[4] at Mochudi and Palapye, renders it not improbable that a vast area in Bechuanaland has been stripped of its covering of Karroo beds only in very late geological times. Some of the ridges may, therefore, owe their main features to pre-Karroo denudation, the minor sculpturing being due to sub-aerial erosion at a much later period.

That this area has been subjected to active river erosion at a late period in the geological scale is indicated by the existence of banks of coarse gravels[5] between Mafeking and Madibi (K. 14), and again about 12 miles further to the west (K. 11). These fluviatile deposits attain an altitude of 4,203 feet above sea-level at the former locality, and 4,155 feet at the latter, and are, therefore, considerably above the level of the country round about. It is evident that these gravel patches are outliers of a former and more extensive alluvial deposit laid down upon a peneplain that extended from the Transvaal over Mafeking with a gradual westerly slope.

[1] G. W. Lamplugh. Quart. Journ. Geol. Soc., Vol. 63, p. 199, 1907.

[2] S. Passarge. Die Inselberglandschaften in tropischen Afrika. Naturwissenschaftliche Wochenschrift. No. 42. Jena, 1904.

[3] See p. 81.

[4] Molyneux. Proc. Rhodesia Sci. Assocn., Vol. VI., pp. 78-84. 1906.

[5] Ann. Rept. for 1905, p. 255.

The whole of the drainage from this quarter converges towards Pitsani, and passes through a great gorge about half a mile in length and in places nearly 200 feet deep, cut in a ridge of hard magnetic quartzites and cherts. This barrier reaches the altitude of 3,924 feet above sea-level, and must have been instrumental in protecting the area to the east from vigorous erosion. The natural conclusion, therefore, is that the high level gravels were deposited at a period when the Molopo had just commenced to cut its way through this obstacle.

The laying down of the gravels, the cutting of the gorge, and the consequent erosion of the drainage basin must have been accomplished during a period of a higher rainfall than the district now possesses, for at the present time it is only on rare occasions that the Molopo flows for more than a week at a time during the wet summer season. The existence of an early period of heavy rainfall *(pluvialzeit)* seems, therefore, fairly well established.

The red marls, overlain by the surface quartzites and siliceous conglomeratic rocks, commence immediately below the great gorge at Pitsani, their position indicating that they were formed after the cutting through of the barrier. They appear to have been deposited in the ancient valley of the Molopo, and may be regarded as a thick stratum of calcareous mud that has been covered over with sand and gravelly material, the latter having been subsequently indurated. The exact reason for the formation of these deposits is not quite clear. It may be that the material was laid down owing to increase of load from growing tributaries, coupled with the decrease of gradient due to the cutting of the gorge. On the other hand similar quartzites and marls, though of less thickness, occur in valleys having much smaller drainage areas.

It may, therefore, be that the clays, sands and gravels accumulated in the valleys consequent upon a period of diminished rainfall. It must be noted that although the surface-quartzites are frequently conglomeratic, and therefore in great part of fluviatile origin, nevertheless there enter largely into their composition well-worn grains of sand, evidently wind-borne.

The hypothesis of a period of lesser rainfall would at the same time account for the intense silicification of the material and its conversion into quartzite; still, it is not unlikely that the process of induration was again in action at a much later period.

The cutting through of the quartzites until the softer marls, and in some cases the bed rock, became exposed, indicates a renewal of river activity that can only be accounted for by a recurrence of humid conditions. Considering the extremely low gradients (about 3 feet per mile) of the rivers for several hundreds of miles westward, it is clear that this renewed activity cannot be accounted for by an increased slope of the river bed brought about by tilting of the drainage area.

The initiation of this second pluvial period is marked by the occurrence of low-level gravels on the Setlagoli River between Buck Reef and Logaging, on the Molopo just below Pitsani, and by the presence of old loops or "cut-offs" along the river below Mabul. A fine example of a loop now above the level of the river bed is known as Daly's Pan.

Most of the rivers do not seem to have been able to clear out the deposits that filled in their former channels; if ever that were the case they have since been unable to cope with the products of sub-aerial weathering and the quantity of blown sand from the west.

All the larger rivers rise in areas where the hard rocks are frequently exposed, but the small valleys exist entirely in sand-covered country. In the rainy season the rivers flow for a short time, and ultimately the water soaks into the bed of the river and percolates along the sand of the valley bottom. Many of the rivers exist merely in name; for example, the Matlapin Spruit. Although over 40 miles in length, water never flows along its middle reaches. The bed is being obstructed by the accumulation of wind-borne sand and rain-wash, so that in several places the gradient of the valley bottom is reversed.

At the present day the rainfall is high enough to enable vegetation to fix the mantle of red sand, otherwise the rivers would long since have had their channels obliterated. As it is, the disappearance below ground of the surface quartzites on the Molopo, below Mabul, is proof of the invasion of the drainage area by red sand from the Kalahari region of the north-west.