The Underground Water-Bearing Properties of some of the more important Formations in the Union and portions of South West Africa.

by

HERBERT FRANCIS FROMMURZE.

Presented in part fulfilment of the requirements for the degree

of

DOCTOR OF SCIENCE

in the Faculty of Science

University of Pretoria.

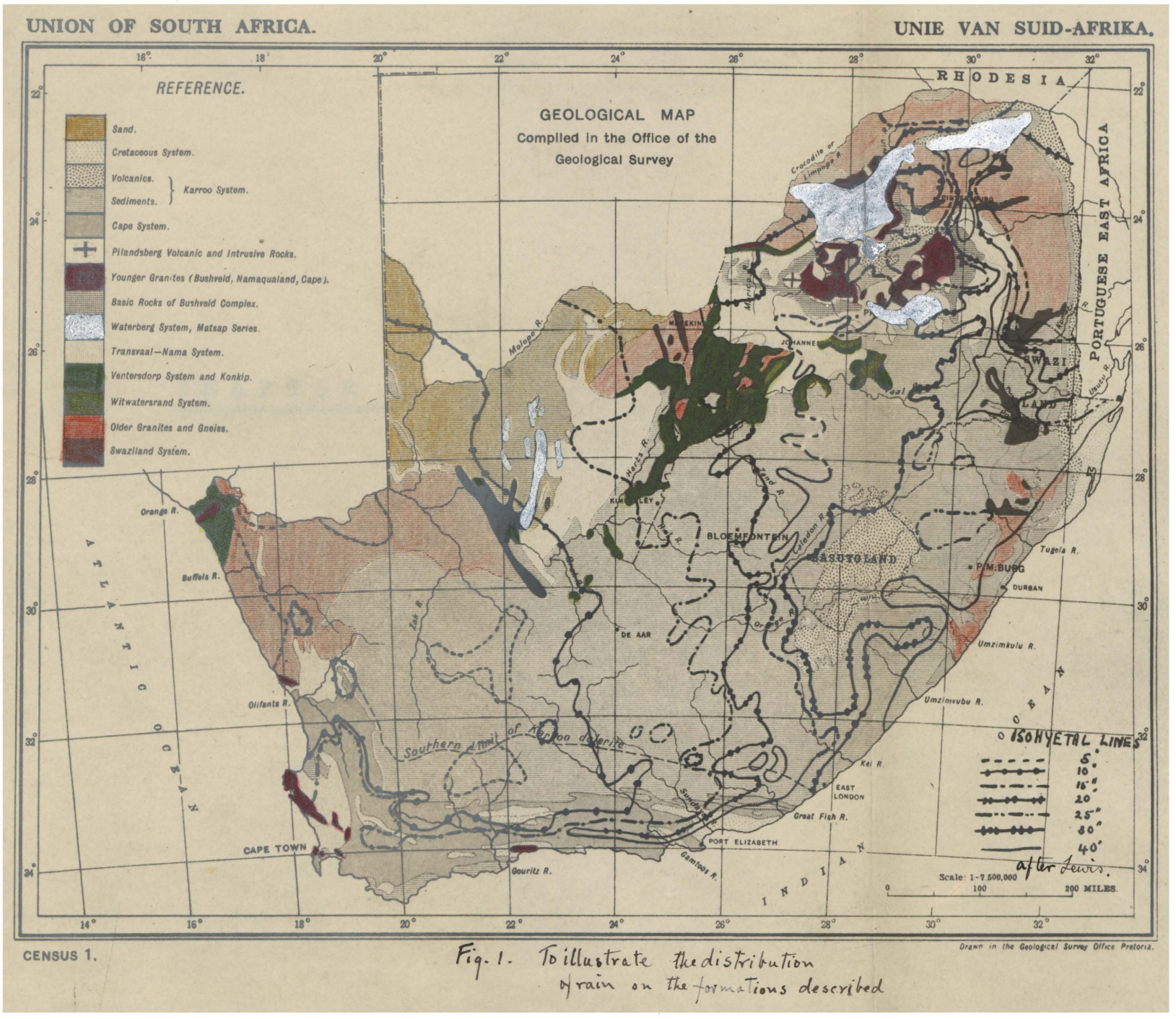
Pretoria,

March, 1936.

C O N T E N T S.

CHAPTER I.

UNION OF SOUTH AFRICA. UNIE VAN SUID-AFRIKA.



CENSUS 1.

Fig. 1. To illustrate the distribution of rain on the formations described

INTRODUCTION.

This account is of work started under Dr.A.L. du Toit in the Irrigation Department during the years 1921-1925 who published a summary of results obtained up to that time in the Transactions of the Minutes of Proceedings of the South African Society of Civil Engineers in 1928. On returning from a period of 5 years spent in South West Africa where attention was also given to underground water problems it was found that a mass of data had accumulated and this has continued to accumulate.

This work has been tabulated and analysed up to the latter part of 1935 and so it is possible to present the results obtained from 20,000 boreholes sunk by the Union Irrigation Department's Boring Branch, 1,500 boreholes sunk by the Old Cape Government and several thousand results communicated by private drilling contractors. With this mass of information it has been possible to study the various aspects of this problem in greated detail than has been done before, and many new facts have emerged as the result.

During the course of the time spent with the Irrigation Department and later the Geological Survey many of the sites of the boreholes have been visited and the rock formations through which they extend determined, from others samples have been received and determined in the Geological Survey. It is realised that the data from boreholes not visited may contain inaccuracies, but it is believed that the information given is essentially reliable and the generalizations regarding the water-bearing properties and the prospects of the different formations are sound.

The/...

The analysis and tabulations of the results have all been done by the writer and most of the card indexing as well. Latterly assistance with the clerical work was obtained from the Native Affairs Department and from the Librarian of the Geological Survey.

Thanks are due to Dr.A.L.du Toit for advice and criticism and Mr.A.D.Lewis, Director of Irrigation for permission to use the boring records.

RESULTS.

The results dating as they do from 1900-1935 are representative of both dry and rainy seasons. It is known that the water levels rise after rains and fall after droughts ad the following figures will show. (Figs.2,3 & 4.) These results are representative of both conditions.

In earlier drilling operations advantage was taken of the more advantageously placed situations and thus it would be expected that the earlier results would be much better, but it has been found that generally there is practically no idfference e.g. the Crystalline Rocks in the Pietersburg District. Average yield per borehole

1909 - 1921	20,700	gallons per diem.
1921 - 1925	20,800	" " "
1925 - 1930	20,100	" " "

This is the same for other formations in other parts as well though differences are sometimes somewhat greater.

GENERAL.

The geological structure undoubtedly plays a major part in controlling the occurrence of the underground water. Folding and faulting together with uplift and erosion have brought to the surface the large area of the Crystalline Rocks. Large displacements which have occurred along major faults have restricted the circulation of undefground water in the neighbouring areas, as e.g. the

large/...

large faults in the Dolomite and Pretoria Series.

Solution channels in the Dolomite are controlled partly by the structure and partly by other factors. These channels permit a fairly widespread circulation but faulting and folding frequently confine them to limited areas. Most of these channels lie below the level of the major streams and their tributaries. In most instances the channels permit the circulation of underground water in interstream areas.

The structure in the areas underlain by the Karroo series appears favourable for a widespread circulation (e.g. the Great Karroo and the Springbok Flats) and in places as in the Auob and Nossob Areas, South West Africa such a circulation exists; but the character of the sediments is not equally favourable. The rapid change in character of the sediments along the strike and dip where sandstones are replaced by impervious shales and the presence of shales and shaly sandstones are not favourable for a widespread circulation of underground water. The presence of well developed joints and bedding planes is very favourable but the innumerable intrusions of intrusive dolerite and the low porosity of the sandstones again upset the rapidity and continuity of flow.

The structure of the Pretoria beds, a series of dipping quartzites and shales with intrusive diabases is highly favourable to a widespread circulation.

Not only do the major elements of the geological structure influence the underground water but minor features are equally, or possibly even more important. These minor features exert a great influence locally upon the occurrence of the water. Most failures to obtain adequate supplies of water are due to locating the site in a structurally unfavourable place.

The/...

The numerous igneous intrusions into the sedimentary rocks play a great part in affecting the circulation of underground water in the intruded rocks, springs often occur in the vicinity of these intrusions. The chief examples are the intrusive dolerites in the Karroo Series, the intrusive diabase sills in the Pretoria series, the dykes and quartz veins in the Dolomite and the crystalline rocks. In dissected areas underlain by schist or gneiss boreholes should be located so as to take advantage of the accumulation and circulation of the underground water as shown in Fig.5.

Fig.5.

A has a small catchment area, and water that seeps into the ground moves down the planes of schistosity. B has a larger catchment because water is available from the schistosity planes intersected and supply is augmented by water moving down the joint planes. This principle is applicable in many of the areas underlain by the crystalline rocks.

Thus as can be seen and as is mentioned often further on the minor structures play a very large part in underground water conservation.

ARTESIAN CONDITIONS.

The term artesian is used here not to denote any borehole in which the water rises above the water-table or local underground water level(1), but boreholes in which the hydrostatic pressure is sufficient to raise the water level above the surface of the ground.

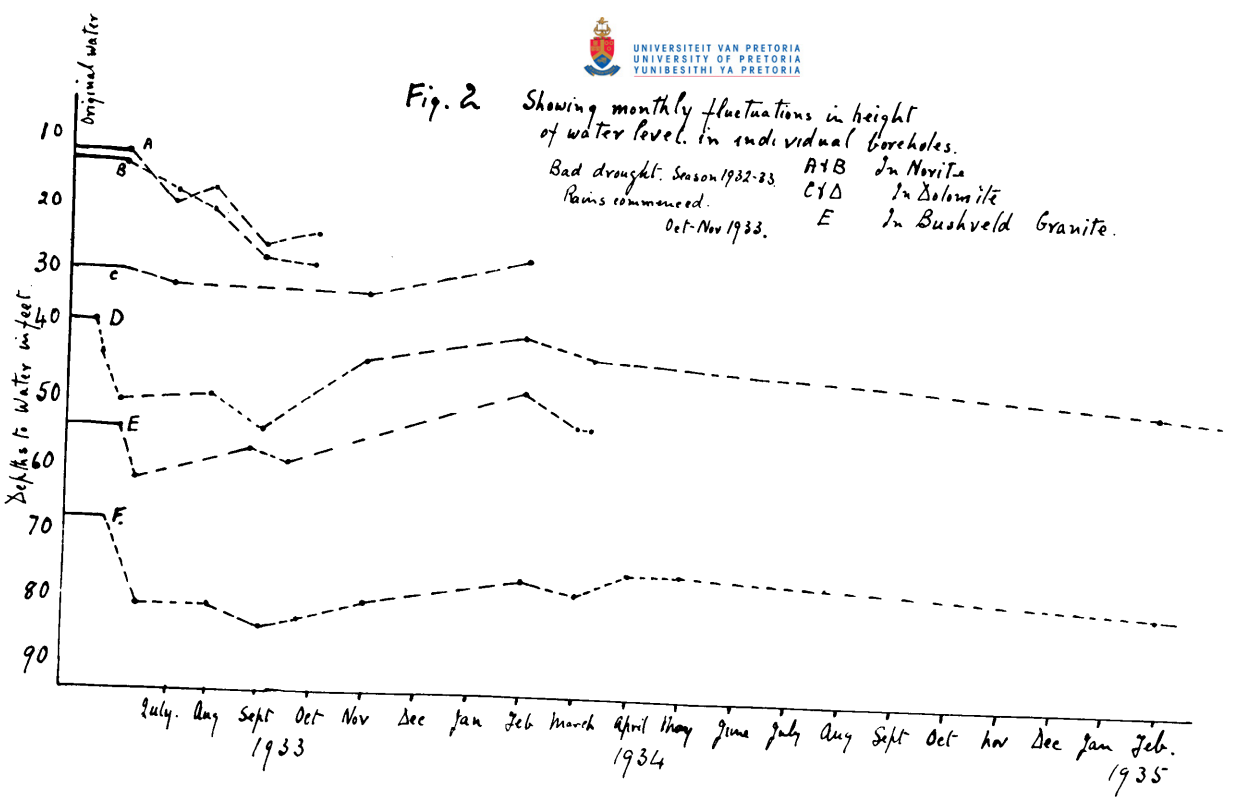
There/...

(1) O.E.Meinzer - Outline of ground-water hydrology with definitions. U.S.G.S.W.S.P. 494.

Fig. 2 Showing monthly fluctuations in height of water level in individual boreholes.

Bad drought: Season 1932-33.
Rains commenced.
Oct-Nov 1933.

A & B In Norite
C & D In Dolomite
E In Bushveld Granite.



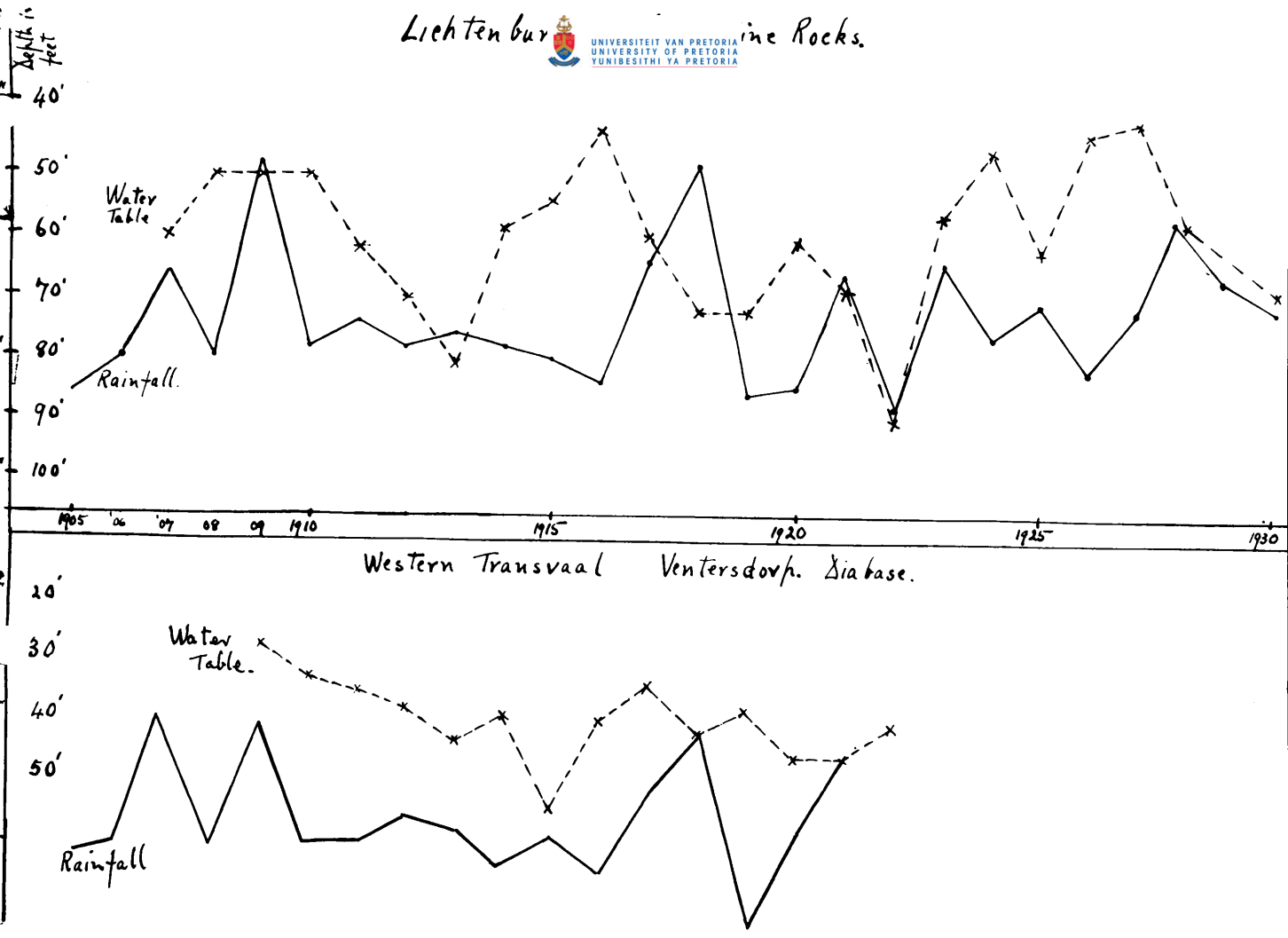


Fig 3

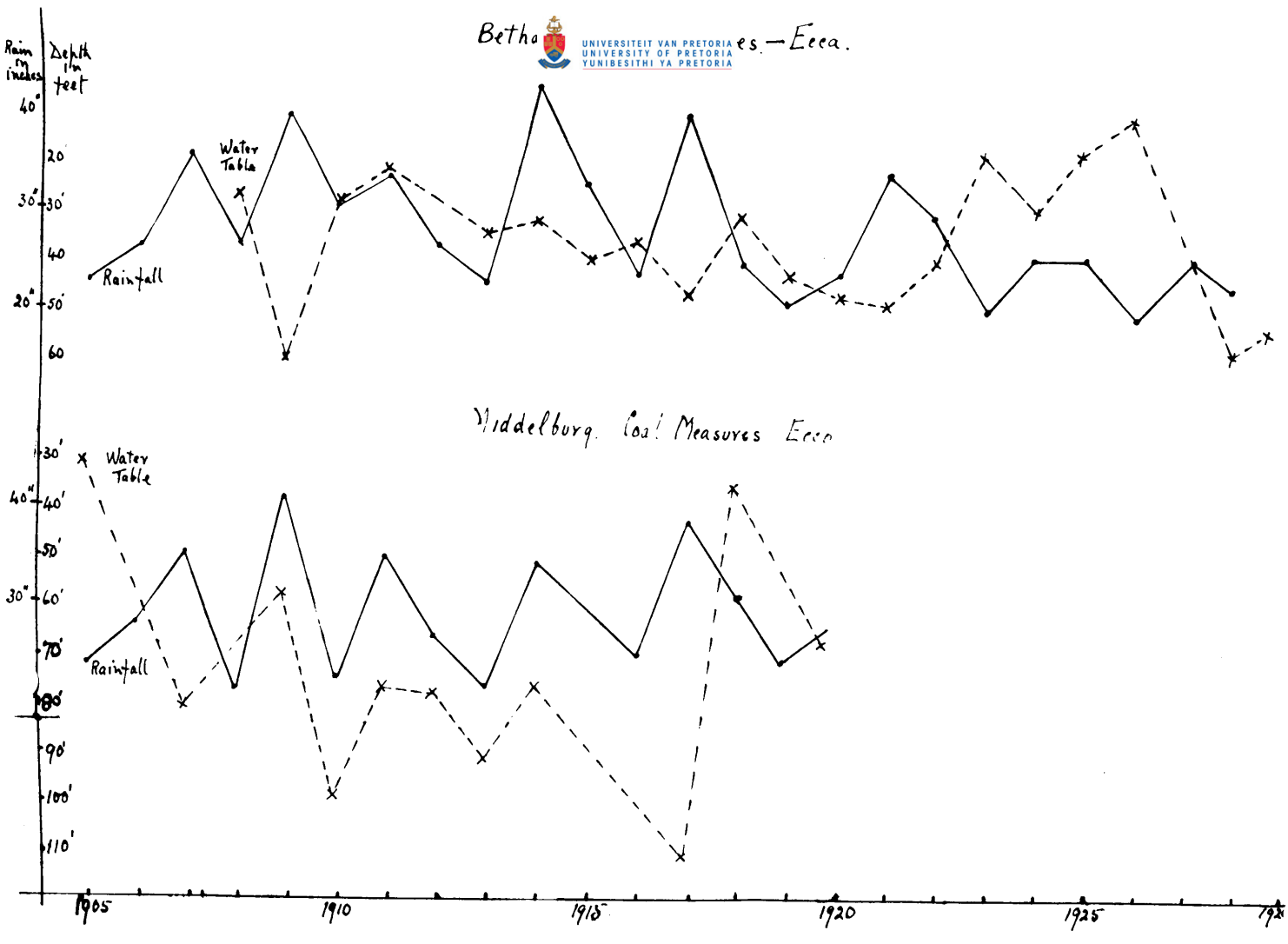


Fig. 4.

There are no large artesian basins or slope structures in the formations dealt with here. Artesian areas of small extent are to be found in the Karroo Series in Gibeon District[2] South West Africa in the Dolomite Series in the Springs and Barkly West Districts and in the Crystalline Rocks in Namaqualand.[3] A few odd flowing boreholes are due to relatively local structures.

The Great Karroo and the Springbok Flats areas both possess the requisite structure but according to du Toit in the case of the latter "The intake area on the north may be insufficient, the beds themselves are not conspicuous for permeability, while there are certain concealed ridges, which might interrupt the movement of water along the bottom of the basin. Such a barrier was struck in the 1546 foot borehole on the farm Diepsloot, while practically all the other deep borings, from 500' to over 800' have given only limited pumping supplies.

There is even less reason for supposing that the Great Karroo constitutes an artesian area. The porosity of the sandstones is low, while the formation is intersected by a maze of dolerite intrusions, which would act as barriers to the underground circulation.

In the Gibeon District South West Africa,[4] a fairly uniform dip of the pervious Ecca sandstone has produced flowing boreholes, which occur along the Auob and Nossop Rivers.

In the Dolomite area a few flowing boreholes are reported. These evidently penetrate solution channels that

contain/...

---

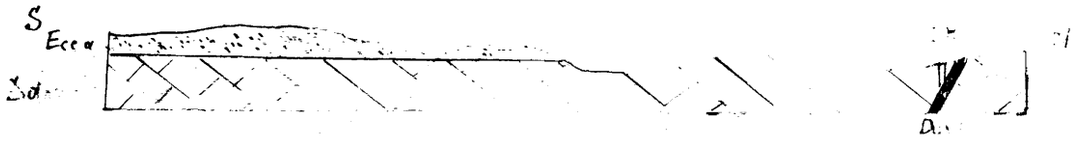
(2) H.F.Frommurze - Flowing boreholes in the Gibeon Rehoboth and Gobabis Dists. S.W.A. (T.G.S.S.A.)

(3) Merensky H. Artesian Water in Namaqualand. Joh. S.A.M. Eng. Jl.1928. No.1898 pp.627-628.

(4) A.L.du Toit. Geology of S.Africa.

contain water under sufficient head to make them overflow. Unless the channel is closed at or near the lower end there is not likely to be sufficient head to produce a flowing borehole.

Fig. 6.



On the farm Goedgedacht 38, District Springs, Transvaal, a borehole sunk by the African and European Investment Company struck water at 450' in broken dolomite which rose to the surface and flowed at the rate of 8,000 gallons per hour; at 1800' the borehole pierced an igneous dyke. (Fig.6.)

The borehole at the Hotel in Delmas in the same district about 5 miles away flows at the rate of 100 gallons per hour under evidently similar conditions. At Boetsap in the Barkly West District, Cape Province, a borehole overflowed under similar conditions. The Dolomite forming high ground to the west and a shale band formed the impervious layer.

An unusual occurrence of artesian water in the area underlain by the Crystalline rocks in Namaqualand has been described by H.Merensky.(x)

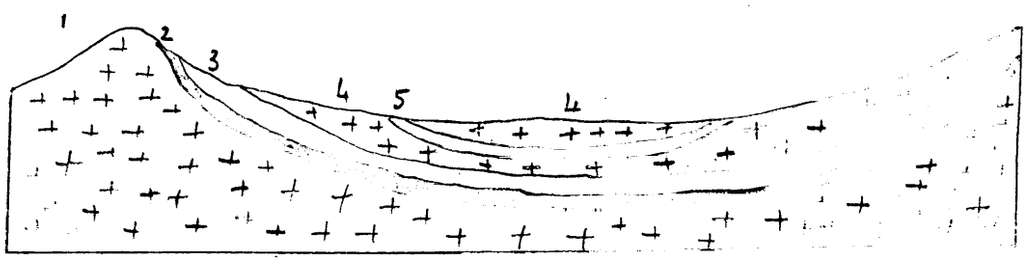


Fig.7. After Merensky.

Merensky points out the novelty of this occurrence where jointed and laminated gneiss forms the aquifer and quartzite (2) the impervious bed. Boreholes in this area have yielded up to 6,000 gallons per hour, the water being under

high/...

(x) H.Merensky. Artesian Water in Namaqualand. Joh.S.A.M. Eng. Jl.1928.No.1898 pp.627-628.

high pressure.

He states further that he has been able to locate five similar synclines and has found that not only the troughs but also the limbs of the structures are capable of yielding considerable supplies.

A further possible area of artesian water is the western extension of the Sunday River Valley (2) where Stormberg lavas and tuffs lying in a basin with impervious Stormberg clays and marls below may provide water under pressure. The quality of this water is very doubtful as mos of the ground water in the locality is brack.

---

(2) H.F.Frommurze. Chapter on Underground water in the Explanation to Sheet 150 Sundays River.

CHAPTER II.

THE WATER BEARING PROPERTIES OF CRYSTALLINE ROCKS.

INTRODUCTION.

These rocks have been extensively bored into for water because boring has been the only means of supplying water to large areas and so making these tracts available for settlement. This is especially so in the case of the drilling done by the Government, as very large areas in the Northern and Western Transvaal and in Namaqualand and Bushmanland which are being opened up and settled under the Land Settlement Policy are underlain by the Crystalline Rocks.

In 1925 10% of the boreholes sunk by the Government since the date of Union penetrate the ancient granites and gneisses.(x I) To-day this figure has risen to twelve percent.

Most of this drilling activity in these rocks has taken place in the Northern Transvaal (see Fig.8) followed by the Western Transvaal and Bechuanaland, while the North-Western Cape has only a few boreholes in comparison with its dimensions.

TOPOGRAPHY.

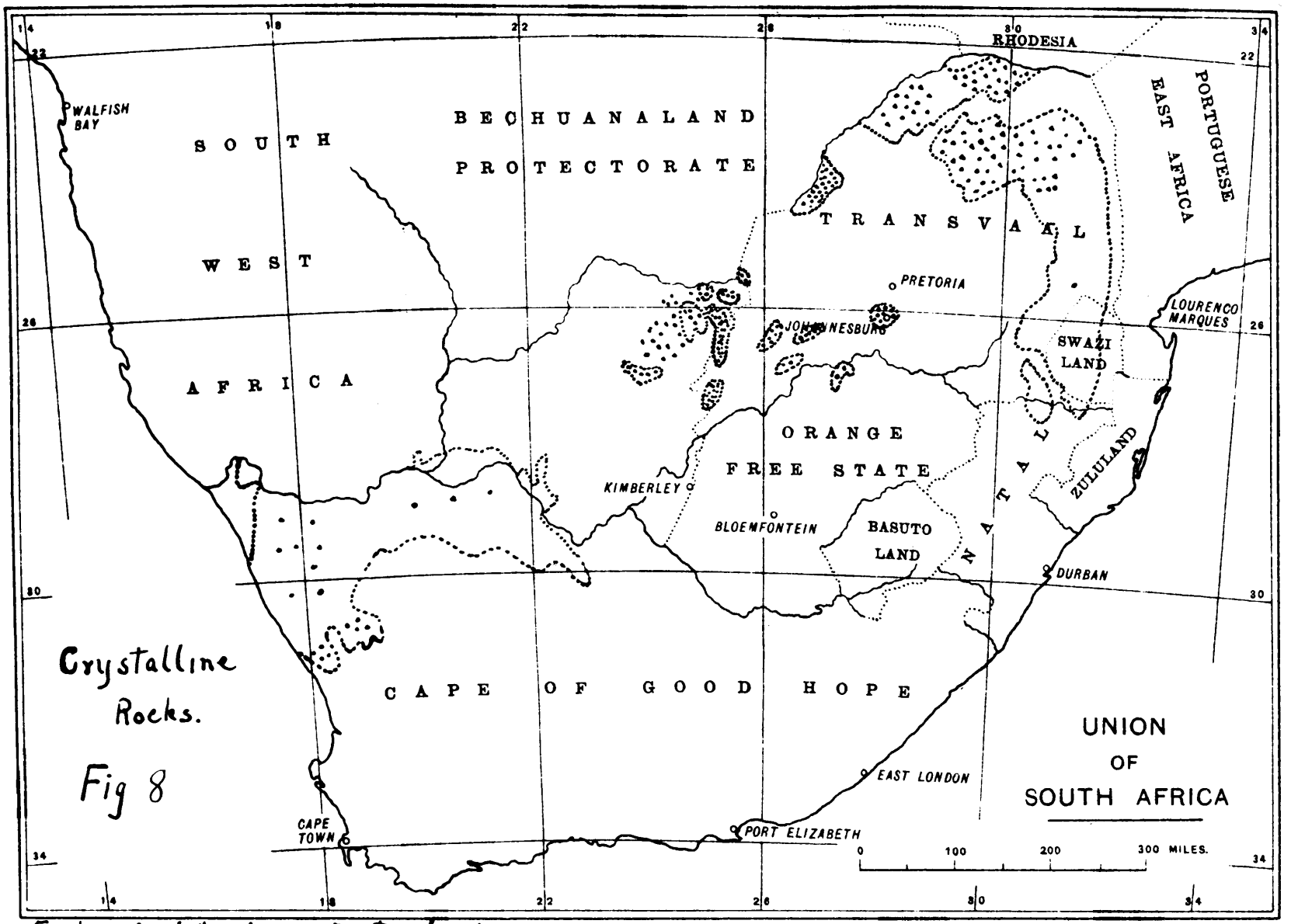
Du Toit(x 2) divides the whole area of Crystalline Rocks up as follows:-

"(a) Barren ranges and rock floored valleys with curved surfaces scaling off under insolation (as in the arid central belt of Namaqualand); (b) bare exfoliating hills rising from a plain of deep red sand that is mostly underlain by

the/...

(x I) Du Toit Borehole Water Supplies in South Africa Trans. and Mins. of Proc. S.A.Soc.C.E.

(x 2) Du Toit Loc cit.



the more gneissic and friable types (Bushmanland); (c) bush-clad undulations and flats with reddish soil and bare knobs or tors (Pietersburg); (d) rolling country with coarse pale soil concealing the decomposed rock and showing few outcrops (Western Transvaal); (e) red sandy, bush-covered plains with the fresh rock close to surface in places (Eastern Lowveld); and (f) bushy plains with great thickness of superficial deposits concealing the solid rock as in Northern Rustenburg, Mafeking, and Vryburg".

WATER SUPPLIES.

The quantity of water available from the underground supplies in these rocks is dependent upon their behavior under weathering, which in its turn depends upon, firstly, rainfall and, secondly, topography. This is illustrated by the following table:-

DISTRICT OR AREA	ANNUAL AVERAGE RAINFALL	DEPTH TO WATER	AVERAGE YIELD PER BOREHOLES IN GALLONS PER DIEM	PERCENTAGE OF FAILURES.
Van Rhynsdorp	5"	121'	7460	44
Kenhardt	5"	93"	9270	58
Namaqualand & Bushmanland	5-10"	91'	12070	47.3
Vryburg	15"	94'	16600	30
Mafeking	20"	98'	18730	36
Northern Rustenburg	20"	117'	18500	59
Western Transvaal Schweizer Reneke-Christiana	18"	57'	19000	25
Lichtenburg	20"	40'	28240	7.5
Ventersdorp, Klerksdorp Wolmaransstad	22"	33'	25560	25
Pretoria-Johannesburg	35"	47'	24900	22
Northern Transvaal Waterberg	15"	80'	10400	55
Potgietersrust	20"	79'	16430	30
Zoutpansberg	23"	77'	19700	23
Pietersburg	30"	65'	20400	20
Letaba	33"	70'	25200	34
Barberton	35"	60'	42700	30

It is seen that the yield and the depths for each area react to the increase in the rainfall; this result being modified by excessive weathering in the rock, when the yields drop. The same happens if the position of the site is far from a drainage line when the percentage of failures increases.

In conclusion it may be stated that it is almost impossible to foretell the success of a borehole in the crystalline rocks. The chances of success are 7 in 10, but this varies in the different areas according to the topography of the ground and the rainfall.

The water is to be sought for in (I) joints, decomposed areas i.e. if decomposition (x4) has not gone too far so as to seal the passages within the rock (3) in and against diabase dykes and sills, quartz and pegmatite veins, crush zones, etc.

The magnitude of the supplies obtained are surprisingly good averaging 7500 ——— 28000 gallons per day at average depths from 60 - 200' which compares favourably with results obtained in the United States of America (xI) (13000—28000 at depths of from 30 to 300'), in Kenya (x2) where an average of 24,400 gallons per day was obtained at 154', and in Southern Rhodesia 2000 - 20,000 gallons per day. (x3)

Distribution/...

(xI) Ellis.E.E. Occurrence of water in crystalline rocks U.S.G.S.W.S.P.160.

(x2) Sikes H.L. Underground water resources of Kenya Colony. Kenya Colony and Protectorate.

(x3) Dixey A practical handbook of water supply.

(x4) Sandford K.S. Sources of water in the N-W Sudan p.412 Geographical Journal London, Vol.LXXXV No.5 May 1935.

DISTRIBUTION OF THE CRYSTALLINE ROCKS.

(1) In the Transvaal

(a) Northern and Eastern Transvaal. Comprising Pietersburg, Zoutpansberg, Waterberg, Rustenburg, Letaba, and Barberton.

(b) South Western Transvaal, Bloemhof, Christiana, Wolmaranstad, Klerksdorp, Lichtenburg and Ventersdorp.

(c) Johannesburg - Pretoria mass.

(2) In the Cape Province

(a) Mafeking and Vryburg.

(b) Kenhardt, Prieska, Van Rhynsdorp, Bushmanland, Namaqualand.

(1a) The Crystalline rocks in the Northern and Eastern Transvaal. (x1) & (x2)

The granitic and gneissoid comples occupies practically the whole of the low-lying portions of the surface of the country stretching northwards from the ranges south of Pietersburg to the Limpopo and beyond. Eastwards it is continuous with the area underlain by granites, gneisses, and schists which extend from Pietersburg beyond the Murchison Range along the lower courses of the Selati, Letaba, and Olifants Rivers.

The country north of Pietersburg, however, differs from that to the east and especially from that about the Murchison Range in the comparatively small development of the more basic types of Schist. The rocks of the northern portion of this area include many massive types in which a gneissic structure is only feebly developed and which appear to have been derived entirely from rocks of igneous origin.

An enormous variety of rocks is to be found in this/...

(x1) Traverse of Zoutpansberg G.S. Tvl. Rept. 1906.
(x2) A.L.Hall - Handbuch der Regionalen Geologie Band VII - 7a - Union of S.A.

this area; massive granites, gneissic granite and true gneiss occur, the variation being due to differential movement during consolidation. Basic Schists, Marbles, and Quartzites belonging to the older rocks invaded by the granite, coarse masses, dykes and sills of pegmatite; younger basic intrusion, dolerites and gabbros; and various rocks formed by assimilation of older formations by the granite all play their part in the general complex. Weathering is extensive, both chemical and mechanical, and large areas of porous decomposed rock are produced which extend downwards to more than fifty feet where the rainfall is heavy as along the Drakensberg Escarpment.

In the Low Country mechanical weathering predominates with production of typical rounded forms; this is also seen in Pietersburg District.

Country underlain by the Crystalline Rocks is generally fairly well bushed - and covered with red and white sandy soil on the flats.

UNDERGROUND WATER SUPPLIES

Operations for boring for water have been carried out extensively in this northern and north-eastern area and up to the time of writing the results from 800 boreholes have been reviewed.(x3) The results are as follows:

District./...

(x3) A.L. Du Toit - Borehole Water Supplies in the Union of S.A. Trans. Mins. Proes. S.Af. Soc.C.E. 1928.

DISTRICT	WATERBERG	POTGIETERSRUST	ZOUTPANSBG.	PIETERSBG.	LETABA	BARBERTON
No. of holes	20	75	332	283	77	19
Av.depth in ft.	166	136	150	146	150	164
Av.depth at which water is struck.	122'	98'	108'	100'	100'	103'
Av.depth to which water rises(rest level).	80	79	75	64	70	60
Av.daily quantity in gallons.	10400	16430	23500	19400	25200	42700
Per cent of failures	55	30	24.4	25	34	30
Per cent of holes striking water at depths greater than 300'	-	-	0.6	-	-	-
Per cent of holes deeper than 300' striking water above 300'	-	-	6	2.4	-	5
Per cent of holes deeper than 300' blank.	10	3	3	2.1	3	-
Annual av.rainfall in inches.	15	20	23	30	33	35

A consideration of these interesting results show a rising yield with the increase in rainfall proceeding from west to east reaching a maximum in the Zoutpansberg District. Thence proceeding southwards and eastwards there is a pronounced fall in the Pietersberg area though the rainfall is increasing, indicating the fact that this rainfall has not such easy access to the countr rock, probably due to the thicker covering of soil and the extreme effects of weathering, the result being to close the crevices and pores with argillaceous and colloidal material hindering infiltration.(1) This point is further stressed when the results obtained in the crystallines in the Barberton District are considered where the rainfall is from 25 to 40". Here although phenomenal results have been obtained at selected spots, the effect of the extreme chemical weathering is very obvious.

Thirty per cent (30%) of the boreholes are failures and in the log of each is reported "decomposed rock, running sand, running mud" etc., indicating that the texture and cohesion of

the/...

(1) Borehole Water Supplies in S.A. by Du Toit and the Journal of the Hyderabad Geol. Surv.Vol.2 pt.2.W.S.P. No.1 Capt. Leonard Munn.O.B.E.

the rock has been destroyed by decomposition.

The high percentage of failures from the Letaba is due to the above causes with the addition of large areas of close grained schists, which have been found to give poor results when drilled into,(1) especially so when the drilling takes place away from the main surface drainage lines, differing in this respect from the area round Bandolier Kop Northern Transvaal, and the Genesa block in the Vryburg district.(1) This fact is particularly noticeable along the Murchison Range where, when the drilling takes place away from the course of the Selati River or its tributaries, results are poor and failures increase.

A further noticeable feature is that although the mean level of the water when struck differs by 22' in the different areas, the mean rest level differs by only 20', Drilling to depths exceeding 300' in this section of the crystalline rocks would appear to be of no value. Failures are high but include all holes not giving more than 1000 gallons per 24 hours, also those which were abandoned owing to various technical difficulties met with by the driller.

On separating as far as possible the results obtained from the different types of rock the following are obtained:-

(1) SCHISTS.

	Pietersburg.	Zoutpansberg.	Letaba
Av.total depth of borehole in ft.	173	143	160
Av.depth at which water was struck in ft.	116	119	110
Av.depth to which water rises in ft.rest level	83	80	81
Av.daily yield in galls.	12000	12200	20000
Percentage of failures	11	11	36

(2) Crystalline/..

(1) Borehole Water Supplies in S.A.by Du Toit and the Journal of the Hyderabad Geol.Surv.Vol.2 pt.2.W.S.P. No.1. Capt.Leonard Munn. O.B.E.

(2) CRYSTALLINE LIMESTONES.

	Pietersburg	Zoutpansberg	Letaba
Av.total depth of borehole in ft.	104	145	
Av.depth at which water is struck in ft.	58	124	
Av.depth to which water rises in ft.rest level	38	97	
Av.daily yield in galls.	35600	18950	

(3) BASIC INTRUSIONS (DIABASES, GABBROS,ETC.)

Av.total depth of borehole in ft.	150	144	125
Av.depth at which water is struck in ft.	110	107	71
Av.depth at which water rises in ft.rest level	71	73	49
Av.daily yield in galls.	23150	26090	35000
Percentage of failures	22	18	27

The points brought out by the above tabulation are the comparatively poor results obtained in the schists, and the high yields from the basic rocks. The limestones vary greatly in their results in the two districts quoted which may be due to the chemical weathering which has had a bad effect on the water-carrying properties of the granites, but makes the limestone better aquifers by enlarging more rapidly the solution cavities and channels.

The conclusions arrived at from a study of these results, and also of the probability curves attached (see Figs.8.a,b,c,etc.) are:

(1) That if boring sights are scientifically selected there is a fair chance of getting water until a depth of 180' is exceeded; below this depth the possibility is remote and drilling becomes speculative.

(2) One in every four boreholes is likely to be a failure increasing to one in every three in Letaba and

Potgietersrust/..

Potgietersrust, and one in every two in the Waterberg. This is due to a variety of causes, drilling on unlikely sites, not continuing operations to a requisite depth, various accidents during the course of drilling making it more economical to move the site, extreme conditions of weathering, and the presence of unfissured blocks which consequently contain no water.

(3) Schists should be avoided where possible and the basic intrusions be taken advantage of, as the latter act (a) as underground dams to the water in the porous zones and joints, (b) cause subsequent minor jointing and fissuring in the surrounding rock, (c) are more jointed, fissured, or decomposed than the surrounding rock and thus carry the water themselves. The same applies to quartz reefs, aplite and pegmatite dykes, etc.

(4) The futility of drilling below a depth of 300' in the hope of getting a supply of water is made very obvious by the figure of 0.6% of holes which strike water below that depth. The rest of the holes deeper than 300' either strike water above that depth or are total blanks.

(5) Apart from the surface decomposition which gives rise to basins and zones of porous rock the water is associated chiefly with the joints which the probability curve seems to indicate are about 20 to 40' apart, and are weathered and porous from 5 to 10' on either side. The hard fresh rock does not carry water. (x)

Summary/....

(x) K.S. Sandford Sources of Water in the N.W. Sudan Geog. Journal Vol. XXXXV 5. May 1935.
C.W. Grabham. Water Supplies in the Anglo-Egyptian Sudan Khartoum p.34./93

SUMMARY OF BORING RESULTS.

QUANTITY IN GALLONS PER DIEM.

PIETERSBURG CRYSTALLINES.

ept in feet	Total No. of bore-holes from which information was obtained	QUANTITY IN GALLONS PER DIEM									
		1000	1 - 10000	10- 20000	20- 30000	30- 40000	40- 50000	50- 60000	60- 70000	70- 80000	80- 90000	90- 100000
0-50	29	2	7	6	2	3	2	4	2		1	
51-100	86	3	29	25	7	6	4	4	2	2	4	
101-150	48	1	22	12	3	2	1	1		5	1	
151-200	25	2	12	4	1	2	1	2		1		
201-250	12		9	1	1		1					
251-300	2		1			1						
TOTALS	202	8	80	48	14	14	9	11	4	8	6	
ZOUTPANSBERG CRYSTALLINES												
0-50	37		2	6	3	5	1	5	3	9	3	
51-100	89	2	26	19	19	6	2	2	4	8	1	
101-150	77	1	36	20	6	3	3	4		3	1	
151-200	44		21	13	4	2		2		2		
201-250	12		9	2	1							
TOTALS	250	3	94	60	33	16	6	13	7	22	5	

CRYSTALLINE ROCKS IN THE NORTHERN RUSTENBURG DISTRICT.

DISTRIBUTION

The area underlain by these rocks in this district lies to the north of the Witfontein Rand and is bounded by the Marico and Crocodile Rivers.

The formation consists of coarse grey and pink granite and biotite gneiss. Veins of quartz and pegmatites are of frequent occurrence, and there are also dyke-like intrusions of diabase.

Exposures are rare. The country is flat with gentle slopes towards the rivers. Extensive deposits of deep sandy red and brown soils are interrupted occasionally by belts of grey or black clayey soils (black turf). A little "ouklip" and some surface limestone is to be seen associated with the

turf./....

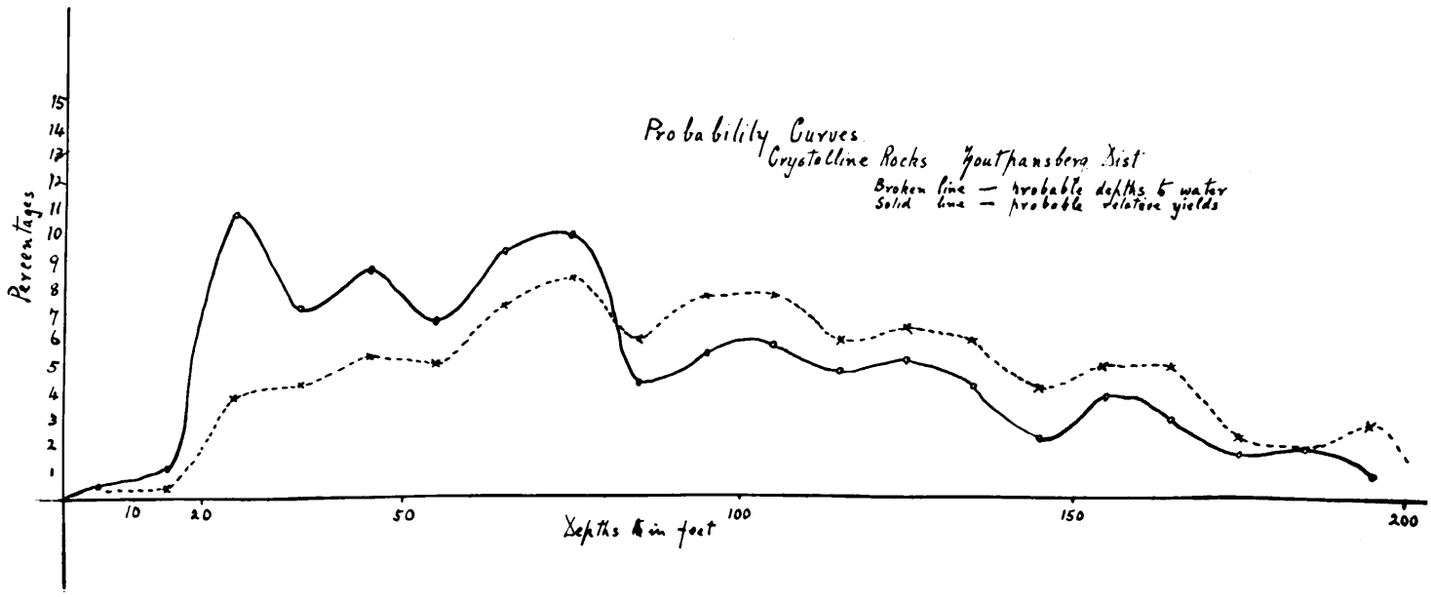


Fig. 8a.

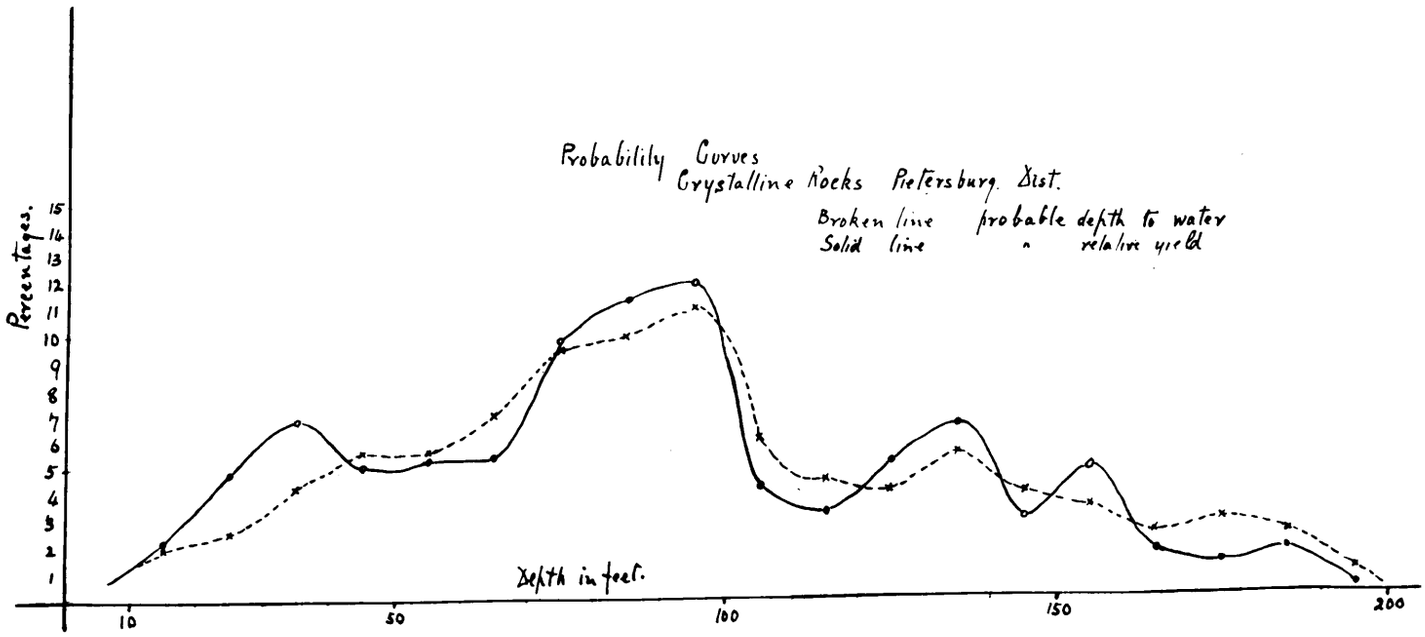


Fig. 8b.

turf. These belts usually follow the lines of drainage, and the limestone has undoubtedly been derived from the dolomite of the Witfontein Rand to the South, having been brought down in solution in times of flood from that quarter A few miles to the South-west of the Crocodile River and running roughly parallel to it is a more undulating belt of country along which exposures of granite and gneiss are fairly common, especially about the locality known as Witpoortje on the road from Holfontein to Oolies Drift.

The Calcareous Tufa is often found beneath the soil covering and in places attains a great thickness. Especially so is this along the Holfontein and the Khamanianes sloots where it occurs in rather marked zones. The average thickness of the limestone as calculated from the measurements made in 60 boreholes is 56'. It is remarkable that this considerable overburden of a porous and absorbent nature does not seem to have any effect on the water supplies obtained and with the exception of one case, B.H.No.3547 does not carry any water itself, particularly as it has been noticed that large floods from the south are rapidly absorbed on these plains (x) nor does the absence of this covering occur where there are failures because in the case of 31 holes which failed to strike water the average depth of the tufa was 48'.

The rock is often found decomposed to considerable depths, as much as 195' having been reported, while a further feature of this rock is its broken nature which according to borehole logs persists to depths of 140'-150'. In one case a six inch vein of decomposed material carrying water was reported at a depth of 216' from the surface.

Observation/...

(x) Du Toit.A.L. Borehole water supplies in the Union of South Africa.

Observation in the field has shown that this decomposed and jointed granite carries most of the larger supplies of water, and in this way it is similar to the crystallines further north and east. A point of difference however is that the schistose and foliated varieties of rock are apparently in no way superior to the compact granites in their water bearing capacities, which is different to the occurrences N and S. In the same way the basic intrusions prove to be poor water carriers here as they are in the Pretoria-Johannesburg area and differ from those of the northern area where they are superior to the invaded rock.

The jointed nature of the rock on the other hand has its disadvantages as the joints tend to deflect the drill from the vertical and many of the failures are due to this cause, as the boreholes have to be abandoned before reaching the depth necessary to obtain water. In other cases cavities developed along joints absorbed water to such an extent that drilling had to be abandoned.

UNDERGROUND WATER SUPPLIES.

The averages calculated for the 234 boreholes sunk in this area up to date are set out below:-

		Diabase only.
Number of holes	234	37
Average total depth of borehole in feet.	188	203
Average depth at which water was struck	160	170
" " to " " rises	117	124
Average daily footage yield in gallons	18,500	17,200
Percentage of failures	50	59%
Percentage of holes drilled deeper than 300' which strike water below 300'	Nil	
Percentage of holes which strike water above 300'	2.5	
Percentage of holes which are totally blank	Nil	

Two facts emerge from this analysis

(a) The waters are very deep here and

(b) The failures are higher than in any other part of the Union;

but in spite of these adverse features, the yield per

successful/....

successful borehole is distinctly good.

SUMMARY OF BORING.

NORTHERN RUSTENBURG CRYSTALLINES.

Quantity in gallons per diem.

Depth in feet	Total No. of boreholes from which information was obtained.	1000	1-10000	10-20000	20-30000	30-40000	40-50000	50-60000	60-70000	70-80000	80-90000
0-50											
51-100	21	2	8	4	1	1		2	1		
101-150	30	5	8	9	3		2	2			1
151-200	48	4	20	14	3	4	2	1	2		
201-250	15	1	4	7	1	2					
251-300	3		2	1							
TOTALS	117	12	42	35	8	7	4	5	3	-	1

In connection with the high number of failures it should be pointed out, however, that 30% of these were abandoned for various reasons before they were deep enough. In this formation if the rock does not get too hard, no hole should be abandoned before a depth of 250' is reached except for reasons of economy. A further 20% of the failures struck water but less than half a gallon a minute.

That there are localities practically without underground water in this area seems to be the case, for on the adjoining farms Smithfield, Worcester, and Swellendam a total of 10 boreholes failed to give a practical supply of water. Others with similar unfortunate records are Merino Walk, Middelveld, Zuurverdiend, Moorland 449, Modderpan 792, Tartentaal Pan (Portion of), portion of Hartebeestkuil; Loggerinde Hoek and portion of Tyldindal 61. It would appear that here as in Mafeking the results from the crystallines are always better along the "laagtes" than on the bults differing from the findings in the area around Bandolier Kop and the Genesa Block.(xl)

(xl) Du Toit A.L. Borehole Water Supplies in the Union of South Africa.Trans.of Mins.of Proc.of S.Africa.Soc. C.E.1928.

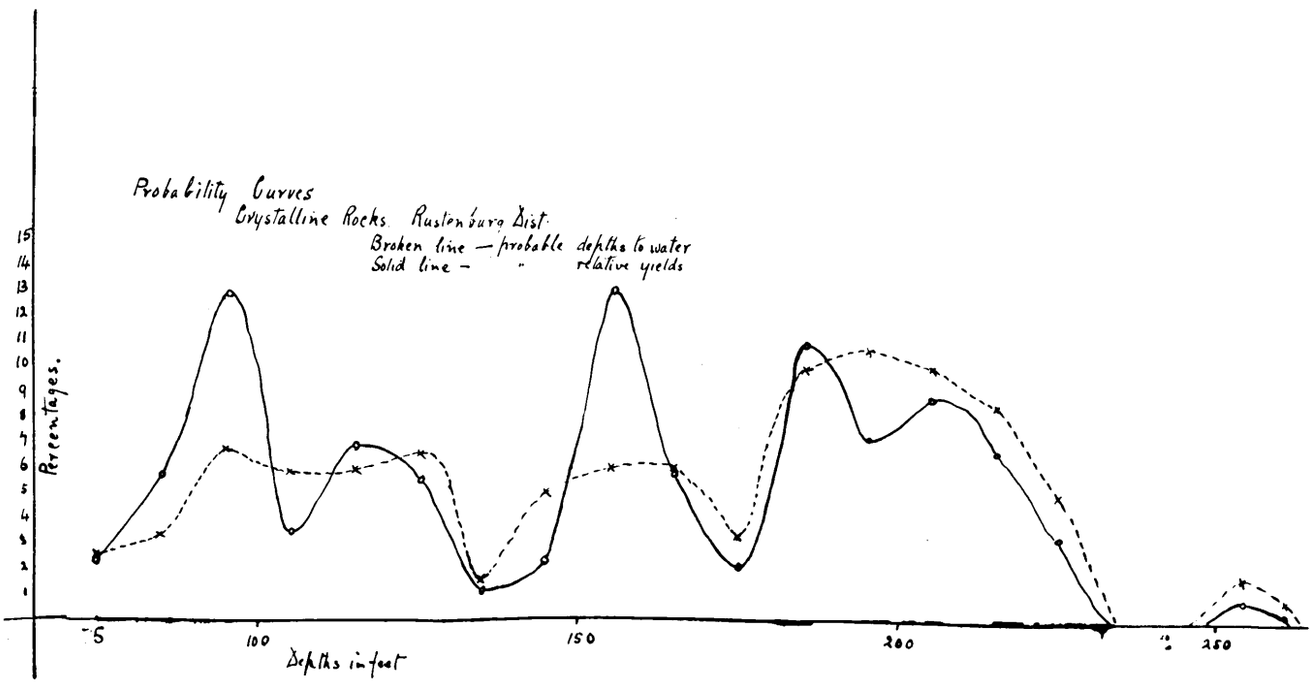


Fig 8c

(1b) The Crystalline Rocks in the Western Transvaal.

DISTRIBUTION.

Comprising three large exposures (a) in the Ventersdorp-Klerksdorp and Wolmaranstad Districts; (b) in the Lichtenburg District and (c) in the Schweizer Reneke and Christiana Districts, the rocks are exposed by folding and denudation or denudation alone of the overlying Ventersdorp and Witwatersrand Series.(x2)

The outcrops, which are not common, usually occur as low banks along streams or in valley bottoms such as in the case of (a) the Schoonspruit Valley; (b) the Hartz Valley and (c) the Jagdspruit Valley. The country underlain by these rocks is generally low and slightly undulating and extensive deposits of sandy soil, alluvium and vlei deposits in the nature of grey clays and black turf effectively conceal most of the solid rock.

LITHOLOGICAL.

The rock is often highly decomposed at the surface and sometimes down to a considerable depth.(x2)

Specimens have shown that most of the rock is a medium grained grey rarely pink muscovite granite, schists are not common and are very seldom to be found as outcrops. Diabases are also rare.

The position of the rock on the lower ground, its degree of decomposition and the fair rainfall have combined to make this rock a fair underground water carrier as an examination of the results obtained by boring will show.

UNDERGROUND WATER SUPPLIES.

In the first area comprising portions of the

Ventersdorp-/...

(x2) Molengraaf. Geology of Portion of the Klerksdorp Dist. T.G.S.S.A. 1905.

Ventersdorp-Klerksdorp and Wolmaranstad Districts the results of 67 boreholes have been examined and the averages are as follows:-

Average total depth in feet	104
" depth which water was struck	66
" depth to which water rises	33
" daily quantity in gallons	25,560
Percentage of failures	17.9
(1) Total failures	25%
(2) Insufficient water	66%
(3) Not deep enough	9%
Percentage of boreholes deeper than 300'	Nil

In the second area which lies entirely within the Lichtenburg district the following results were obtained:-

Number of Boreholes	240
Average total depth of boreholes in feet	118
Average depth at which water was struck	85
Average depth to which water rises	40
Average daily yield in gallons	28,240
Percentage of failures	7.5
(1) Total failures	72
(2) Insufficient water below 1000gpd.	28
(3) Holes not deep enough	nil
Percentage of boreholes deeper than 300'	nil

The third area comprises portions of the Schweizer Reneke and Christiana Districts. The rainfall here is lower and the average results correspond.

Number of boreholes	105
Average total depth of borehole	118
Average depth at which water is struck	90
Average daily quantity obtained per borehole	19,000
Average depth to which water rises	57
Percentage of failures	25%
(1) Total failures	50%
(2) Water below 1000 gpd.	40%
(3) Holes not deep enough	10
Percentage of boreholes deeper than 300'	nil

SUMMARY/.....

SUMMARY OF BORING RESULTS.

LICHTENBURG CRYSTALLINES

Quantities in gallons per diem.

Depth	Total No of boreholes from which information was obtained	1000	1-10000	10-20000	20-30000	30-40000	40-50000	50-60000	60-70000	70-80000	80-90000
0-50	49		15	10	7	4	8	1		2	2
51-100	120	2	31	24	24	8	14	4		9	4
101-150	41	1	7	12	12	3	3		1	2	
151-200	12	1	4	4	1		1	1			
TOTALS	222	4	57	50	44	15	26	6	1	13	6

SCHWEIZER RENEKE - CHRISTIANA - BLOEMHOF CRYSTALLINES.

Depth	Total No.of boreholes from which information was obtained	1000	1-10000	10-20000	20-30000	30-40000	40-50000	50-60000	60-70000	70-80000	80-90000
0-50	16		5	2	1	2	2			3	
51-100	62	1	28	10	10	5	3	2		1	2
101-150	23	1	14	5	1		3				
151-200	3		2								
TOTALS	104	2	49	17	12	7	9	2		4	2

As seen the reduction in rainfall is followed by a reduction in yield and a greater depth to the supply.

(1c) Pretoria-Johannesburg "Crystalline Rocks".

The name "Old Granite", given to the rock which forms the greater part of this area, arose from the necessity of distinguishing these bodies from the later granitic intrusions forming part of the great Plutonic Complexes of the Bushveld and Palabora where the granitic rocks are known as the "Younger" or "Red Granite".

The latter rocks are also developed in the South and South Western Cape.

The Old Granite, together with associated schists forming the group which we have called the Crystalline Rocks, is the oldest formation in this area, and forms the floor

upon/...

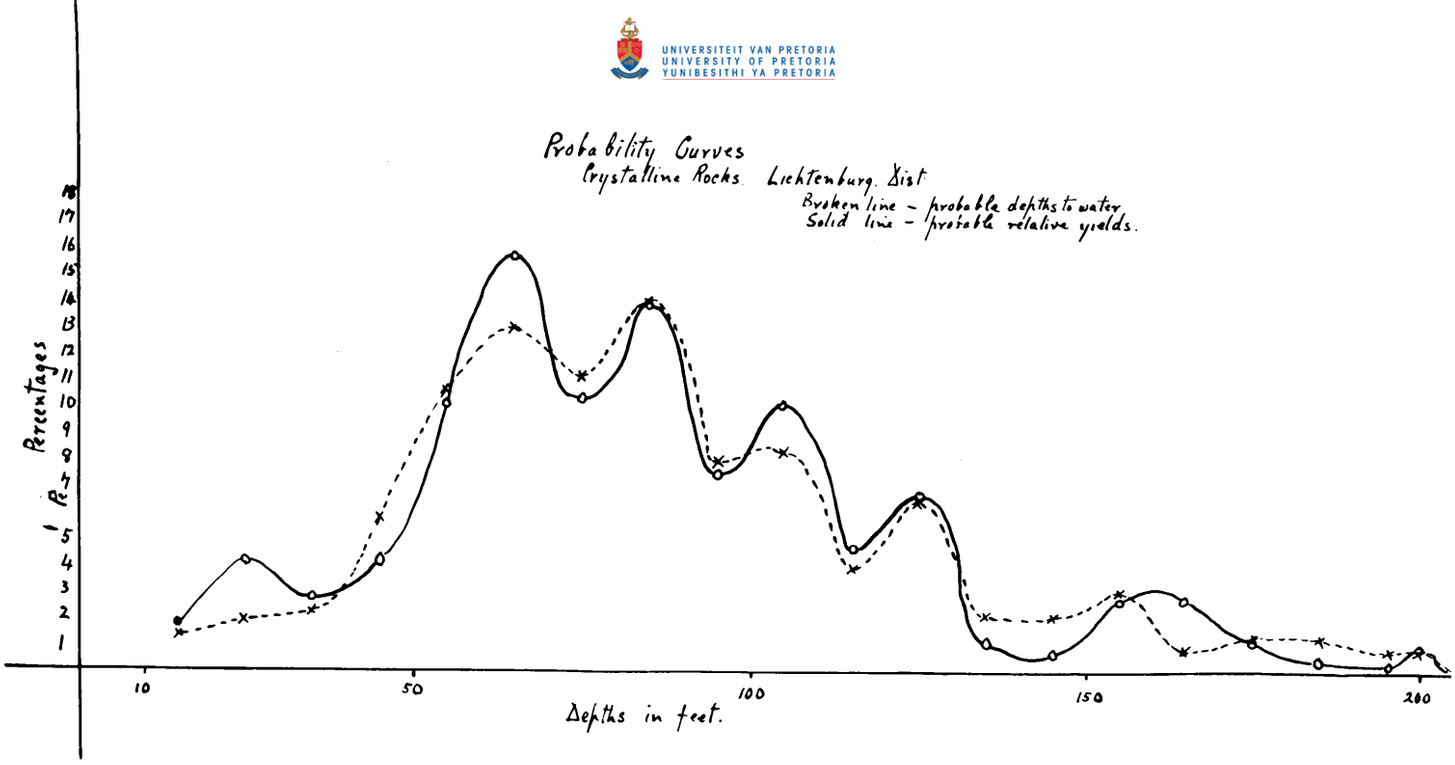


Fig. 8d.

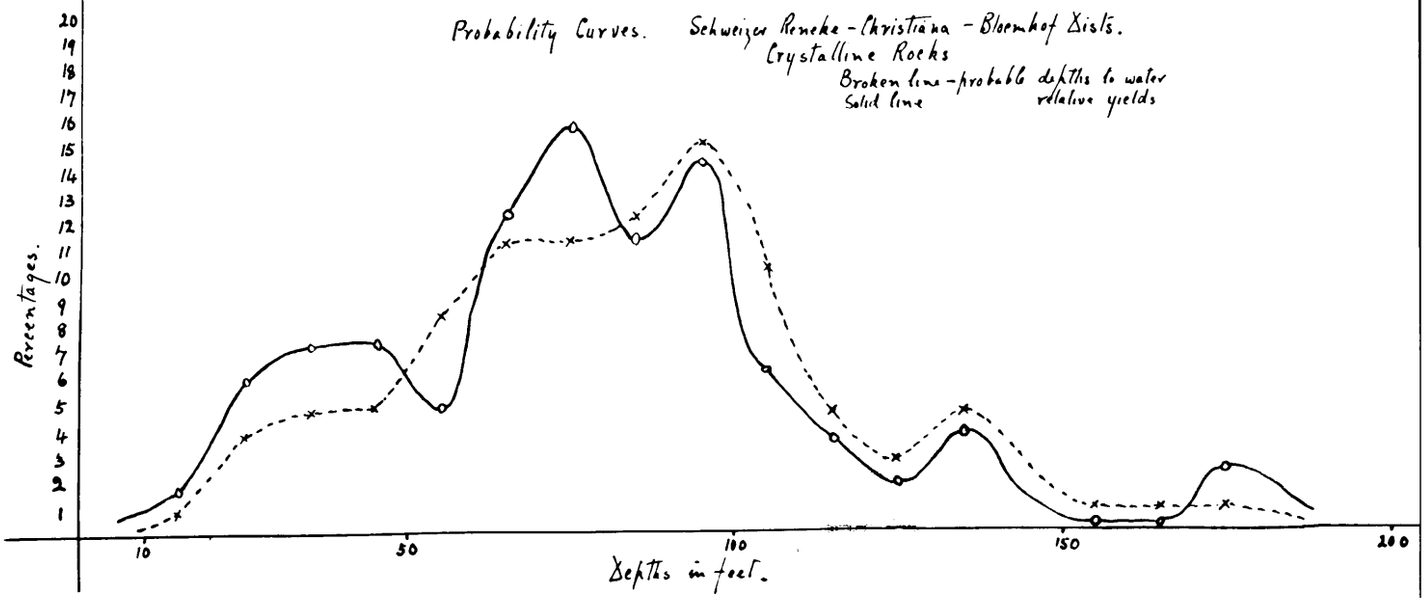


Fig. 8a.

upon which the oldest sedimentary formations have been laid down. It may be regarded as the central rock mass of the area both physically and geologically - representing a denuded granite dome from which the sedimentary formations dip away on every side.

DISTRIBUTION.

Situated between the towns of Johannesburg and Pretoria, immediately north of the former, it forms an extensive tract of comparatively low-lying undulating country consisting of alternating "bults" and "vleis". It terminates abruptly to the south against the well defined escarpment formed by the Witwatersrand System and to the north by the low ill-defined rise formed by the Black Reef Series.

The shape of the exposure is roughly elliptical measuring about 28 miles by 20 miles giving an area of approximately 300 sq.miles over which the granite is exposed.

The surface is covered by grass, but bushes only grow in narrow strips along stream courses, basic dykes, crush zones and along sheltered northern aspects.

Situated as it is on the northern slopes of the main watershed of the Transvaal, the drainage system consists of a number of small streams flowing in a general northerly direction together constituting the head-waters of the Crocodile and its tributary the Jukskei River.

LITHOLOGICAL:

By far the larger portion of the area is occupied by granite, the predominating type of which is a coarse pinkish-grey rock with a few flakes of white mica, and a little biotite and hornblende. Modifications of this type are frequent, usually less acid in character and occurring in well marked bands in the more acid rock. These

diorites/...

diorites are more common in the marginal portions of the area.

Highly foliated varieties are also met with especially along conspicuously developed lines of crush which traverse the area. Schistose rocks are common along the line of junction with the quartzites at the base of the Witwatersrand System. These variations have an important bearing on the water-carrying capacity of this group. Tough acid rocks identified as quartz felsites are found to the north of Krugersdorp near Mulders Drift, and small areas to the north and east of Krugersdorp and West of Zuurfontein are characterised by a series of basic rocks consisting mainly of amphibolites and Serpentines.

In addition the granite is traversed by numerous intrusive dykes and irregular bodies of rock generally classed as diabase, which also cut the Witwatersrand system. They show no signs of foliation and crushing, but at the contact the granite is often softened and crushed.

In close proximity to the central mass, yet separated by younger rocks and the Rietfontein fault of some magnitude is a long narrow strip of granite.

It outcrops intermittently from Elandsfontein No.11 a few miles East of Johannesburg, in an easterly direction as far as the farm Vlakfontein No.7.

North of the above locality and east of the central mass, the granite again appears at the surface on the farms Tweefontein No.16 and Zesfontein No.17C. It occupies an elliptical area four miles long and one mile broad, partially covered by thin Coal Measures. Surrounded by Black Reef Series dipping to the east and west it has apparently been exposed along an anticlinal fold with a north and south axis which is connected with an extensive system of faulting

extending/...

extending into the neighbourhood of Pretoria.

UNDERGROUND WATER SUPPLIES.

A total of 188 boreholes have been sunk in these rocks up to the present, and the results give the following averages:

(1) For the granite only

Average total depth in feet	130
Average depth at which water was struck in feet	94
Average depth to which water rises in feet	47
Average daily quantity in gallons	15,000
Percentage of failures	35%
" of holes deeper than 300'	2%
Exceptional supplies i.e. greater than 100,000 gpd.	0.7%

In the case of the failures 50% were total failures and 20% had insufficient water, in the case of the remainder holes were not bored deep enough. Of the holes over 300' none obtained water from below that depth.

(2) Average for the diabase intrusions and the schists.

	Diabase	Schists.
Number of holes	10	34
Average total depth in feet	133	132
" depth at which water was struck in feet.	90	94
" " to which water rises in ft.	45	39
" daily quantity in gallons	8,500	36,000
Percent of failures	30%	nil

The schists give exceptionally good results, followed by the granites the diabase yielding the least of the three, which is different to the results obtained in the districts of Pietersburg, Zoutpansberg and Letaba where the schists have the smallest yield and the diabases the highest doubtless due to lithological and topographical differences.

The position of the schists in this area at the base of the Orange Grove escarpment receiving the run off from the hard lower Witwatersrand Series is such that the replenishment of the underground water is large. This coupled with their porous nature gives conditions which are

suitable/...

suitable for the development of the large supplies.

That the diabases themselves give poor results here is obvious but experience in selecting sites in this area has shown that the presence of a diabase dyke or sill is a feature to be taken advantage of.

That dry parts occur in this area has become obvious, where evidently due to the fresh unchanged nature of the granite, its position on elevated ground, and the tightness of the joints, subterranean conditions are such that the collection and storage of water underground is not favoured. The vicinity of the Half-way House is an example of this.

In selecting a site the first thing to be looked for here is an area of schists; if these do not occur then diabase dyke or sill or one of the many crush zones might be utilized. Failing allthese, surface signs which point to the fact that weathering has taken place in the rock below should be sought. It is advisable to avoid the massive outcrops of fresh hard rock wherever possible.

(2a) Crystalline Rocks in Bechuanaland (Mafeking and Vryburg).

DISTRIBUTION:

The area consists of a slightly undulating country of monotonous aspect. On the south drainage is effected by the Dry Harts River, while on the north are the various tributaries of the Molopo, namely the Mosita, Setlagoli and Maretsani Rivers, and the Ramathlabana Spruit. To the west are the Mashowing and Kuruman Rivers.

In the east there is comparatively little vegetation, most of the timber having been cut down for use in the Kimberley mines or destroyed by bush-fires, but west of the railway the country is usually covered with large thorn trees, while the ground is thickly grassed.

Over/...

Over almost the whole of the division of Mafeking, (x) and westwards through Genesa the basement rock is granite and gneiss, but exposures are not frequent on account of the considerable depth of reddish-yellow sandy soil. At many places depressions in the older rocks have been filled by shales and boulder-clay of the Dwyka formation. This latter is seldom of sufficient depth to carry underground water.

LITHOLOGICAL:

The rock where exposed is usually a well foliated muscovite-granite or gneiss, with the foliation planes dipping at a high angle. The rock may be veined by pegmatites and aplites or traversed by quartz-reefs both of which practice has shown to have an influence on the movements of underground water.

Both granite and gneiss are more or less decomposed, and this alteration extends below the surface to a variable depth; the more micaceous gneissic varieties are usually altered to a greater degree than the compact unfoliated granites. The reason for this is the different rates of expansion and contraction of the constituent minerals by which planes of weakness are developed in the rock. The very well-banded gneisses, with regular layers of quartz, felspar, mica and hornblende, may have a high degree of fissibility imparted to them through this process, aided by mineral decomposition. This condition is favourable for the penetration and retention of rain water.

In boring, so long as the granite encountered is decomposed as shown by cavities, fissures, clouded felspars, softness, etc., there is always a possibility of obtaining water. In some cases apparently solid rock has contained

numerous/....

(x) du Toit.A.L. Underground water in South-East Bechuanaland, Cape. T.Trans.S.A.Phil.Soc.1906.

numerous microscopic fissures and cavities and the borehole has yielded a considerable supply. The latter condition usually exists along joints.

The more compact varieties of granite will in most cases yield little or no water. In boring or sinking wells, sites should not be chosen where the granitic rock forms marked outcrops; if possible preference should be given to sites situated where pans occur on the formation.

Here as elsewhere in the Union and indeed in other parts of the (x) world the granite and gneiss have proved most uncertain rocks in which to bore for water and failures must be expected. (see averages).

The rainfall in this area averages about 22" per annum. The run-off is very low, hence practically the whole of the rainfall will have to be accounted for by the process of storage, evaporation and transpiration.

UNDERGROUND WATER SUPPLIES.

The average results obtained from 210 holes bored since Union and 25 holes which are pre-Union show some interesting figures.

It can be deduced fairly easily from the better results obtained previous to 1909 that only the most favourable sites were used first, and the fall in daily yield and increase in depth to the water which came later indicates that the expansion which took place forced people to utilise the less favourable sites.

AVERAGES.

Total number of boreholes	210
Average Total depth in feet	168
" depth at which water was struck	125
" " to which water rises	98
" daily yield in gallons	18,730
" daily footage	5-10
Percentage of failures 1/3 of which are not deep enough.	36%
% Over 300' in depth of which 20% are without water, 60% obtained water before 300' was reached and 20% have water below 300'.	5%

(x) U.S.G.S. Water Supply and Irrigation Paper No.160. p.19. Occurrence of water in crystalline rocks by E.E.Ellis.

In the more westerly of the two Railway Grants in this district the superficial deposits overlying the crystalline rocks were found to attain considerable depths so that boring had to be continued to depths greater than usual before striking water. The superficial deposits were sand, limestone, Kalahari red clays and surface quartzites or silcretes.

The average results obtained from 60 boreholes sunk in this area differ considerably from those in the rest of the district and are thus presented separately viz.

Total number of boreholes	60
Average total depth in feet	360
" depth at which water was struck	272
" " to " " rises	220
" daily yield in gallons	11,900
Percentage of failures	56%
Percentage of boreholes over 300' in depth	24%
Average depth of superficial deposit in the successful boreholes	224
Average depth of superficial deposit in the unsuccessful boreholes	270

In Vryburg 152 holes are recorded and the averages are as follows:

Average total depth	150
" depth at which water is struck	105
" " to which water rises	94
" quantity of water per day in gallons	16,600
" ~~daily footage~~	
Percentage of total failures	30.3%
" of boreholes over 300' deep	2%
" " " striking water below 300'	.6%

Generally the fact emerges that apart from some boreholes sunk in the Genesa Block in Vryburg, observation shows that it is advisable to take advantage of the drainage lines or laagtes wherever possible, as in the Rustenburg area; particularly is this so in the northern portion of this area.

In the Mafeking Railway grant mentioned before, holes sunk on the bults were,with few exceptions, failures. Similar results were obtained in the northern section of

Vryburg,/...

Vryburg, but here even some of the laagtes such as the Kagole and Makgaalo failed to produce results in certain portions, evidently due to the physical condition of the underlying rock.

(2b) The Crystalline Rocks in the Van Rhynsdorp, Namaqualand and Kenhardt District:

(1) NAMAQUALAND.

The coastal belt or Sandveld: This country consists of a low sandy shore followed inland by a wide expanse of red white sand, which varies from several to in some places seventeen miles wide, through which the underlying crystalline rocks rarely come to the surface. It is poorly watered, but derives benefit from the sea-mists. The latter supply sufficient moisture to keep a desert type of vegetation, consisting of euphorbias, mesembryanthemums, aloes, acacias, and a few grasses, in good condition, so that a comparatively large population of sheep farmers are able to derive sustenance for their flocks.

The rocks seen are mostly schists and schistose granite seamed with quartz veins and pegmatite dykes.

The rainfall is low, about 5" per annum, of which over 75% falls during the winter months. In spite of these unfavourable conditions large supplies of underground water are stored in this area as is evidenced by the waters obtained in shafts along the old narrow gauge railway at Five Mile and Seventeen Mile Station, and also the several springs discharging along the coast and at Koekfontein and Soebatsfontein.

(2) THE STRIP OF HILLY COUNTRY LYING BETWEEN THE ZANDVELD AND THE BUSHMANLAND PLAIN:

The level of this portion stands at from 1,000 to 3,000 feet above the sea. The surface is uneven, consisting of deep valleys filled with sandy soils lying between large and small hills of granite often dome shaped.

In/...

In the valleys the major farming operations, wheat growing, of this part of the District are carried on.

Various granites generally in a fairly fresh and solid condition are the chief rocks exposed, basic intrusions are rare. This is the best watered part of the District, the water issuing generally as small springs from joints and decomposed zones in the hard rock, without any regularity with regard to horizon. These joints and zones are also made use of for tapping underground water with the drill.

(3) BUSHMANLAND PLAINS.

Out of this great flat the tops of chains of hills emerge, formed chiefly of highly altered sediments and gneisses with an occasional intrusive body of granite. Between these projections are large deep valleys filled with granite debris and sand often consolidated by carbonate of lime into a soft rock. This recent formation has been proved to extend to a considerable depth in places; e.g. at Goubies Vlei 200' was encountered in a well, at Noisabies 350' is reported from a borehole, and in a well at Bloemhok 150' was pierced.

At the bottom of this loose material generally on the old valley floor or in the decomposed rock forming the valley floor are streams of water which can be tapped at suitable spots by boreholes.

The valleys gradually fall towards the Orange River where, as at Pella and Henkries, large streams issue at the surface, these being formed by the joining of the various underground waters.

VAN RHYNSDORP.

Here conditions are very similar to those in Namaqualand i.e. low rainfall, sand covering the coastal belt, desert vegetation, etc.

The sandy coastal strip is followed inland by an area in which rugged hills of granite outcrop which gradually

disappear/...

disappear in a sandy plain, thus corresponding in a small scale to the three features of Namaqualand.

The rock exposed is generally gneissose granite though occasional areas are seen in which the parallel structure is not marked. A large variety of both granite and gneiss is found. Both rocks crop out in great curved surfaces that are kept bare and free from vegetation by the splitting off of slabs along cracks roughly parallel to the surface. This process also goes on in the rocks with a gneissose structure that is not highly developed and may be seen on any of the conspicuous kops or klips in the Hardeveld such as Krakal Kop, Olifants Voet and Oskop all of which show the roughly concentric breaking up of the coarse gneissose granite.

The more gneissose the structure of the rock the easier it weathers in this area, as seen by the fact that the hard granites generally form the tops and slopes of the hills.

KENHARDT: AND SOUTHERN GORDONIA.

This area is practically an eastern continuation of Bushmanland consisting of vast sandy plains and sparse hilly outcrops of rocks. The main drainage line, the Orange River and its tributaries, has cut through the sand covering and exposed the rock which varies tremendously in kind and composition all sorts of schists, gneisses, granites and intrusions aplites, pegmatites, and basic rocks are to be seen, but the general classification is Swaziland System with intrusive Old Granite and Gneiss.

UNDERGROUND WATER SUPPLIES:

Compared with other areas underlain by these rocks in the north and east of the Union the boreholes are very sparsely distributed over this vast tract of country as owing to the poor nature of the vegetal covering the number of

inhabitants/....

inhabitants carried per square mile is very low.

In Van Rhynsdorp a total of 40 boreholes in these rocks have been considered of hwich 38% are total failures and 6% have insufficient water for practical purposes.

The average results areas follows:-

Average total depth in feet			215
" depth to water in feet			171
" " to which water rises in feet (rest level)			121
" daily quantity in gallons			7,460
Daily footage			2'-20'
Total failures			38%
Holes with water but insufficient for use			6%
			44%
Holes with depth greater than 300'			20%
" " " " " "	without water	2.2 %	
" " " " " "	with water above 300'	6.7 %	20%
" " " " " "	with water below 300'	11.1 %	

The outstanding feature here is the comparatively exceptional depths at which the water can be found in this area as e.g. in the boreholes Nos.9365, 9388, 11531 and 12068, the respective depths being 374', 365', 338' and 360', this is rare and can only be parallelled in the crystallines of the Northern portion of the Mafeking District. Similar to the conditions found in the latter district is the presence of 200-300' of superficial deposits on top of the rock itself.

Another peculiarity of the underground water is its saltness. This however it shares with the waters obtained fro other formations which occur under similar conditions of low rainfall on the Atlantic Coastal belt such as the Malmesbury Beds both here and in the Malmesbury District also the younger granite in the Malmesbury District.(x)

The (*) superficial deposits which conceal so much of the older rocks in this area are known to contain $CaSO_4$ and NaCL,etc. derived from their origin and subsequent submergence under the sea, and it is possible that water percolating downwards from a meteoric origin at the surface to the site of underground storage above or in the hard fresh rock beneath,

must/...

(x) Explanation Sheet 1 Cape Town. Chapter on Underground Water. H.F.Frommurze.

(*) Science Bulletin No.5 Dept. of Agric. - Olifants River Soils C.F.Juritz - D.Sc.

must dissolve some of these salts.

KENHARDT:- Boring results.

Average total depth of borehole in feet	164	
" depth to water	135	
" " to which water is struck	93	
" daily yield	9,270	
" daily footage	6-15.	
Percentage of total failures	39%	58
" of holes with insufficient water to use	29%	
Holes over 300'	nil	

The best results are obtained from the small areas of Swaziland schists, the harder and fresher granites and gneisses not proving so favourable and giving rise to practically all the failures. In one case on the property Hedly Plains a hole in the hard gneiss proved a failure while within a few yards another penetrating soft schist gave a useful supply of water.

NAMAQUALAND AND BUSHMANLAND:-

Number of boreholes		149	
Average total depth of borehole		162	
" depth at which water was struck		122	
" depth to which water rises		81	
" daily yield		21,545	
Percentage of total failures		30	
" " holes with insufficient water to use		10.0	52%
" " holes not deep enough		12.0	
" " " deeper than 300'	without water	12.0	
" " " " " "	striking water below 300'	9	33%
" " " " " "	above 300'	12	
" of boreholes with brack water		12%	
Exceptional supplies		0.6%	

C H A P T E R III

THE VENTERSDORP SYSTEM AND ITS WATER BEARING PROPERTIES.

INTRODUCTION.

Consisting of several groups, for the most part of igenous rocks, the Ventersdorp system has a wide distribution (Fig.9) and is important as a water bearer.

As generally represented there is a thick group of ancient basic lavas which rest unconformably upon the older systems with or without a basal development of sandstone, quartzites and conglomerates. In addition there are more limited areas of acid lavas, breccias and cherts which sometimes form ridges as on the western side of the Schoonspruit Valley, Ventersdorp district, and are most unsatisfactory to drill, though otherwise they are of little importance.

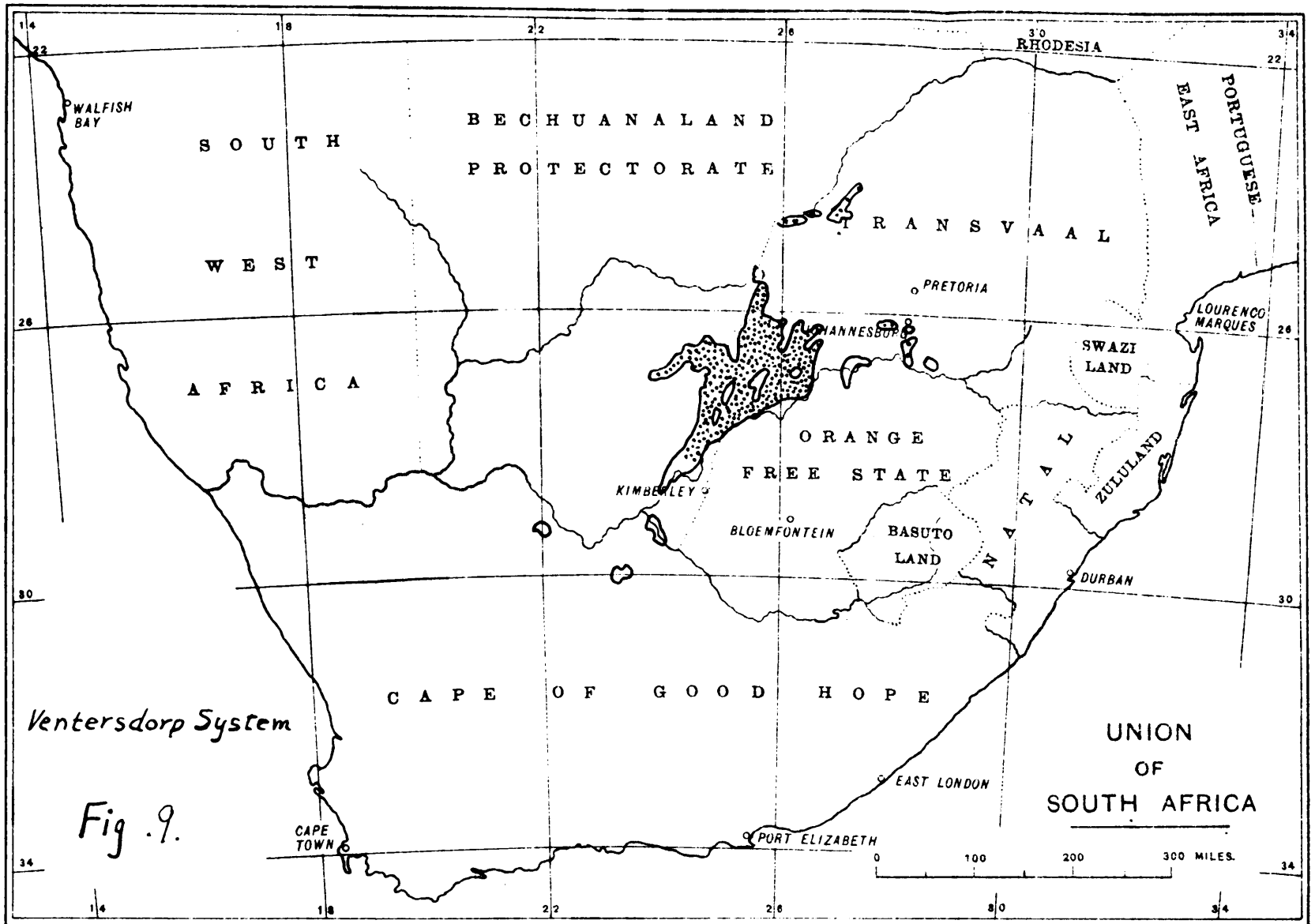
The sedimentary rocks are lithologically very similar to the quartzites and this resemblance is found also in their water bearing properties.

The greater part of the system however is built up of the igenous rocks and the bulk of the water drilling has taken place in these latter rocks.

DISTRIBUTION

The bluish green lavas, generally known as the Ventersdorp diabase or amygdaloidal covers a vast region from Greylingstad in the Transvaal south-westwards through Christiana and Kimberley down to the junction of the Orange and the Vaal. In the Heidelberg-Greylingstad area the lavas appear as low ridges which arise out of plains of coal measures and build up the Suikerbosch Rand and the Klipriviersberg south of Johannesburg. Reappearing

again/...



again in the neighbourhood of Ventersdorp and Klerksdorp they spread out over an extensive piece of country bounded on the South by the Vaal River, and on the north by Lichtenburg.

The limit to the west is an imaginary line drawn from near Ramathlabama Spruit in the Bechuanaland Protectorate to a point just west of Vryburg and thence following the Harts Valley, the rocks making an irregular belt through Barkly West, Kimberley and Herbert.

Within this area roughly 400 miles long and 150 miles in greatest width there are a number of inliers of older granite and other formations (see Chapter on crystalline rocks for these), while there are also covering patches of the Karroo system, these become more numerous to the South and East until the volcanic rocks disappear entirely beneath this mantle of younger strata. Of these detached areas at least two are known of fair dimensions, one north of the Dwarsberg in the W.Transvaal and the other west of the Doornberg in the Prieska District.

TOPOGRAPHY.

Excepting the hills mentioned above, and a few other low elevations, the volcanics give rise to undulating or flat country and over wide areas in the South/western Transvaal and in Eastern Bechuanaland, there are few marked courses, pans are numerous and the run off is therefore low.

Generally there is a steady falling off in the amount of the average annual rainfall from east to west Heidelberg with 35" and Prieska with 12" representing the extremes, which fact must be borne in mind when discussing the underground water of this generally uniform formation. Grassland with scattered thorn trees in the east passes

into/...

into grass with Vaalbosch (Tharchonanthus camphoratus) in the west and mixed veld with Karroo bush in the extreme Sout-west.

LITHOLOGY.

The lavas are uniform in character consisting of blue-green fine grained types of andesites, or rocks of more basic composition. They are rarely porphyritic with large pale yellowish crystals of plagioclase felspar. The ferromagnesian minerals have been altered usually to fibrous hornblende or epidote.

Some parts of the rock are compact and strong, other parts are markedly amygdaloidal the cavities being filled with agate, quartz, calcite or chlorite. There are also hard green volcanic agglomerates and breccias. Several thousand feet is the thickness which has been measured in different places and it is known that this mass of erupted matter is not due to one single outpouring, but is built up of a succession of relatively thin separate flows which vary in their individual thickness and texture.

Usually the central portion of each flow is more compact than either the top or bottom, amygdaloidal structure is commonly developed at the base, but more distinctly towards the summit of each flow layer, and frequently the rock in such positions is full of elongated steam holes which contain agates and other secondary minerals.

Consequently this rock, unlike the intrusive diabases in other series, is not one homogeneous mass but consists of layers of varying degrees of hardness which fact shows in the borehole records. Further there are the surfaces of broken continuity between one flow and the next, while the adjacent rock on either or both sides is frequently porous. These characteristics naturally facilitate the percolation downwards and storage of rain/

rain-water, particularly so where the formation has been tilted.

The breccias are generally harder than the lavas but break down under the agency of the weather in a similar manner.

The acid lavas are harder and much more resistant and in most cases yield little or no water as in the case of the tough rhyolites and quartz porphyries to be found in Mafeking District, between Geneva and Vryburg and around Wolmaransstad. These varieties are best avoided if possible.

The sediments which are, in places where they are conformable difficult to distinguish from those of the upper Witwatersrand beds consist of conglomerates, felspathic sandstones, grits, quartzites and more rarely cherts and limestones. North of Klerksdorp there are upper sediments, limestones and cherts chiefly, and elsewhere in the western Transvaal interbedded quartzites have been noted in the lavas.

Over a very large part of the areas concerned the lava flows are nearly flat but in certain belts they attain a dip of thirty degrees sometimes even more, as in the area south of the Witwatersrand and in the north-western Rustenburg District. In the absence of sedimentary partings it may be difficult to make out the angle of dip especially over flat country with few good outcrops. However it has been found possible by following resistant layers or bands with some defining peculiarity, to determine the dip of the formation. This may prove of great importance in selecting sites for boring for water, because the direction and amount of dip influence the water supply here just as in sedimentary rocks.

It is generally found that on the higher or more elevated areas the diabase forms ridges or nearly continuous

outcrops/...

outcrops of bare rock. It is desirable to avoid such areas in selecting boring sites as it is found that the chances of success here are much less. In flatter regions, however, there is generally a soil covering of a red to brown colour and a clayey character, out of which project isolated smooth or pitted lumps of lava in a fresh and hard condition. Some of these are not joined to the solid rock beneath, but are residual fresh cores developed by weathering and underlain by soft decomposed diabase. Drillers often find these hard spheroidal cores embedded in soft material during the progress of a borehole and this so-called boulder formation causes great difficulty. Great variation has been found in the depth to which decomposition has taken place and also the degree to which it has gone Commonly the contact planes between flows are attacked by the weathering and are changed into water-planes, while the softer minerals filling pores and amygdales in the more amygdaloidal varieties may be dissolved out by the circulating waters leaving a spongy mass.

The inviting looking vleis where it would seem impossible to fail in obtaining water in a borehole often prove great disappointments because the dark grey to black "turf" soil gives way to solid rock at a shallow depth. It is probable that this sticky overburden acts as a puddle blanket and hinders infiltration.

In the regions of lower rainfall the calcium and magnesium carbonates formed during the decomposition of the silicates in the lavas are not entirely removed in solution, but are precipitated in the pores and fissures of the weathered rock or in the subsoil above, forming sheets of porous white limestone, which often contains boulders and fragments of diabase. For such a process to have

operated/...

operated the evaporation of the weak carbonate bearing solution must have been extensive, and this naturally assumes a shallow depth for the ground water. Consequently the presence of such deposits of calcareous tufa on the diabase, particularly if in restricted areas or narrow bands often below the general level, may be taken as possible indications of shallow supplies beneath, as it has been noticed that springs in this formation often issue from soil or rubble highly impregnated with lime.

The tufa sometimes attains a great thickness - over 100 ft - and it would appear that these deposits had been formed to the detriment of the ground water for the yields of the boreholes which penetrate such abnormal quantities of tufa are decidedly low in many cases.

Sometimes the lime is derived from extraneous sources as along the Kaap Plateau and east of Mafeking where lime charged waters from the higher dolomite have covered the diabase with calcareous tufa.

THE QUARTZ PORPHYRIES AND ACID LAVAS:

These compact acid lavas are generally confined to the lower part of the System and have mostly been buried under the sediments or diabasic lavas, consequently they have a limited distribution which is fortunate as they are generally hard fine grained rocks which are practically waterless.

The large area between Vryburg and Genesa has been searched for water and of the number of attempts made by the drill to find it in this hard and compact porphyry, most were without success.

Further areas of porphyry are near Modder River Station in the Kimberley District, Omdraai Vlei. The hardness of this rock has been responsible for the conspicuous

Hakwassi/...

Makwassi Hills near Wolmaransstad. In the Northern Rustenburg District there is an interrupted narrow belt of hard acid lavas and breccias along the northern edge of the Bushveld syncline from Derdepoort on the Marico River to near Vliegepoort on the Crocodile River.

THE VENTERSDORP SYSTEM

(1) In the Transvaal.

(a) The South-Western corner.

The area lying between the towns of Wolmaransstad and Vryburg and extending northwards towards Lichtenburg and Mafeking is classed as high veld having an elevation of 4,000-5,000 feet above sea level. The country possesses a gently undulating character with belts of small trees and bush scattered throughout. With the exception of the Makwassiberg east of Wolmaransstad there are no conspicuous hills. The general slope of the land is towards the south-west and it is intersected by shallow valleys draining southwards into the Vaal River.

The principal rivers are :- the Makwassi Spruit which passes through Wolmaransstad; the Banboes Spruit situated a few miles further west; the Harts River which rises in the neighbourhood of Lichtenburg and passes through Schweizer-Reneke; and beyond the boundary of the Transvaal the Dry Harts which passes through Vryburg. Thus it is seen there is very little surface water apart from pans which are numerous and the area has depended on drilling for water for its development.

Outcrops of diabase are fairly numerous in this area; but there are considerable stretches covered by excellent soil which is responsible for the good quality veld obtained here. The soil is mainly from the decomposition of the diabase.

Boring/...

Boring for water has been extensively carried out in this area, a total of 2494 boreholes having been completed since the date of Union.

The average figures for the whole area is as follows:-

Total number of boreholes	2494
Average total depth in feet	97
Average depth at which water is struck in feet...	67
" " to " water rises(rest level) in feet	38
Average daily yield pumping inggallons	20,500
Percentage of failures	22

Of the failures; 54% were total failures giving no water whatsoever though drilled down to below the average depth to the water; 19% were not deep enough generally abandoned by the owner of the farm or due to mechanical difficulties making it advisable to bore elsewhere; and 27% struck water which measured less than 1,000 gallons per 24 hours.

Among the successful holes are 15 having a capacity when pumped of giving 100,000 gallons per diem or more. Flowing holes only average 0.2% however. Only 0.3% of the holes were drilled 300' or deeper and of these more than half obtained water above that depth.

In general in this formation water is to be found at a comparatively shallow depth and the drilling is fairly rapid and cheap.

VENTERSDORP DISTRICT

Seventy-two boreholes have been drilled in this formation in this area and the averages are as follows:-

Average total depth of borehole in feet	101
Average depth at which water was struck in feet ...	65
Average depth to which water rises rest level in feet	46
Average daily yield in gallons	18,000
Percentage of failures	12,3%

Of/...

Of the failures 33% were total failures, 22% struck water of no practical value and 45% were not carried deep enough for various reasons.

Only one borehole attained a greater depth than 300 feet, but water was struck above that depth. One borehole yielded 100,000 gallons per diem.

Generally, however, in spite of the rainfall in this area the yield is below the average for this formation.

Summary of reported yields in the Ventersdorp Volcanics of this area:-

Depth to water in feet.	Total No. of boreholes from which information was obtained.	Yield per 24 hours in gallons.							
		Up to 1000	1- 10,000	10- 20,000	20- 30,000	30- 40,000	40- 50,000	50- 60,000	60- 100,000
Up to 50	17		3	6	4		3		1
50-100	34	2	10	11	8	2		1	
100-150	9		7	1		1			
150-200	2		2						
TOTALS	62	2	22	18	12	3	3	1	1

KLERKSDORP

Klerksdorp is the district with the highest individual average quantity of water per diem, viz:-

Total number of boreholes from which information was obtained	477
Average total depth in feet of borehole	95
Average depth at which water was struck in feet ...	69
Average depth to which water rises rest level in feet	39
Average daily quantity of gallons	22,200
Percentage of failures	24
" " boreholes deeper than 300'	0.2
" " flowing holes..	6
Average annual rainfall	20-25"

Of the failures 64% were total failures 17% struck water of no practical value and 19% were not drilled deep enough.

The average daily yield is above the usual and the average depth below, otherwise results are fairly consistent with little that is exceptional.

Summary/...

SUMMARY OF RESULTS IN THE KLERKSDORP DISTRICT.

Depth of water		0-50	51-100	101-150	151-200	201-250	Total
Total number of holes from which information was obtained.		134	180	33	8	1	356
Up to 1000 g.p.d.	Yield per 24 hrs. in gallons.	3	3	1		1	8
1-10,000		37	62	13	6		118
10-20,000		33	38	9	1		81
20-30,000		23	35	3			61
30-40,000		13	12	3			28
40-50,000		10	11	2			23
50-60,000		5	3				8
60-70,000		3	1				4
70-80,000		4	10	2	1		17
80-90,000		3	3				6
90-100,000		2					2

LICHTENBURG

The greatest number of the boreholes are situated in this district, since it is the largest of those dealt with.

The averages are as follows :-

Total number of boreholes from which information was obtained	828
Average total depth of boreholes in feet.	98
Average depth at which water was struck in feet.	70
" " to which water rises rest level in feet.	37
Average daily quantity in gallons	21,500
Percentage of failures	17
" of boreholes deeper than 300 feet.	.1
" of flowing holes	.5
Average Annual rainfall	20"

Of the failures 64% were total failures 30% gave insufficient water to be used and 6% were not deep enough.

The above adheres closely to the general average of the whole southwestern area.

In the deep hole water was struck at 68'

SUMMARY OF RESULTS.

Obtained in the Lichtenburg District.

[illegible].

Depth to water in feet. / Quantity in gallons per diem.	0-50	51-100	101-150	151-200	201-250	TOTALS.
Up to 1000	6	5	6			17
1-10,000	70	132	39	4		245
10-20,000	59	98	20	2		179
20-30,000	41	43	12	4		100
30-40,000	16	20	2			38
40-50,000	22	18	4			44
50-60,000	17	5	1			23
60-70,000	3	3	1			7
70-80,000	7	15	1			23
80-90,000	6	2				8
90-100,000	2					2
100-110,000	1	2				3
110-120,000	1					1
Total number of boreholes from which information is obtained.	251	343	86	10		690

SCHWEIZER RENEKE.

Total number of boreholes from which information was obtained.	284
Average total depth of boreholes in feet.	106
" depth at which water is struck in feet.	66
" depth to which water rises (rest level) in feet	50
" daily yield in gallons per 24 hours	16,400
Percentage of failures	30
" " deep holes	.7
Average annual rainfall	17"

The failures which are high in comparison with the general average are divided into 50% of total failures, 31% in which a supply of water too small to use was obtained, and 19% which were not carried deep enough.

In the deep holes 50% were total failures and 50% obtained water above 300 feet.

There were 5 boreholes which yielded 100,000 gallons per diem and over.

SUMMARY OF RESULTS OF BORING FOR WATER IN THE SCHWEIZER RENEKE DISTRICT.

Depth to water in feet.		0-50	51-100	101-150	151-200	201-250	TOTALS.
Total number of boreholes from which information was obtained.		48	110	30	8	2	198
Up to 1,000	Yield per 24 hrs. pumping.	6	4	2	1		13
1-10,000		15	42	17	4	1	79
10-20,000		13	31	7	3	1	55
20-30,000		6	16	3			25
30-40,000		2	7				9
40-50,000		1	5	1			7
50-60,000							
60-70,000							
70-80,000		1	2				3
80-90,000		1					1
90-100,000		3	3				6

WOLMARANSSTAD.

Total number of boreholes from which information was obtained.	494
Average total depth of boreholes in feet.	86
" depth at which water was struck in feet.	54
" depth to which water rises rest level in feet.	30
Average daily quantity in gallons.	17,600
Percentage of failures.	25
" " deep holes, i.e. deeper than 300 feet.	4
Average Annual rainfall.	22.7'

The failures here divide up into 53% total failures, 40% with insufficient water to use and 7% which were not deep enough. In the case of the deep boreholes 50% struck water at a greater depth than 300 feet and 50% at a shallower depth.

Summary/...

SUMMARY OF RESULTS - WOLMARANSSTAD DISTRICT.

Depth to water in feet.		0-50	51-100	101-150	151-200	201-250	TOTALS
Total number of boreholes from which information was obtained.		123	127	31	3		284
Up to 1,000	Yields per 24 hours in gallons	6	9				15
1-10,000		50	60	23			133
10-20,000		26	25	6	1		58
20-30,000		19	9		1		29
30-40,000		18	11	1			18
40-50,000		9	7	1			17
50-60,000		2	2		1		5
60-70,000							
70-80,000		3	1				4
80-90,000		2	3				5
90-100,000							

BLOEMHOF AND CHRISTIANA:-

Total number of boreholes from which information was taken	338
Average total depth of boreholes in feet	100
Average depth at which water was struck in feet	70
Average depth to which water rises rest level in feet	42
" daily quantity in gallons per 24 hours	21,900
Percentage of failures	26.9%
" " deep holes (over 300 feet)	.26%
Average annual rainfall	17.1 ins

Investigating the failures it is found that 39% are total failures, 38% have insufficient water for practical use and 23 % have not been carried deep enough.

SUMMARY OF RESULTS: BLOEMHOF AND CHRISTIANA.

Depth to water in feet		0-50	50-100	100-150	150-200	200-250	250-300	TOTALS
Up to 1,000	Yields far 24 hours in Gallons	2	2	3				7
1-10,000		33	59	19	5			116
10-20,000		18	40	4	2			64
20-30,000		9	22	5				36
30-40,000		6	11					17
40-50,000		8	11	3				22
50-60,000		3	7	2				12
60-70,000		2	1					3
70-80,000		3	5					8
80-90,000		3	3					6
90-100,000		4	2					6
100-110,000		1						1
TOTALS		92	163	36	7			298

GENERAL:- (1) It is well known that the whole of the area under discussion is covered by innumerable small outliers of Karroo series, a fact demonstrated by the bore-hole records where varying thicknesses of sandstone, shales and conglomerates are frequently reported as lying above the diabase. The presence of these sedimentary strata do not appear to have any influence on the water bearing capacity of the diabase in any way, however, as large and small supplies are obtained from the diabase, etc., beneath this covering with equal degree of variability as from the boreholes in which diabase only is reported.

(2) A further point of interest is the fact that the rainfall is reflected to a certain extent in the underground water, e.g.

Klerksdorp	Annual Average Rainfall	25.2"	Average daily yield per borehole	22,200 Gals
Lichtenburg	do.	23.7"	do.	21,500 "
Wolmaransstad	do.	22.7"	do.	17,600 "
Schweizer Reneke	do.	17"	do.	16,400 "
Ventersdorp	do.	25"	do.	18,000 "
Bloemhof & Christiana	do.	17.1"	do.	21,900 "

These last two districts however do not follow this rule and it is probably due to the fact that in the case of the former district the situation of the rock forming higher ground with the river valleys cutting through to older rocks beneath has the effect of draining the under-ground supplies to a certain extent. In the latter districts the presence of the Vaal river must have a beneficial effect on the underground storage as it would act as a zone of replenishment to the rock.

Analysing the results still further it is found that the earlier holes generally give better averages than the latter(x), and that there is a drop in the quantity per diem per borehole, but many factors play a part in this,

such/...

(x) See also du Toit Borehole Water Supplies in the Union of South Africa. Trans.of S.A.Soc.of Civil Engineers, 1928

such as the extension of drilling operations into less favourable areas, and years of rainfall above the average, etc. It will be noticed that in the case of the Wolmaransstad, Bloemhof and Christiana Districts there has actually been a rise in the last period calculated which would show definitely that the underground supplies are not diminishing. It is thought that improved methods of boring have made it possible to get more water from each hole, the fact that boring machines go deeper is really no help because the increase in the average depths of holes is very slight.

SEE TABLE 1.

(b) THE AREA AROUND JOHANNESBURG.

The volcanic flows have an aggregate thickness of several thousand feet and occupy a considerable extent of the surface near Johannesburg, resting immediately upon the uppermost beds of the Witwatersrand system and dipping beneath the Dolomite of the Klip River Valley. The outcrop extends from Luipardsvlei in the West to Finaalspan in the East and includes the rough ground known as the Klip-Riversberg.

Another occurrence of this rock, small in size but important, begins in the east at Kempton Park and extends westwards through Bezuidenhout Valley and beneath Park Station to Braamfontein. This latter is decomposed to great depths in places, especially the western section, and many of the large Johannesburg buildings derive their supplies from boreholes in this rock, yields of up to 4,000 gallons per hour having been obtained at an average depth of 250-300 feet.

The general averages are as follows :-

No./...

TABLE I. ANNUAL AVERAGES FROM DRILLING IN THE VENTERSDORP DIABASE FOR COMPARISON.

DISTRICT	YEAR 1904-1919				YEAR 1920-1925				YEAR 1926-1930			
	No.of holes	Depth in feet	Quantity in gallons per 24 hours	Failures.	No.of holes	Depth in feet.	Quantity in gallons per 24 hours.	Failures.	No.of holes.	Depth in feet	Quantity in gallons per 24 hrs.	Failures.
Klerksdorp	155	94	26,070		67	96	20,450		162	91	118,310	
Lichtenburg	478	94	22,400	17%	115	104	21,100	18%	106	110	15,400	40%
Ventersdorp	20	83	21,170	20%	20	98	17,840	5%	22	121	14,600	18%
Bloemhof & Christiana	170	102	22,900	37%	65	93	16,500	34%	16	110	21,000	31%
Wolmaranstad	169	84	21,000	33%	66	90	15,000	30%	135	90	15,900	37%

No.of Boreholes	21
Average total depth of borehole in feet	150
Average depth at which water is struck in feet ...	82
" " to " " rises(rest level) in feet	38
Average daily yield in gallons per diem pumping ...	16,400
Percentage of failures	5%
" " boreholes deeper than 300 feet	5%

The failures are total failures and the deep holes struck water before 300' was reached.

THE HEIDELBERG AREA:-

West of Heidelberg the Volcanics also cover quite a large region forming the chain of hills known as the Zuikerboschrand along the Zuikerboschrand River, above its confluence with the Blesbokspruit. The lavas measured from the Elsburg series on Driefontein No.28 to the commencement of the sedimentary series of the Ventersdorp System near Fortuna Station have a thickness of about 5,000 feet and dip at angles from 10° to 40°.

Averages:-

Number of holes	20.
Average total depth of borehole in feet	105
Average depth at which water is struck	67
" " to " " rises rest level	31
Average daily yield pumping in gallons	15,400
Percentage of failures	15%

(c) IN THE NORTHERN TRANSVAAL, RUSTENBURG & MARICO DISTRICT

These boreholes are situated in the North West of the Transvaal where the Ventersdorp sediments and Volcanics extend between the old Granite and the Black Reef Series, though over broad belts much or all of the strata may be hidden by deep soil, so that without detailed examination of every core or tailing from each hole, it is sometimes doubtful as to the exact nature of the formation pierced. The annual average rainfall is from 25" - 30" and it falls during the summer month chiefly in the form of thunder storms with heavy precipitation and large run-off.

The series consists of a lower division of quartzites

quartzitic sandstones, grits and conglomerates which are fairly thick and dip to the southwest at various angles from 12 - 40° . The upper division consists of volcanics, basic in the lower portion and acid above.

Records of 56 boreholes have been obtained and the averages calculated as follows:-

(1) For the sedimentary group :- 24 boreholes.

Average total depth in feet	176
" depth at which water is struck in feet ...	130
" " to " " rises in feet(rest level)	91
Average daily yield pumping in gallons	23,100
Percentage of failures	7
" " holes deeper than 300 feet	Nil

Of the failures 40% did not attain a depth sufficient to exhaust the chances of striking water.

(2) For the volcanic group:- 32 boreholes.

Average total depth in feet	159
" depth at which water is struck in feet ...	116
" " to " " rises(rest level)in feet	79
" daily yield pumping in gallons	13,900
Percentage of failures	50%
" " deep holes	3%

Subdividing the failures 13% are of insufficient depth, 31% strike water which is of no practical use and 56% are totally dry.

The deep holes derive their water from a depth less than 300 feet.

The contrast between the two groups is illuminating. The porous jointed group of quartzites, shales, grits and conglomerates proving a better aquifer than the lava flows with their weathered contacts between successive sheets under similar conditions of topography and rainfall.

2. THE VENTERSDORP SYSTEM IN THE NORTHERN CAPE PROVINCE.

This area of which the Vryburg and Mafeking districts comprise the greater part, forms the geographical and geological continuation of the South Western Transvaal,

CHAPTER IV.

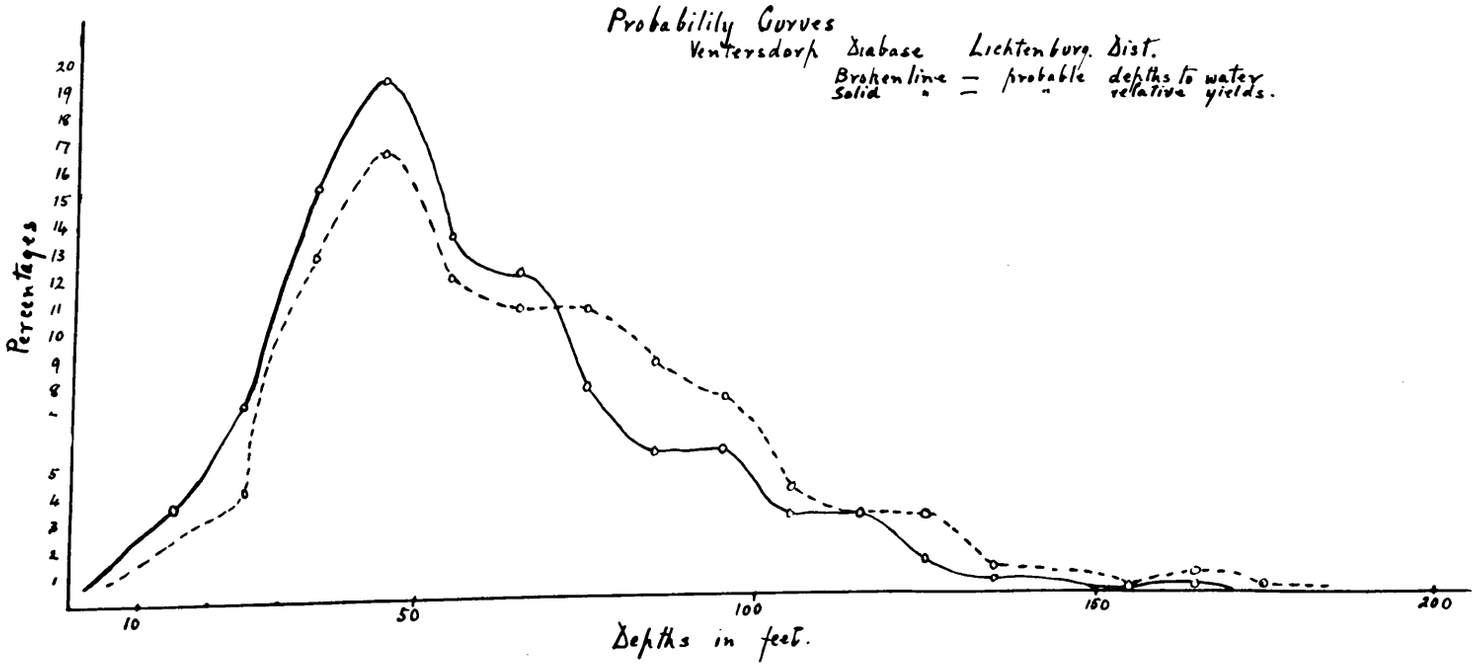


Fig. 9a.

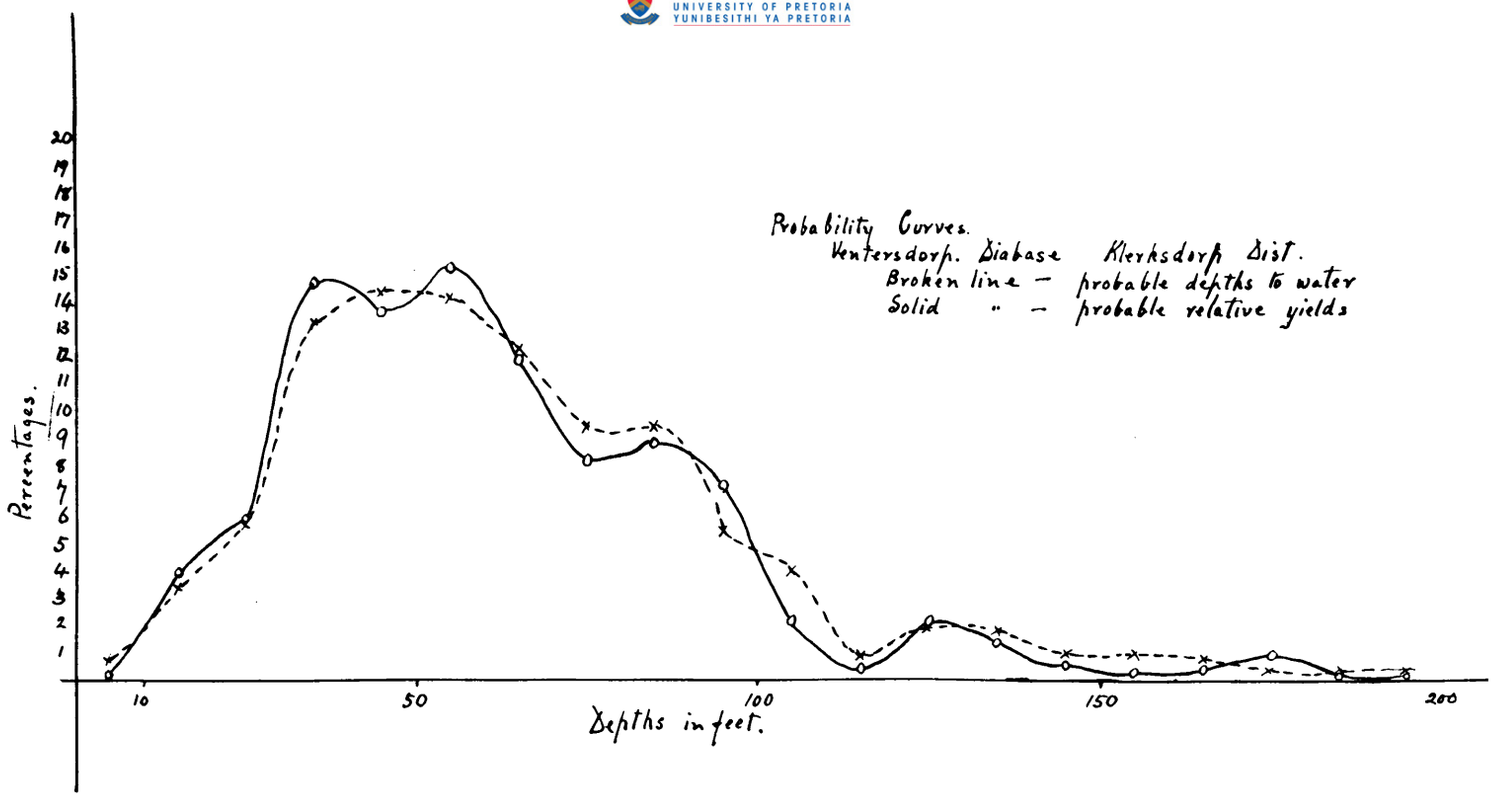


Fig. 9b.

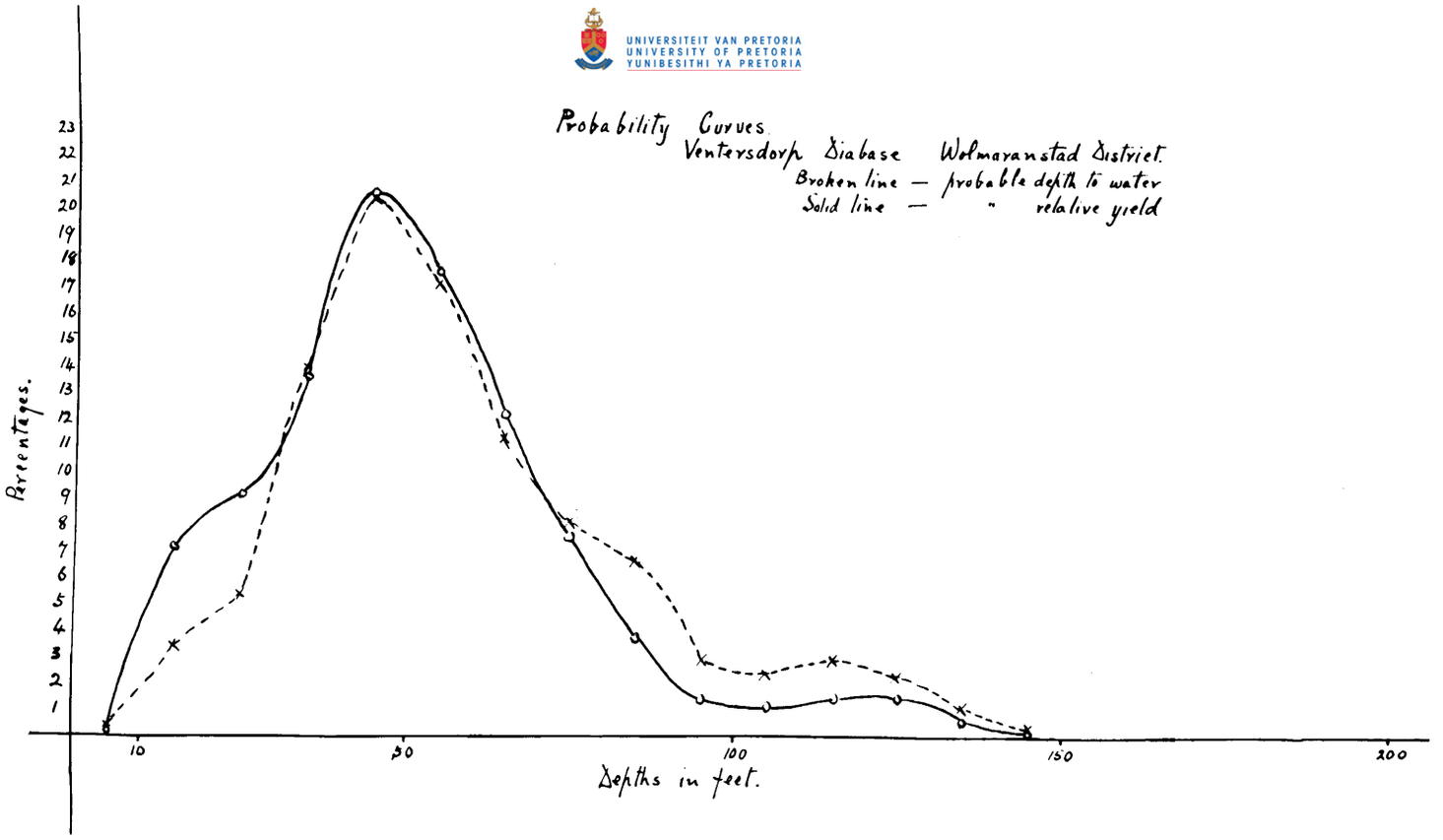


Fig 9c

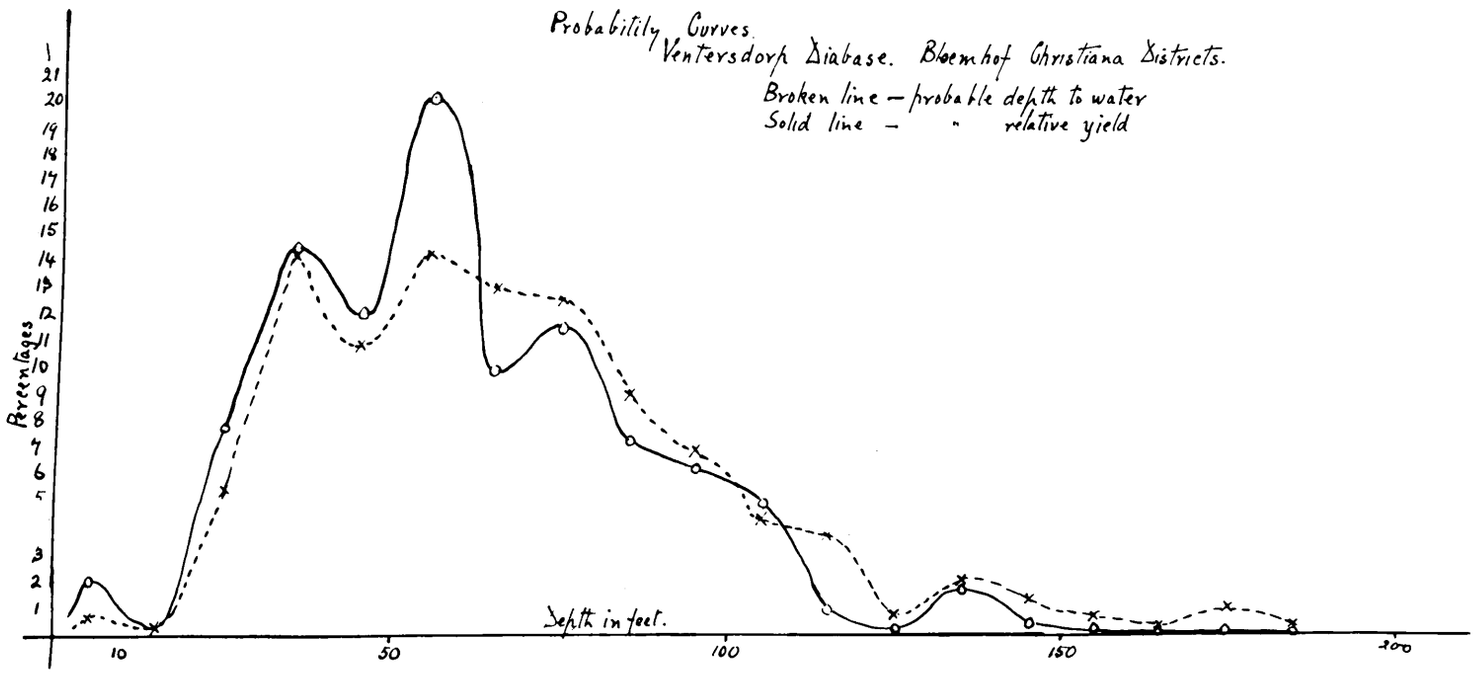


Fig 9d

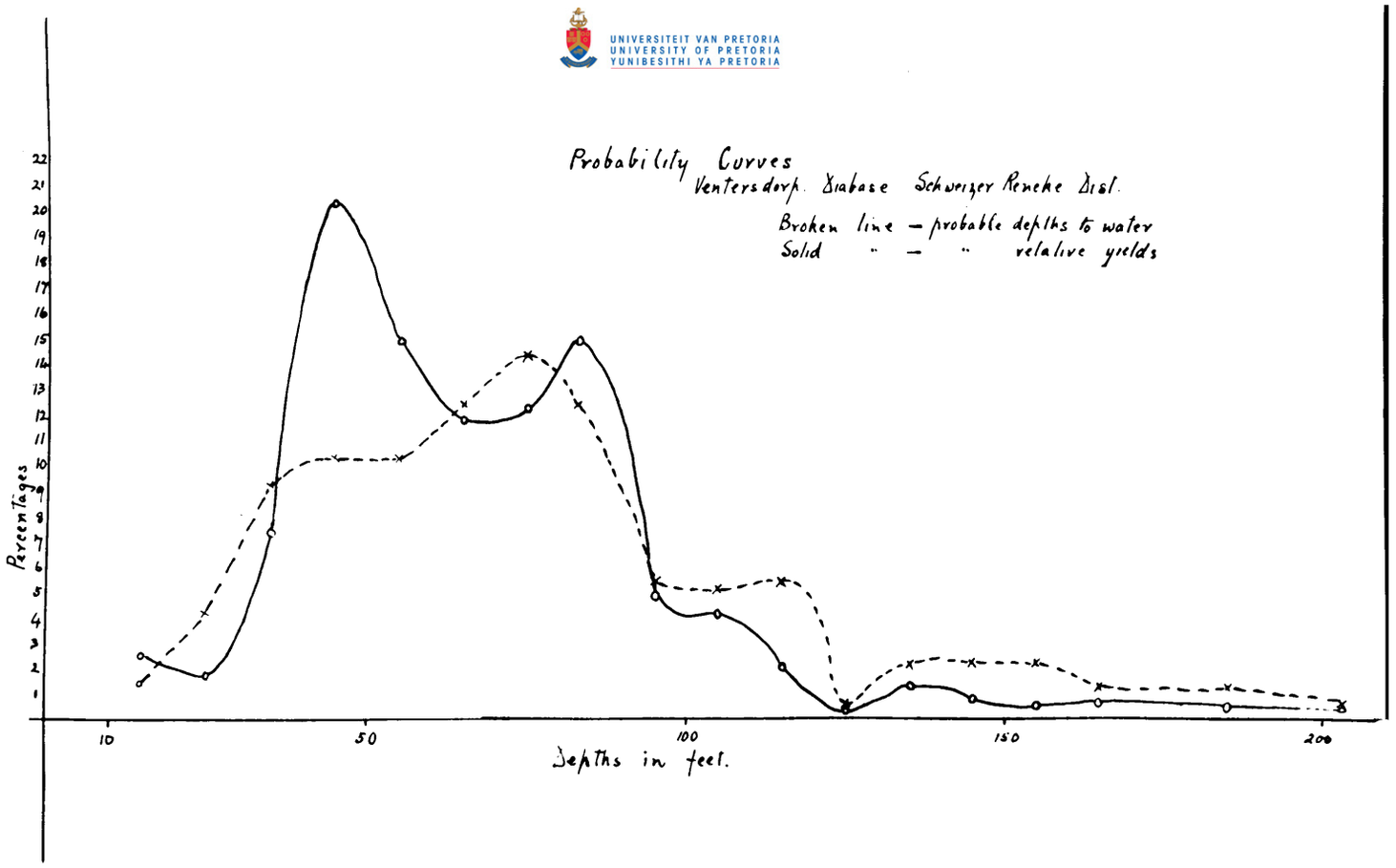


Fig. 9e.

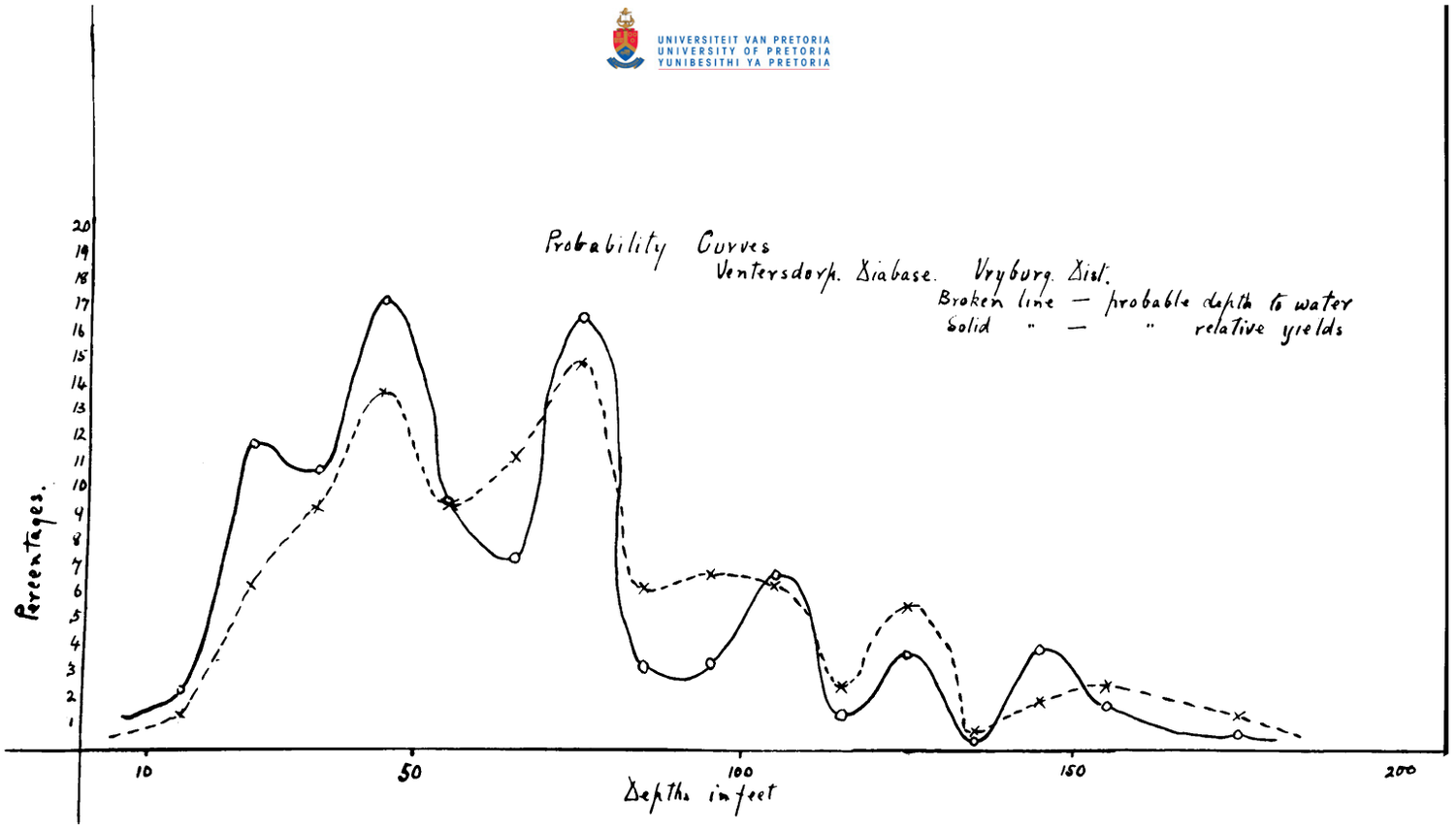


Fig 94

and from Taungs and Fourteen streams the now contracted belt of Ventersdorp rocks extends down the Vaal Harts Valley with minor exposures just within the boundary of the Orange Free State through the districts of Barkly West, Kimberley, to Prieska. The system is divided into two main groups, the Zoetlief series at the base and the Pniel series overlying unconformably. The former occupies a very restricted area.

The normal blue amygdaloidal lavas are often interbedded with coarse breccias and fine-grained tuffs, as in the Hope Town and Herbert Districts, where a band of coarse volcanic breccia, 50-100 feet thick with many fragments of a more acid variety of lava than the usual diabase covers a wide area and lies immediately above the quartzites of the lower part of the series.

The largest area occupied by the Pniel lavas, though in parts thinly covered by later formations, is that of the Vaal-Harts Valleys. West of Vryburg they are met with at Takoon, where they form a narrow belt consisting of a thin layer of lavas lying between the Black Reef and the Granite; they thicken eastwards by the coming in of more lavas and sometimes flagstones. For some thirty miles north west of Vryburg they rest upon the Zoetlief quartz-porphyries and overlap them at either end. The Pniel beds stretch continuously from Takoon to the Transvaal border near Vryburg, a distance of nearly eighty miles.

North of Vryburg the belt is 37 miles wide and it rests on the crystallines. Although in the basin of the Molopo south of Maretsani the older rocks are exposed, between Setlagoli and Mosita an outlier of the lavas, together with the other rocks forming the system, has been preserved in a synclinal fold.

Pniel beds, consisting of both lavas and breccias,

again occupy a large tract of country from Maretsani to beyond Mafeking while the town itself is built on a massive coarse conglomerate at the base of the formation.

Immediately south of Vryburg the Transvaal system and the Dwyka cover the volcanic rocks for some distance, but the latter appear on the Transvaal border and extend without a break in a South-south-west direction to beyond Barkly West. South of Barkly West they are covered over in wide areas by the Dwyka, which still partly fills the Pre-Karroo valley now being re-excavated by the Harts and Vaal Rivers. The whole series in this area is bent into a very low anticline, trending South-south-west, at Kimberley it reaches a thickness of nearly 1,580 feet, including some 700 feet of quartzite at the base.

The rocks are exposed now and then along the same strike as far as south of Maritz Dam, and evidently lie at shallow depth under the greater part of Herbert and Hopetown Districts.

The series has been much fault-sheared in Prieska, especially near the junction with the granite so much so that in places the lavas have been converted into slaty phyllites in which the amygdales forms eyes.

In the Mafeking and Vryburg districts 240 boreholes have been drilled in this formation. The averages are as follows:-

	Mafeking District	Vryburg District
Number of boreholes	48	195
Average total depth of borehole in feet	140	100
" depth at which water was struck in feet	95	70
" " to which water rises rest level in feet ...	85	50
" daily yield pumping in gallons	23,600	16,400
Percentage of failures	29	23.6
" " deep holes	Nil.	Nil.
Rainfall	22"	12"
Analysis of failures (1) Totally dry holes	43%	37%
(2) Holes not deep enough	7%	37%
(3) Boreholes strike water of no practical value	50%	26%

SUMMARY OF RESULTS OBTAINED IN THE VRYBURG DIST.

Depth to water in feet.		0-50	51-100	101-150	151-200	200-250	TOTALS.
Up to 1000	Yield per 24 hrs pumping in gallons	2	5	1			8
1-10,000		18	40	14	4	1	77
10-20,000		8	19	4	2		33
20-30,000		8	3	4			15
30-40,000		5	8	2			15
40-50,000		3	1	1			5
50-60,000			1				1
60-70,000				1			1
70-80,000		5	1				6
TOTALS		49	78	27	6	1	161

The lower average yield per borehole in Vryburg can be partially explained in the light of the lower rainfall in that area. A further explanation lies in the fact that obeervations show that where the lavas have been recently stripped of a covering of Lower Karroo the yields are generally poor, as at Vryburg Railway Station, Hayfield, Kalabas Kop and Thornhill, etc.

In the majority of these boreholes a covering of calcareous tufa is reported. This varies from a few feet to as much as over 100 feet. It would appear that this mantle generally has a beneficial effect on the amount of water available, but when very thick it would appear to be the opposite.

CONCLUSIONS:-

The formation as a whole is an excellent underground water carrier, as the yields are fairly consistent, the depth to the water generally not great and the failures comparatively low.

To improve the percentage of success fresh rock and highly decomposed rock should be avoided as well as areas

where/...

where the tufa covering is very deep.

The amount of rainfall affects the yields in this formation in the same way as it does those in the Crystalline rocks and the Dolomite, but only up to a certain point. If decomposition has gone too far the movement of waters underground is impeded and the infiltration into the hole suffers; in this respect the lavas are similar to the Crystallines. On the other hand if the rock is very fresh the waters also cannot move in quantity however much the rainfall, and low yields result.

Deep boring has not proved of any value in this formation as more than half the successful holes carried deeper than 300 feet have obtained their supplies at depths shallower than that.

UNDERGROUND WATER BEARING PROPERTIES OF THE DOLOMITE.

INTRODUCTION.

As almost all the large rivers of the Transvaal have their sources in this series, much has been written (1) about the underground storage of water in this formation and a lot of investigation and guaging has been done for the purpose of utilizing the many large springs for irrigation. Most of this deals with the springs and their outputs, however, the purpose here is to deal with the general underground water conditions and the likelihood of success that the attempts to exploit them by drilling,etc., will meet with.

Dolomite is a sedimentary rock composed of carbonates of lime and magnesia, with subsidiary amounts of manganese and iron either as carbonates or oxides and a little silica. The proportion of the two principle carbonates varies greatly.

This hard blue to grey rock has a texture somewhat similar to limestone, though in a characteristic curved and rhombohedral cleavage it differs slightly. It is reputed to have a higher porosity than calcareous limestone, but determinations carried out on South African samples (2) show porosities varying from 0.0% - 0.3%.

The dissolving action of meteoric waters, which generally contain CO_2 in solution, on limestone and dolomite is well known. Generally all the $CaCO_2$ is carried away in solution/...

---

(1) A.L.Hall, Geology of the Hennops River Ann.Rep.G.S.1904. Humphrey.Geology of the Klip River Ann.Rep.1909.Geology of the S.W.Portion of the Marico Dist.Ann.Rep.1908. A.L.du Toit.Explanation to Sheet 52,Johannesburg Underground waters in the Dolomite also Geology of S.Africa. E.T.Mellor. Geology of the Central portion of the Potchefstroom Dist.Ann.Rept.for 1907. Rept.of the Klip River Investigation Committee,Pta.1910. Intercolonial Irrigation Rept.1905.Pta.

(2) W.Wybergh. The Building Stones of the Union of S.Africa, Memoir 29. Geological Survey.

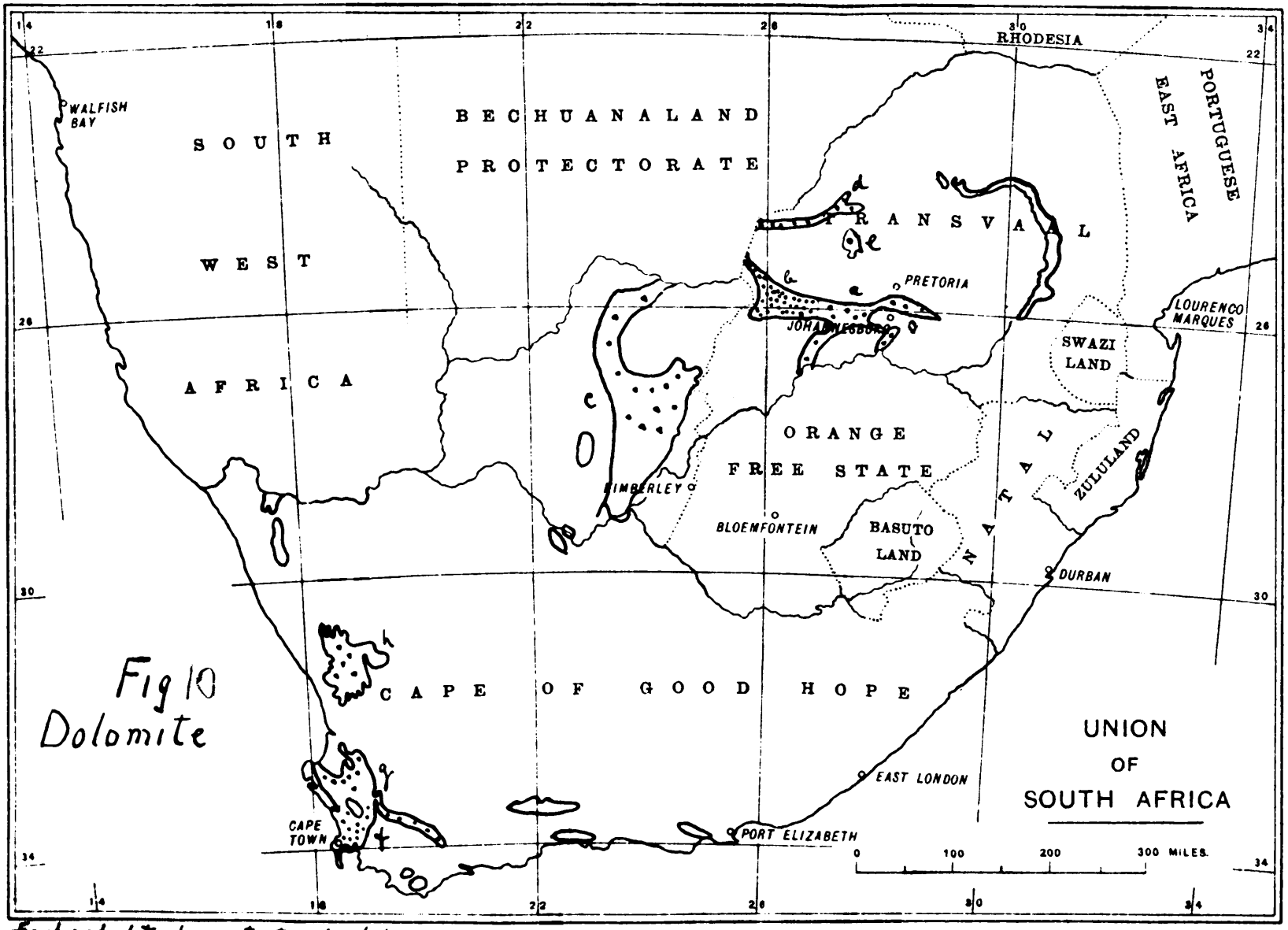


Fig 10
Dolomite

Each red dot represents ten boreholes

c
d
e

h
g
h

solution while the $MgCO_3$ iron-oxide, silica, and the hydrated oxide of manganese (Wad) contained in the dolomite, together with the silica of the chert bands, the clay of the interbedded shales and the decomposition products of dykes intersecting it, remain behind.

A portion of these weathering products fills dry fissures in the dolomite, but mostly they form a layer of red soil and chert fragments which cover the bare rock. This layer varies in thickness from a few inches to several feet, when it is absent the rock lies exposed with a characteristic wrinkled and furrowed surface which gave rise to the name of "Olifants Klip".

The porosity of the dolomite (mentioned before) is not sufficient to explain the large quantities of water stored in this rock so the network of fine cracks and fissures intersecting the rock has to be considered as well. These cracks and fissures which decrease in depth allow rain water, full of dissolved carbonic acid gas derived from the atmosphere, to percolate into the rock mass and dissolve lime from the dolomite. This reaction goes on continuously and indefinitely as witnessed by the lime-content of dolomite waters.

Once the fissures are large enough, surface water can flow in them as is seen during storms, etc., when large flows disappear into this rock. Instances have been recorded where rivers have been engulfed and continued their course subterraneously, and the whole nature of a stream can be changed when it flows over this rock.(x) The chemical action is now aided in its erosive powers by the mechanical action of sand and stones. Fissures change to galleries and caves are formed. The undermining action is further

aided/....

(x) Explanation to sheet 53. Ventersdorp: Dolomite and Underground water, by H.F.Frommurze.
H. Hanger: Underground erosion in the Dolomite. S.Af. Geographical Journals, 1922.

aided by the collapse of the upper layers.

These underground courses follow the most tortuous paths and are impossible to trace from the surface. Their existence, however, is well known and many can be inspected. On account of this phenomena this formation is the only one where the law recognises that underground water may travel in "known and defined channels". An inspection of any series of caves will show the irregularity of the subterranean course. The flow of the stream may be interrupted by cascades and rapids, caused by intrusive dykes or masses of fallen rock debris. A dyke or fall of rock often closes the channel altogether and the stream will then find another outlet, the old spring would then be said to have dried up. This coupled with the unceasing downward trend of the chemical and mechanical erosion is an ever present danger in the dolomite and should be thought of when towns depend for their water supplies on springs issuing from this series.

Often the roofs of the caves fall in and these large subsidences are known as "sink-holes" or "wonder gats" many of which are to be found in the Transvaal, often dry, but sometimes they still contain large supplies of water.

DISTRIBUTION:(1)

In the Transvaal and Orange River Province the Dolomite follows conformably upon the Black Reef Series, sometimes with a sharp boundary, sometimes by means of passage beds. It encircles the Bushveld Region making an outcrop from 4 to 12 miles wide, though broadening extensively in Marico and Lichtenburg and carrying many pans. It is obscured by Waterberg Beds in the neighbourhood of

Nylstroom/...

(1) Handbuch der Reg.Geol. The Union of S.Af. A.L. Hall. The Dolomite Series.

Nylstroom and by an extensive covering of Karroo Strata between Delmas and Carolina, the limit of the basin being indicated by deep borings in Bethal District.(2)

Between Randfontein and Ventersdorp the central region is all but separated from the large auxiliary basin of the Potchefstroom district by a narrow sagging anticline(3) of Black Reef Quartzites, and the Dolomite splits into two, one arm going in a south-westerly direction down the Mooi River and across the Vaal to Vierfontein, while the other follows the Klip River to Vereeniging with a subsidiary basin between Germiston and Heidelberg.

The southern side of the Potchefstroom basin has been twisted up in the doming of the Parys granite region and the Dolomite standing on edge or even overturned passes beneath the Karroo. Borings at Kroonstad have proved it at a depth of 1,000 feet.

The Dolomite basin in the East Rand mining area(4) has proved important as its fissured and water-bearing nature has led to difficulties in shaft sinking and high pumping costs. Isolated strips of dolomite are found in the Bushveld on the Crocodile River west of Boshoff's Berg, west of Warmbaths and at the junction of the Elands and the Olifants River.

In the Cape Province the Dolomite is called the Campbell Rand Series and builds the Kaap Plateau with a maximum width of 80 miles, bounded by a rocky escarpment on the south-east and by ranges of Griquatown Beds on the west. To the north the Kalahari beds cover the series except at

Morokwen./...

---

(2) Du Toit. Geology of S.Africa.
(3) Explanation to Sheet 53. Ventersdorp. H.F.Frommurze. Chapter on Underground Water in the press. Explanation to Sheet 52. Union Geol.Survey.A.L.du Toit.
(4) Chapter on Underground-water in the Dolomite.

Morokwen. Borings on the Mafeking border show the rock to be present at moderate depths.

West of the Kuruman Hills the Dolomite comes to the surface in the Postmasburg Maremane anticline. There is a further occurrence near Prieska.

LITHOLOGY:

Du Toit estimates the thickness of these beds in the Transvaal to vary from 5,000 feet in the west down to about 120' in the east.

The series is composed entirely of well-bedded magnesian limestones with subordinate bands of chert. The limestone occurs in solid beds of blue-grey, compact, or minutely crystalline rock, pink red and purple varieties also occur. The chert is white grey or black in colour, and is present as layers of varying thickness up to several feet following the bedding and as large irregular masses or veins generally more abundant in the upper part of the ofrmation. In the lower part of the Dolomite especially in the Cape Province layers or lenses of shale are common and an occasional quartzite band. In the west and north in the Transvaal a banded ironstone horizon is developed.

WEATHERING:

The blue-grey rock weathers to a brown colour, with a wrinkled, corrugated, channelled appearance from which the name "Olifants Klip" has been derived. The brown colour is due to the oxides of iron and manganese derived from the weathering of the small quantities of the carbonates of those elements present in the dolomite. By the removal of the soluble calcareous portions the siliceous and cherty bands and nodules stand out from the surface. As in other limestone formations, solution plays a big part in the weathering and consequent surface topography, and sinkholes and wondergats are numerous. Over wide areas the

rock/....

rock is hidden by deep red soil, full of lumps of chert and blackened by layers of manganese dioxide. In drier regions the formation is covered by porous calcareous tufa.

Caves are numerous, the most important of which are those at Wonderfontein, Sterkfontein, Koster, Six Miles Spruit, Pretoria, etc.

WONDERGAT:- sometimes contain water as at Mafeking, Geluk, Makapansgat.

SOLUTION:- in depth has lead to the collapse of patches of Coal Measures as at Delmas, Welbedacht, Syferfontein and Zuurbekom, Lenz and Lawley and south of Wonderfontein.

Rogers (4) ascribes the formation of the Blink Klip Breccia to the sagging and breaking of the Jaspers into similar solution hollows in the Dolomite.

SPRINGS:- The numerous springs with outputs of relatively great magnitude show that great volumes of water are stored underground in the dolomite, seemingly in the joints, fissures and solution channels as the porosity of the rock is so low.

IN THE TRANSVAAL	REASON FOR SPRING AT THIS POINT.	GUAGED OUT-PUT PER DIE
(3) Pretoria Springs Fountains	Fault	6,000,000
" " Rietvlei	do.	3,000,000
(2) Steenkopjes	?	10,000,000
Oog van Mooi Rivier		11,000,000
Bank	Dyke	10,000,000
Wonderfontein	"	13,000,000
Oog van Schoonspruit	Contact	9,000,000
Turffontein	Dyke	5,000,000
Gerhardminnebron	Fault ?	13,000,000
(1) Eye of the Marico River	Contact	5,000,000
Linokana	Dyke	2,140,000

IN/...

---

(1) Humphrey. Geology of the S.W.portion of the Marico Dist Ann.Rept.Geol.Survey 1908.
(2) W.van Warmelo. S.A.Irrigation Magazine Vol.3.No.1.1924.
(3) A.L.Hall. Geology of Pretoria and Neighbourhood. Explanation of Geol.Map of Environs of Pretoria.
(4) A.W.Rogers. Ann.Report G.C. for 1905 & 1906.

IN CAPE PROVINCE.	REASON FOR SPRING AT THIS POINT	GUAGED OUTPUT PER DIEM.
Kuruman		4,000,000
Bothetheletsa		9,160,000 (appro
Groot Koning	Dyke	420,000 "
Griquatown		-
Groot Boetsap	Layer of Shale	-
Manyeding		9,000,000 "

These large springs form the sources of all the rivers in the Transvaal. The outputs fluctuate according to the seaso

AREAL:

In considering the underground water in detail the Dolomite has been divided into three main groups according to the annual average rainfall.

GROUP 1, which has an annual average rainfall of from 25" - 30" comprises the districts of Heidelberg, Springs, Pretoria, Witwatersberg, Germiston, and Vereeniging.

In this large tract of country composed for the most part of undulating plains covered with the typical poor red soil characteristic of the Dolomite, outcrops of rock are comparatively rare. The rainfall is high and the run-off practically negligible. In addition the run-off from the surrounding harder formations such as the Pretoria Series to the north and south and the Witwatersrand Ventersdorp and Old Granite rocks in the centre is available for absorbtion so it is not surprising that large quantities of water are to be found underground, as the following average show:-

Number of borehole records examined	126
Average total depth of borehole in feet	119
Average depth at which water is struck in feet	85
" " to which " rises (Rest level) in feet	42
Average daily quantity of water available for pumping in gallons	39,200
Percentage of failures	17%
Total failures	12%
Holes probably not deep enough to strike water	2.5%
Water insufficient for practical use i.e. water supply under 1,000 gallons per day	2.5%
Percentage of Holes deeper than 300'	3.1%
" " " without water deeper than 300'	.6%

Water/...

Water struck above depth of 300' in holes deeper than 300'	.5%
Water struck below depth of 300' in holes deeper than 300'	2.0%
Percentage of flowing holes	2%
" " holes with exceptional water supplies, viz. above 100,000 gallons per day	3.1%

SUMMARY OF BORING RESULTS IN GROUP I DOLOMITE.

QUANTITIES IN GALLONS PER DIEM.

Depth in feet	Up to 1000 g.p.d.	1001-10000	10-20000	20-30000	30-40000	40-50000	50-60000	60-70000	70-80000	80-90000	100000 & more	Totals
0-50		5	2	1		4	2	4			1	19
51-100	1	6	10	2	3	4		2	1	5	1	35
101-150		8	1	4	1	3	2	1			1	21
151-200		3	3	1		1	1					9
201-250		1				1	1					3
251-300					1							1
301-350		1		1								2
TOTAL	1	24	16	9	5	13	6	7	1	5	3	90

RESULTS PER DISTRICT.

District	Number of Bore-Holes	Rainfall	Av.Total depth of borehole in feet.	Av.Depth at which water was struck in feet.	Av.Depth to which water rises in feet.	Av.Quantity pumped per day in gallons.
Springs	14		166	123	28	48,000
Pretoria	53		103	62	37	37,000
Witwatersrand	39		130	103	60	36,300
Vereeniging	4		110	92	39	34,050
Heidelberg	15		106	83	43	30,000

These results show that in spite of the bad name which the Dolomite has with drillers the average results obtained by boring are the highest for any formation. The exceptional yields in the Springs area are due partly to the basin - like structure assumed by the Dolomite here and partly (xl)

to/....

(xl) See also The Geology of the Country surrounding Johannesburg. Explanation to Sheet 52 by E.T.Mellor with chapter on Underground Water in the Dolomite Areas by A.L.du Toit Union Geological Survey,Pretoria,1921.

to the high rainfall. In addition the country underlain by the Dolomite has a lower elevation than that surrounding it. It is in this area that large quantities of water have been met with in the course of mining operations (2) usually associated with a sheet of intrusive olivine dolerite of post Karroo age which conforms roughly to the curvature of the basin (cf.Pretoria area).

In the Pretoria area, the Dolomite country forms the elevated strip to the south of the town Pretoria turning south eastwards towards Delmas along the Pretoria-Delmas Dolomite trough and south westwards past Magaliesberg to join with the main mass of Group 2. The runoff in this area is very low and the underground flow in the Dolomite is stopped to the north by faults. The Hennops River Valley forms a drainage line along which large amounts of underground water are absorbed. Another interesting feature in this area is the dependence of the spring outputs and the level of the water in the boreholes on the rainfall. The Fountains Spring at Pretoria decreased 1,100,000 after the drought in 1932-33 and the level of water in boreholes at Six Miles Spruit dropped 20-30' at the same time. Sheets of intrusive diabase roughly parallel to the outcrop of the Pretoria Series have proved very useful in confining the underground water to definite horizons.

The Vereeniging,Heidelberg and Witwatersrand areas are all situated on the south of the great watershed (Witwatersrand) and form low lying country between escarpments of the Pretoria Series on the south and west, and the Ventersdorp amygdaloid (Klipriversberg) on the north and east. There are numbers of large vleis and the drainage line of the Klip river is situated in the area. It is in

this/....

---

(2) A.L. du Toit. loc.cit.

this valley that the pumping stations of Zwartkopjes and Zuurbekom are situated, where in the case of the former a maximum 5.65 million gallons per day were pumped from 4 boreholes, and in the case of the latter a maximum of 6,000,000 gallons per day.

GROUP 2. The second group consists of the Potchfestroom, Klerksdorp, Ventersdorp, Lichtenburg, Southern Rustenburg and Southern Marico Districts.

It is a large area and extends from the Ventersdorp District eastern border just west of the town of Krugersdorp west-wards to the Bechuanaland border at Lobatsi and to the south down the Mooi River valley to the Vaal River below Klerksdorp. The eastern section is very similar to that described in Group I, low lying country between escarpments of other rocks, undulating and soil covered, but with few outcrops. There are numbers of large vleis and several large springs.

To the west, however, there is a change, the typical red soil covering is persistent throughout, but outcrops are more numerous, and there are stretches of country covered with chert outcrops and shed chert, which are very poor agriculturally.

The rainfall (20-25") is lower than in group I. and this is reflected in the results obtained in boring for water.

The run-off is also very low.

The averages for this group are as follows:-

Number of borehole records examined	325
Average total depth of borehole in feet	118
" depth at which water is struck in feet	77
" " to " " rises (rest level) in ft.	53
Average daily quantity of water available for pumping in gallons	32,700
Percentage of failures altogether	30.5%
" " total failures	16.6%
" " boreholes probably not deep enough to strike water	9.2%

Percentage/...

Percentage of boreholes with water supply insufficient for practical use, i.e.under 1000 g.p.d.	4.6%
Percentage of boreholes deeper than 300'	3.7%
" " " " " " without water	nil
" " " " " " with water struck above depth of 300'	2.4%
Percentage of boreholes deeper than 300'with water struck below depth of 300'	1.2%
Percentage of flowing boreholes	0.9%
" " boreholes with exceptional supplies, i.e.above 100,000 g.p.d.	3.7%

SUMMARY OF BORING IN DOLOMITE GROUP II.

QUANTITIES IN GALLONS PER DIEM.

Depth in Ft.	Up to 1000 g.p.d.	1-10000	10-20000	20-30000	30-40000	40-50000	50-60000	60-70000	70-80000	80-90000	90-100000	100000	Tots
0.50	2	10	6	9	4	5	2	3	1		1	5	48
51-100	2	21	15	14	13	11	9	1	7	1	3	3	100
101-150		16	12	4	1	4	1		2	1			41
151-200		8	5	1	1	3							18
201-250		3	1		1		1						6
251-300			1	1									2
301-350					1								1
351						3							3
Totals	4	58	40	29	21	26	13	4	10	2	4	8	219

DISTRICT RESULTS.

District	Number of boreholes.	Rainfall.	Av.Total depth of borehole in feet.	Av.Depth at which water was struck in feet.	Av.Depth to which water rises in feet.	Av. Quantity pumped per day in gallons.
Klerksdorp	30		101	77	45	47,000
Lichtenburg	120		104	70	40	33,100
Potchefstroom	41		102	72	50	32,300
Marico	49		114	87	50	30,000
S.Rustenburg	13		111	97	62	27,800
Ventersdorp	70		159	131	93	20,500

The Klerksdorp and Potchefstroom areas lie on the southern side of the great anticline and in an area of higher rainfall (25") than the others. Here as in Group 1, outcrop are rare and large vleis and springs are numerous in the red-soil covered flats. The Mooi River valley and the Koekemoer Spruit have proved very fruitful to the driller.

The other districts are on the northern side of the anticline./...

anticline. In Ventersdorp the presence of a large tract of elevated country underlain by Dolomite in which the chert content is high and known as the Klipveld, where yields from boreholes are poor and drilling is difficult, has had a lowering effect on the general average for this district. Otherwise conditions are similar to those in the two previous areas, especially along the Schoonspruit and the Upper Mooi River where large springs issue. In the Southern Rustenburg, Lichtenburg and Marico areas the Dolomite outcrop attains its greatest width from north to south. Here the country becomes almost featureless, just wide plains covered with red soil and sparse grass and some large pans. In Marico and Lichtenburg the presence of a number of intrusive quartz veins has had an influence on the movements of the underground water particularly in the neighbourhood of Ottoshoop (1) where several large springs issue forming many huge vleis. The shallow water table had an adverse effect on the working of the gold reefs in this area, to-day, however, observations show that there has been a considerable fall in this depth.

The large vleis round Lichtenburg and Polfontein have also proved good areas for drilling for water, as also the contacts between the Dolomite and the underlying Ventersdorp Volcanics and the overlying Pretoria Series at Linokana north-west of Zeerust.

The Dolomite outcrop which has thinned out very considerably continues in a north-westerly direction to Lobatsi where drilling for water by the Bechuanaland Protectorate Administration and the Cold Storage has proved very fruitful.

GROUP 3. The third Group is located in the northern Cape

Province/...

(1) A.L. Hall,B.A.,F.G.S. & W.A.Humphrey,B.A.,Ph.D. The Geology of the Country round Zeerust and Mafeking, Pretoria,1910.

Province and extends from Morokwen in the northern Vryburg District down to below Griquatown in the south a distance of 170 miles. It attains its greatest width from east to west from Vryburg to Kuruman.

This large extent of Dolomite forms a huge plateau, known locally as the Kaap Plateau. It is almost featureless, monotonous miles of sparse grass, sand, tufa, with very few bushes and occasional Dolomite outcrops. Characteristic of Dolomite country are the large springs as at Morokwen, Kuruman, Bothethelesta, Manyeding,etc.,sinkholes as at Daniels Kuil, and the "Bos-aars", intrusive igneous dykes marked by trees and bushes with chains of wells and boreholes alongside them.

Boring records available are limited to the Kuruman,Vryburg and Barkly West Districts. They are tabulated as follows:-

Total number of boreholes records examined	127
Average total depth of boreholes in feet	145
" depth at which water was struck in feet	112
" " to " " rises (rest level) in feet.	61
" quantity available per diem for pumping in gallons	25,000
Percentage of failures	23%
" " total failures	9.4%
" " boreholes probably not deep enough to strike water	10.0%
" " " with water supply insufficient for practical use i.e.under 1000 g.p.d.	11.8%
" " boreholes deeper than 300'	4%
" " " " " " without water	0.8%
" " " " " " with water struck above depth of 300'	0.8%
" " " deeper than 300' with water struck below depth of 300'	2.3%
Percentage of flowing boreholes	nil
" " boreholes with exceptional supplies, i,e.above 100,000 g.p.d.	2.3%

SUMMARY OF BORING IN DOLOMITE GROUP III

QUANTITY IN GALLONS PER DIEM.

Depth in Ft.	Up to 1000	1-10000	10-20000	20-30000	30-40000	40-50000	50-60000	60-70000	70-80000	80-90000	90-100000	100000	Totals
0-50		5	1		2	1	3			1		1	14
51-100	1	12	5	5		4	5	1	1	1		1	36
101-150		6	3	2				1	2				14
151-200		6	1	1	1				2			1	12
201-250		3			1								4
251-300	1	3	2										6
TOTAL	2	35	12	8	4	5	8	2	5	2		3	86

District/....

DISTRICT RESULTS.

District	Number of Boreholes.	Av.Total depth of borehole in feet.	Av.Depth at which water was struck in feet.	Av.Depth to which water rises in feet.	Av.Quantity pumped per day in gallons.	Failures.
Kuruman	60	159	137	93	21,740	40%
Vryburg	67	134	95	42	27,400	23%

The rainfall decreases proceeding westwards and the average yields behave in a similar way while the percentage of failures increase. The large yields at Vryburg and Morokwen are situated in the zone of the highest rainfall and near the Dolomite-Black Reef contact.

Generally in this area the country is fairly even or gently undulating and over wide areas the rock is hidden by soil, sand or white porous calcareous tufa. As elsewhere on the Dolomite there is a marked lack of surface streams and run-off is replaced by absorption.

THE NORTHERN AREA:

(1) Rustenburg and Marico.

The main dolomite area forms a regular belt from 4 - 7 miles wide running from the Bechuanaland Border near Ramoutsa eastwards towards the Crocodile River curving to the north-east near the latter and forking, one branch trending north and the other continuing eastwards past Gatkop along the Zand River Valley to the Waterberg District boundary.

The rocks dip at angles of 12-30° generally but in the east the dips are high and much thrust faulting has caused duplication.

Reports show that fairly large quantities of storm water flow off the country to the south,underlain by Pretoria beds and Norite, and are absorbed by the Dolomite. The Rainfall is from 20-25".

Due east of the Pilansberg is a second and smaller area traversed by the Crocodile River.

The/...

The average results obtained here are as follows:-

	1st.Group.	2nd.Group.
Total Number of boreholes	88	14
Average total depth in feet	140	198
" depth at which water was struck in feet.	99	149
" " to which water rises (rest level) in feet	63	69
Average daily yield in gallons pumping	21,500	13,300
Percentage of failures	50%	43%
Total failures	32%	14.3 %
Boreholes probably not deep enough to strike water	7%	14.3 %
Boreholes with water supply insufficient for practical use	10.3%	11.3 %
Percentage of boreholes deeper than 300'	5.7%	7 %
" " " " than 300' without water	4.6%	-
Percentage of boreholes deeper than 300' with water struck below 300'	-	7 %
Percentage of boreholes with exceptional supplies i.e.above 100,000 g.p.d.	1.1%	-
Percentage of boreholes deeper than 300' with water struck above 300'	1.1%	-

Faulting has caused considerable alteration in the Dolomite here and this is reflected in the results which show greater depths and higher percentages of failures This alteration has been increased by the intrusion of basic rocks. Similarly there is a greater development of banded ironstones than usual particularly in group two, which makes the drilling more difficult and the rock more impervious.

The conclusions arrived at from a consideration of these results are as follows:-

1. The Dolomite gives the highest average daily yield of any of the formations investigated, but the percentage of failures is also very high, emphasizing the fact that when a supply is struck it is generally an excellent one.

2. The quantity of underground water available for exploitation by drilling is dependent firstly on the rainfall and secondly on the structure and weathering.(Solvent action of water,etc.) This is just as true in this formation as in the others. The yields decrease proceeding from east to west (see group averages) as the rainfall decreases, in spite of the fact that the channelled nature of the dolomite makes it possible for water to travel long distances underground. The influence of the structure is also obvious in the lower yields obtained in (a) Ventersdorp, due to a zone where

there/...

there is much chert interbedded with the limestone and (b) Northern Rustenburg where faulting and metamorphism of the limestones occur coupled with a development of banded ironstones.

3. The effect of the subterranean channeling is to a certain extent negatived by the igneous intrusions which apparently divided the formation as a whole into compartments though the latter can leak in the form of springs. Otherwise it would be expected that the yields would be more equal.

4. The best places for selecting borehole sites are near igneous dykes and sills, quartz veins, interbedded chert bands, quartzites, and shales, or contacts with more impervious formations. If it is impossible to take advantage of any of these, the operations should be restricted to surface drainage lines. It is found that the high ground and wide flat featureless plains are highly speculative.

5. It is very difficult or almost impossible to indicate the subterranean courses followed by streams in the Dolomite from the surface. An example of this is the fruitless and deep boring which has been carried out in the vicinity of the various large springs in an endeavour to tap their sources, viz. Kloofzicht and Sterkfontein, Pretoria District, Oberholzer, Ventersdorp District, and along the Kuruman River.

WATER BEARING PROPERTIES OF THE MALMESBURY SERIES IN THE SOUTH WESTERN CAPE.

This Series correlated with the Dolomite in the North and consisting of grey and black shales, white, grey and black limestones often crystalline conformably overlies the Nieuwerust Series.

From Picquetberg to the Cape Peninsula and eastwards arenaceous clayslate and argillaceous quartzites predominate, though by the addition of mica phyllites are developed. Sands and thin clayey soils obscure most of the area. White quartz veins are frequent and can be traced by weathered eluvial fragments. (1),(2).

Great lateral lithological variation is displayed

though/....

---

(1) A.L.du Toit. Geology of South Africa.
(2) A.L. Hall. Handbuch der Regionalen Geologie. The Union of South Africa.

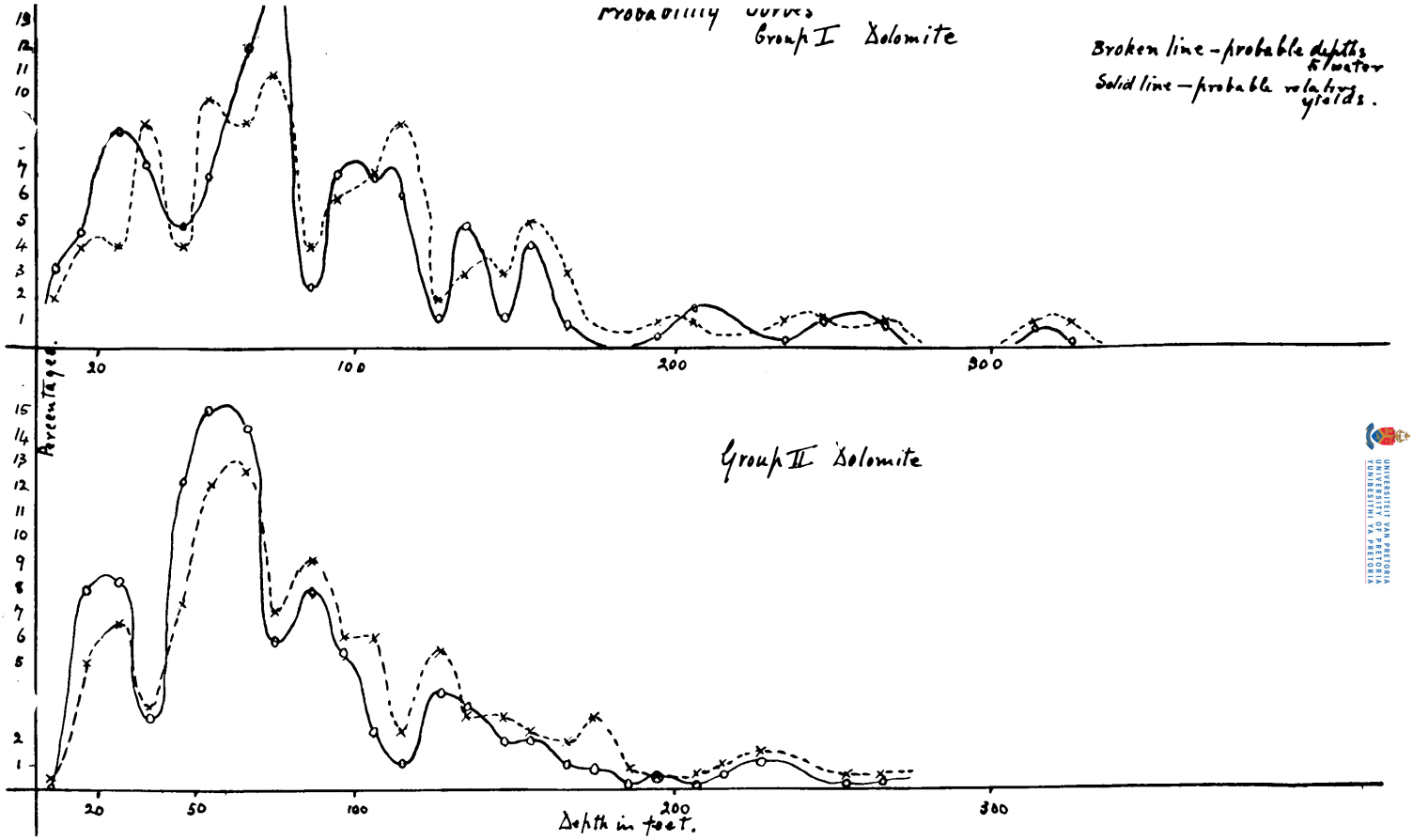


Fig 10a

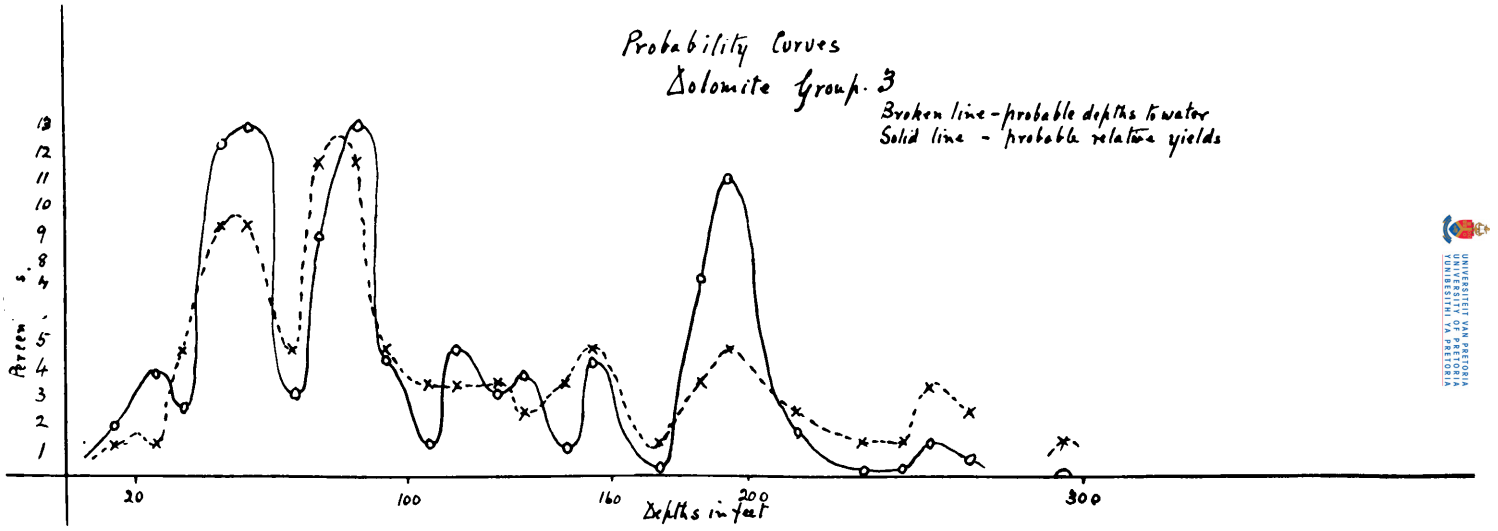


Fig 10b

though faulting and folding are not usually discernible, the continuous parallel outcrops of the various layers seem to point to the fact that both must be extensive.

These generally highly tilted, slaty, flaggy or phyllitic rocks have in places been weathered into white, yellow, or brown, sandy or clayey matter, in places to great depths 100 to 150 feet being recorded in borings.

Whether this decomposition is due to the average annual rainfall of 20-30" alone or was caused by the action of sea-water penetrating into the tilted slates when the ocean covered the coastal plains is not quite certain. It is probable that both agencies have contributed to the breaking down process and that the action has been continuous as the more brackish waters seem to occur to the west under a lesser rainfall.

Boring for water in these beds has met with fair success, especially in the areas under high average rainfall as the Cape Peninsula.(3)

In analysing the results obtained from the boreholes, three groups have been formed, as follows:-

Group 1. The results obtained in the Cape Peninsula, Wynberg, Bellville, Stellenbosch and Somerset West Districts where the Series is under an annual average rainfall of 20-30" and in addition has the benefit of the run off from the higher rainfall areas in this neighbourhood.

Group 2. The results from the Malmesbury and Paarl Districts annual average rainfall of 10-20".

Group 3. The several irregularly distributed detached masses found between the Villages of Van Rhynsdorp and Nieuwerust in the district of Van Rhynsdorp where the rainfall is only 5-15".

In the first group the results of 125 boreholes were examined, many of which were obtained from private drilling contractors.

The averages are as follows:-

Average total depth in feet	160
Average depth at which water is struck in feet	117

Average/...

(3) H.F.Frommurze. Chapter on Underground Water. The Geology of Cape Town and adjoining country. Explanation of Sheet 247 (Cape Town)

Average depth to which water rises (rest level) in feet	33
Average daily yield per borehole in gallons pumping	22,000
Percentage of failures	20%
Percentage of holes over 300' deep	7%
(a) Which are dry	4%
(b) Which strike water above that depth	1.5%
(c) Which strike water below that depth	1.5%
Percentage of boreholes which have supplies of 100,000 gallons per day and over	10%
Percentage of boreholes with brack water	15%

	Group II	Group II
Total number of boreholes	77	46
Average total depth in feet	150	188
Average depth at which water was struck in feet.	112	152
Average depth to which water rises (rest level) in feet	45	50
Average daily yield per borehole in gallons pumping	11,600	28,300
Percentage of failures	30	7
" of deep holes i.e.(over 300')	1	4
" " boreholes with brack water	20	7

The variation between 1 and 2 in both quantity and quality is undoubtedly due to the larger rainfall which the area covered by group 1 gets, as well as the conditions which transmit the run-off from the Table Mountain Sandstone Mountains down to the talus overlying the Malmesbury Beds, where it is held in direct contact with the tilted and pervious decomposed edges of the slates, etc. This phenomenon is particularly noticeable in the Cape and Somerset West Divisions.

It would appear therefore that the available underground water is due to the absorption of rainfall on the spot, or else brought short distances via gravel beds and recent unconsolidated deposits, guided into ill-defined channels by the configuration of the country.

In Group 2 the extensive flat-lying areas do not obtain this benefit except to a small extent along the edges, the rainfall as well is somewhat less.

In group 3 the water level is deeper, but the average yields are surprisingly high. It is thought that

the/...

the reasons for this are: (a) the considerable amount of faulting that has taken place in this area, (b) the benefit of a considerable run-off from the hard mountainous country to the south and east, (c) the development of limestones in the Malmesbury series.

The limestones themselves compare favourably with the dolomite of the Transvaal as an aquifer.

The averages are particularly high. viz:

Average total depth in feet	150
" depth to which water is struck in feet	124
" " " " rises (rest level) in feet.	22
Average daily quantity pumping in gallons	37,200

SUMMARY OF RESULTS OBTAINED IN GROUP I.MALMESBURY BEDS.

YIELD PER 24 HOURS PUMPING IN GALLONS.

Depth to water in feet.	Up to 1000	1- 10000	10- 20000	20- 30000	30- 40000	40- 50000	50- 60000	60- 70000	70- 80000	80- 90000	90- 100000	1000000	Total
0-50		4	4	2								1	11
51-100	2	11	11	13	1	2			2	1		2	45
101-150	2	17	8	11	3	1			1		2	2	47
151-200		7	6	5	2	1			1		1		23
201-250		1											1
251-300			1										1
TOTALS	4	40	30	31	6	4			4	1	3	5	128

CHAPTER V.

THE UNDERGROUND WATER BEARING PROPERTIES OF THE PRETORIA SERIES.

The Pretoria series is the upper portion of the Transvaal or Nama System and overlies the Dolomite and Black Reef Series conformably. This Series consists of quartzites, flagstones and shales much intruded into by sheets of basic igneous rocks related to the Bushveld Complex. There is also a large sheet of contemporaneous andesitic lavas in the lower portion of the Series.

In the Transvaal the Series forms part of the parallel belts of country that constitute the crests of the opposing limbs of the great Witwatersrand anticline. Of these the northern belt is considerably more extensive.

It forms a large roughly oval belt of varying width - at Pretoria 7 miles, to west of Rustenburg 45 miles - extending westwards from the neighbourhood of the Wilge River in the Middelburg district (where it disappears under the Waterberg and Karroo Systems) to Pretoria (45 miles) on to Rustenburg (70 miles) and then to Zeerust (another 70 miles).

At Zeerust it bends northwards and crosses into the Bechuanaland Protectorate. On the northern edge a thinner band runs east to the south western corner of the Waterberg escarpment beneath which it disappears, reappearing some 60 miles to the N.E. at Potgietersrust to again vanish, this time under the amygdaloidal diabase of the Springbok flats. Outcropping again some 40 miles to the east at Molsgat it continues southward as a broad belt until below Machadadorp it is covered up by the Karroo sediments.

The southern belt approximately 20 miles wide extends from the top of the Klip River Valley south of Johannesburg to just across the Vaal River to the west of

Venterskroon/....

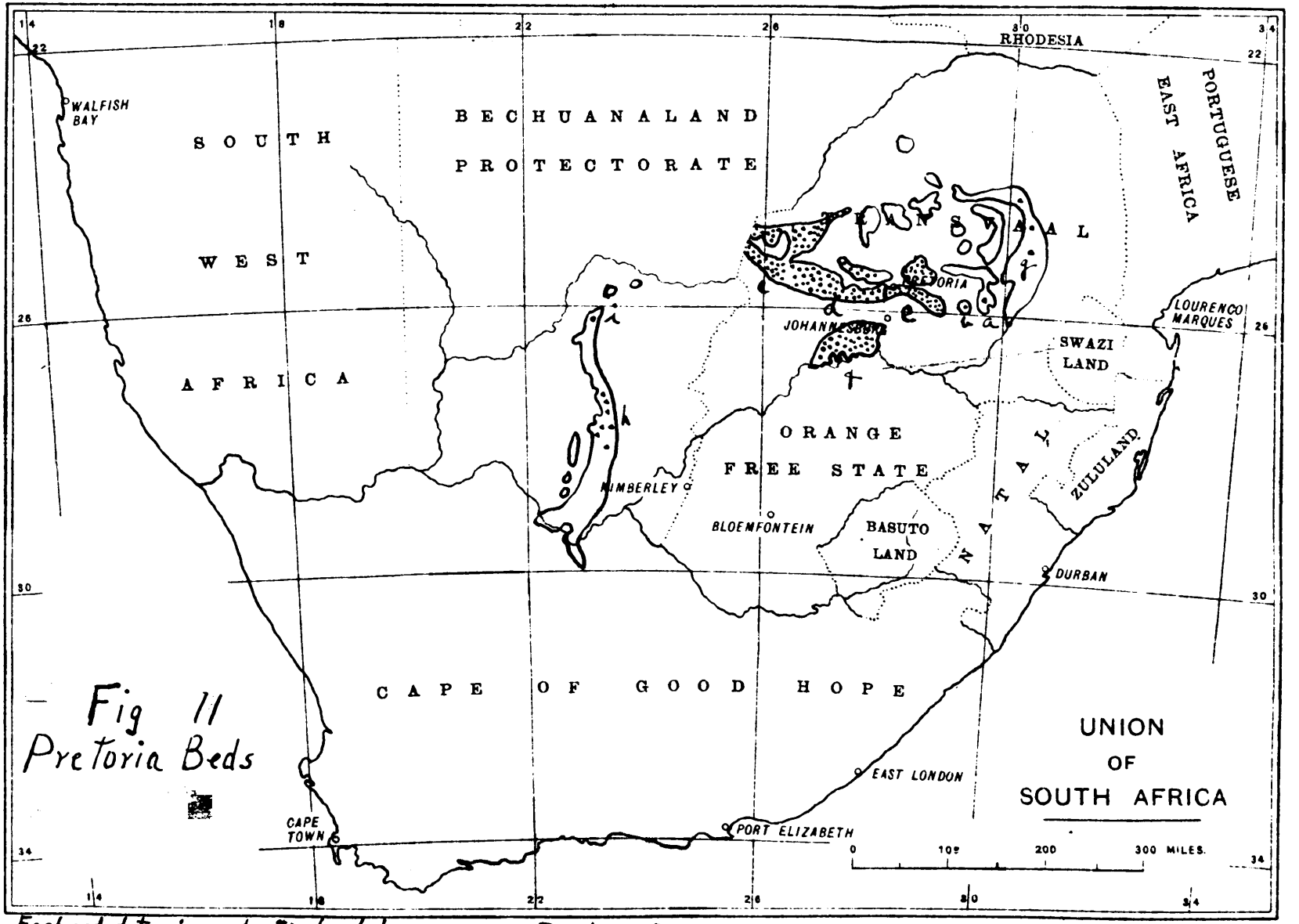


Fig 11
Pretoria Beds

Each red dot represents ten boreholes

a Witte[illegible] d [illegible] 635 g E.Tvl 30
b Middelburg 10 e Marico 253 h Kuruman 76
c Pretoria 370 f Gaberones 253 i Vryburg 10

Venterskroon again disappearing beneath sediment of Karroo age.

Typical section through the series is as follows:

Top: Shale and Intrusive Diabase.
Magaliesberg quartzite with intrusive Diabase.
Shales and slates with intrusive Diabase.

Middle: Daspoort Quartzite.
Contemporaneous amygdaloidal andesite or Ongeluk Diabase.
Shales and slates with intrusive Diabase.

Lower: Timeball hill Quartzite.
Shales with Diabase.

In some areas there is present below the Timeball hill quartzite another thin quartzite separated from the latter and from the dolomite by shales, as for example from Magaliesberg in the Krugersdorp westwards to Zeerust.

TOPOGRAPHICAL.

(1)
"The dependence of topography upon geology is never better exemplified than with this formation. The shaly groups with their associated diabases tend to occupy the lower ground, while the quartzites stand out in ridges running regularly for miles. Very striking are these huge parallel quartzite walls vanishing into the distance, with regged scarps facing outwards and long dip slopes descending evenly on the opposite sides. The rivers have broken through these ranges in narrow and picturesque gaps, as at Hartebeestpoort on the Crocodile River and Baviaanspoort on the Pienaars River." This country forms a great contrast to the flat bare dolomite plains adjoining.

SURFACE WATERS.

The run-off from this series of shales and quartzites is fairly good, another point in contra-distinction to the adjoining dolomite and the streams persue well defined courses. Many such as the Marico, Crocodile, and Pienaars Rivers are perennial except in exceptionally dry seasons.

Certain/....

(1) Du Toit. Geology of South Africa.

Certain portions of this country seem to be without good surface water supplies however as in the south western portion of the Rustenburg District between Tafelkop and Rustenburg south west of the Daspoort quartzite horizon.(2 But generally the surface supplies are fair from the Daspoor range horizon upwards in the succession.

There are numbers of small springs issuing from the Daspoort and Magaliesberg quartzite horizons mostly on the dip slopes. In the case of the latter horizon some issue on the other side as at Buffelshoek and Magatoshoek in the Rustenburg District. These small flows are generall utilised at the base of the hills and seldom get further. At the bottom of the dip slope of the Magaliesberg and Daspoort quartzites in the Pretoria, Rustenburg and Marico Districts a large sandy talus is formed and this porous deposit is found to contain large quantities of stored underground water e.g. as on Rustenburg town lands,etc. This stored body of water also acts as an area of infiltration for the underlying rocks and definitely improves the yields from boreholes in the diabase on the edge of the Bushveld complex where in contact with this horizon.

BOREHOLE WATER SUPPLIES.

Dealing first with the portion of the series exposed from the Wilge River near Bronkhorstspruit westwards to Zeerust and beyond. It has been proved by the drilling of 1,300 boreholes to be generally a very satisfactory underground water carried or aquifer. In adding the Gatsrand and Eastern Transvaal areas a further 280 borehole results are added bringing the total to 1,500. The results from the latter areas bear out further that this formation is a good underground water carrier.

For the purpose of convenience and consistency in tabulating the borehole results the series has been divided

as/....

(2) A.L.Hall. On the South-Western Portion of the Rustenburg District. Annual Report Geological Survey of the Transvaal 1907.

as follows:

Timeball quartzite horizon Timeball shale horizon	Timeball quartzite. From the Timeball quartzite horizon to the bottom of the Daspoort quartzite horizon.
Daspoort quartzite horizon Daspoort shale horizon	Daspoort quartzite. From the top of the Daspoort quartzite horizon to the bottom of the Magaliesberg quartzite.
Magaliesberg quartzite horizon Magaliesberg shale horizon.	Magaliesberg quartzite. From the top of the Magaliesberg quartzite upwards.

In general the shale and slate group alone gives average supplies of from 12,000-40,000 gallons per diem at average depths of from 72'-116'. The quartzites yield on an average from 16,000-32,000 gallons per diem at depths of 80'-112'. The intrusive diabase of Bushveld age - 21,000 to 33,000 gallons per diem at 83-93' and the contemporaneous amygdaloidal lavas 17,000 to 36,000 gallons per day at 27-72 feet.

Thus generally the average yield per horizon is more or less the same, the difference between the highest (Shales only and Intrusive diabase only) and the lowest (Quartzites only) is only 3,000 gallons per diem.

Considering the waterbearing quality of the various horizons in their natural successions there is however considerable variation due to a variety of causes both local and more widespread, as for example the shale below the Timeball Hill Quartzite horizon. Here results are generally good (vide averages), due it is thought to the proximity of the dolomite which it overlies, but areas are met with in which it is difficult to get water as at Platklip No.97 in the Krugersdorp district and surrounding farms where faulting has disturbed the strata and contrary to its usual effect this area has been proved to carry less underground water.

In the case of the intrusive diabase sheets many

are/...

are well known to be in a soft friable and decomposed condition and act as sponges being full of underground water. Sometimes, however, decomposition goes too far, or it may be due to the chemical composition of the rock, and it is found on boring that the soft rock and the water flow together and it is difficult to separate them. This is typical of a sheet of diabase just north of the Daspoort Quartzite and one north of the Magaliesberg Quartzite. Boreholes in these horizons strike large quantities of water mixed with the decomposed diabase in the form of mud, which rushing into the borehole has caused operations to be abandoned. Good examples occurred at Rietondale and Silverton near Pretoria.

The intrusion of the bushveld igneous complex into the Pretoria Series,(x) is held to have caused extensive thermal metamorphism in the beds of this series. This metamorphism has resulted in the change of ordinary soft fissile shales, into hard spotted and highly coloured varieties, also chiastolite and andalusite schists, and cordierite contact hornfelses. A general hardening of the shales has taken place in the earlier stages of the process beyond which the shales exposed in many areas particularly around Rustenburg have not proceeded, in the later stages the rock becomes porous and soft again as in the areas north of Zeerust. The change in the quartzites is not so great chemically as physically. In places recrystallisation has taken place and resulted in the formation of a sugary quartzite with a few secondary minerals.

The intensity of the changes are greater in the west than in the east.

From east of Pretoria to Scheerpoort there is

hardly/....

(x) A.L. Hall. The Bushveld igneous complex. Memoir 28 U.G.S.

hardly any change in the normal condition of the beds except locally in contact with intrusive diabases, fissures as at Silvermine, etc.

From Scheerpoort to the Groot Marico River there is a rapid and marked increase in the intensity of the metamorphism as shown by its results. It is possible that in addition to the thermal agencies the greater pressure which has affected the Pretoria Series as shown by the great fault to the south-east of Rustenburg, which passes through Olifants Nek and displaces the middle and lower quartzites, while the series as a whole shows a sharp double bend in the strike, has also added to the metamorphism noticed.

Lastly from the Groot Marico River westwards to Zeerust the maximum results are seen, rocks being altered from the Magaliesberg horizon to the Timeball horizon and even beyond in the dolomite. The greatest degree of alteration being in the beds contiguous to the bushveld rocks.

These great alterations in the nature and physical structure of the rocks have naturally been reflected in the varying capacities for yielding underground water displayed by the different horizons in the different areas.

A. COMPARISON OF AVERAGE YIELDS FROM THE SHALE HORIZONS IN GALLONS PER 24 HOURS PUMPING.

HORIZON	AREAS					
	Witbank Middelburg.	Pretoria	Rustenburg.	Marico	Gatsrand	Eastern Transvaal
1. Timeball Shale		40,000	20,000	25,900	26,000	16,100
2. Daspoort Shale		30,500	32,000	29,000	28,400	26,000
3. Magaliesberg "	11,500	18,000	23,700			25,000

In group one, the furthest east the shales have only been recently stripped of a cover of younger karroo and Waterberg Beds. In the second group the shales are the least/....

least altered and are exposed to a high rainfall (30") the variations in the yields being due to local conditions as e.g. the Magaliesberg shales in group 2, which are a narrow strip of shales outcropping north of the Magaliesberg range, the restricted outcrop resulting in lower yields. In the Rustenburg Area (Group 3) the effect of the alterations is noticeable and as well as the lower rainfall. The Magaliesberg shales are highly altered here, and their outcrop area is much larger; this has improved the daily yield.

In group 4 the effect of the extreme metamorphism appears to have improved the average daily supply in spite of the lower rainfall. Considering horizons the Daspoort shale is the most consistent, which is not surprising considering its position underlying the floor of a large valley in the middle of the series between the Daspoort and Magaliesberg quartzites.

B. COMPARISON OF AVERAGE YIELDS FROM THE QUARTZITE HORIZONS IN GALLONS PER 24 HOURS PUMPING.

HORIZONS	AREAS					
	Witbank Middelburg.	Pretoria	Rustenburg.	Marico	Gatsrand	Eastern Transvaal
1. Timeball Quartzite			26,800	31,400	10,000	
2. Daspoort "		16,400	18,500	24,000	26,000	
3. Magaliesberg "		16,000	21,000	27,200		18,000

In these horizons the extreme alteration in the west would appear to have improved the water carrying capacities in spite of the lower rainfall.

Another equally important factor is that the dip of these layers flatten out to the west and consequently large areas of quartzite are lying almost horizontal thus offering greater facilities for the infiltration of the rainfall.

In the eastern areas little boring is carried out

by/...

by choice in the quartzites as they form ranges of hills.

In Griqualand West the occurrence of Griquatown Sediments which extends from the Molopo River, North of Morokwen down to below Prieska, is considered to be a facies of the Pretoria Sediments.

They consist of jaspers and ferruginous shales. Underground water here is found to be deep and erratic in its distribution; many entirely dry areas occur, and failures number almost 50% of the total drilled. The average daily yield is 21,000 gallons.

The intrusive diabase of Bushveld age has also given comparatively good results. These basic rocks generally in the form of sills of varying thickness have in places been considerably altered by decomposition due to weathering. In some cases this has gone so far as to completely veil the original character and appearance of the rock.

This process has aided the passage and storage of subterranean waters by breaking down the compactness and increasing the porousness of the rock, but continuing further the weathering process changes the original hard diabase into a gritty clay which becomes either totally impervious or is inclined to move and flow with the water; thus increasing the number of failures and creating a tantalising position where the borehole strikes water which owing to its condition it is impossible to use or to pump out. Experiments by the Boring Branch, however, have shown that by packers and the judicious use of casing it is possible to save some of these water-supplies.

C. COMPARISON OF AVERAGE YIELDS FROM THE INTRUSIVE OR BUSHVELD DIABASE FROM ALL HORIZONS IN GALLONS PER 24 HOURS PUMPING.

Witbank Middelburg Area	Pretoria Area	Rustenburg Area	Marico Area	Gatsrand Area	Eastern Transvaal.
33,000	24,200	30,000	21,200	23,000	22,200

Boreholes where the water has been obtained at the contact or junction of the intrusive diabase and the shales give different results.

COMPARISON OF AVERAGE YIELDS FROM THE DIABASE-SHALE CONTACTS IN ALL HORIZONS IN THE PRETORIA SERIES, IN GALLONS PER 24 HOURS PUMPING

Pretoria Area	Rustenburg Area	Marico Area
36,800	22,200	26,500

As seen they are an improvement on the results from the Intrusive diabase alone but are not quite so good as the Shales by themselves. However, these contacts seldom fail (q.v. Table 3.) to give water and have been found to be good horizons to take advantage of when selecting sites in this formation.

In making a comparison between the (a) Diabase to Shale and (b) Shale to Diabase contact in order to ascertain which was the better it was found that in the Pretoria area it was found that only 25% of the holes drilled, cut the former contact (a). They did not give nearly so great an average yield as (b) and considerably more failures.

In the Rustenburg area (a) gave an average yield of 22,000 gallons per diem as against 13,000 gallons per diem from (b).

In the Marico area (b) was found to be the better of the two, the position being the reverse to that found in Rustenburg area. Metamorphism of the shales at the contacts in addition to the general metamorphism affecting the Series as a whole due to the Bushveld complex, bring about this variation in the water-carrying capacity of similar horizons.

THE ONGELUK DIABASE OR CONTEMPORANEOUS ANDESITE:

This series of contemporaneous lavas attains a great thickness, and forms a continuous belt from near Delmas through the towns of Pretoria, Magalies, Koster and

on/....

on to Zeerust, etc. always flanked on the one side by the Timeball Hill quartzites and on the other by the Daspoort Quartzites both of which make continuous ridges on either side. The diabase is directly overlain by slates and generally has slates beneath it as well but in the west (viz. from Zwartruggens westwards) there is a thin quartzite underlying.

TOPOGRAPHY AND OCCURRENCE.

The diabase as a rule forms low ground following the axis of a valley (trough) e-g. the Hekpoort Valley. It generally displays a considerable surface. From Koster to the west the upper part of the zone makes higher ground to the north.

Other occurrences are in the northern Marico and Rustenburg Districts where it outcrops on the northern limb of the Anticline. In the Potchefstroom and Vereeniging Districts where another anticline exposes a broad belt of this amygdaloidal rock. Here it is considerably narrower in the western portion than further east. This is due to the fact that the beds are normally situated in the west, with a uniform dip of 15° to the south, while to the east the dip decreases and the beds begin to show the effect of the synclinal structure and change in direction of strike; which is so marked a feature in the eastern portion of the Gatsrand. The surface width thus increases from 1½ miles on Kraalkop No.290 to seven miles through Wildebeestfontein No.406.

In the Lydenberg, Middelburg, and Carolina District the contemporaneous volcanic rocks occur at three separate horizons, the first being at the top of the Pretoria Series, the second about halfway down the succession, and the third below the Daspoort Quartzite horizon.

The highest volcanic rocks lie directly above the

uppermost/...

uppermost Magaliesberg Quartzite, between it and the basic edge of the Bushveld Complex. They occupy a narrow band from one to three and a half miles wide trending nearly north and south along the footslopes of the eastern side of the Steelpoort River Valley. They are clearly inter-bedded with the upper strata of the highest Magaliesberg Quartzite and this together with the obviously effusive character of the formation show it to be of volcanic origin.

The second horizon of volcanic rocks sometimes resembles pyroclastic accumulations rather than true lavas and occurs a little above the Daspoort Quartzite, forming a broad belt extending from near Machadadorp southwards to within a few miles of Carolina a continuous outcrop which narrows down considerably towards the south.

The third and lowest horizons of contemporaneous rock lies immediately below the Dwaal Heuvel or lowest Daspoort Quartzite and is all amygdaloidal lava of Andesitic character. The base of this succession is emphasized by the Ongeluk Quartzite as in the Western Transvaal.

LITHOLOGY:

In the Pretoria, Rustenburg and Marico Areas the volcanic group is quite different to the intrusive diabase sheets of Bushveld age with coarsely crystalline texture so common in the Pretoria Series. It is fine grained, greenish in colour, often flinty, and sometimes studded with amygdales filled with quartz and other minerals. In many respects this formation compares with the lavas in the Ventersdorp System.

That the horizon however is not a single flow, but is built up of several successive lava sheets is suggested by the varying lithological characters.

These successive sheets sometimes present porous upper surfaces, thus there are through the formation planes

of/....

of separation along which water could travel, and as the g group is generally dipping at angles of from 5 - 15° and sometimes more, there are created favourable conditions for the conservation of underground water supplies.

In the west (Marico Area) the lavas have been altered along with the other members of the series and the rock shows occasional devitrification.

In the central area (Gatsrand) the lavas exhibit similar characters and vary from compact close-grained rocks to a rock in which the quartz filled amygdales are as large as nuts.

In the eastern Transvaal the upper horizon shows amygdaloidal characters, flow-structure, agglomerates and similar features. There is evidence too that these rocks have undergone some metamorphism, as silicification and recrystallization of the ground mass has taken place. The second horizon of effusives consist of agglomerates and tuffs with inclusions of burnt shales chiefly, less frequent are pieces of fine-grained igenous rocks, either of intrusive diabase or the earlier lavas. The lowest horizon are greenish fine grained partly amygdaloidal rock about 800' thick. In their general characters they compare closely to the Ongeluk Series in the Cape Province.

BOREHOLE WATER SUPPLIES:

Drilling in this formation usually progresses rapidly as it is so often found decomposed, yielding as a result red and white clays and red soils. The decomposition often goes deep covering the solid rock with a mantle of soil and clay 40-60' and exceptionally 100' deep. As for example in the boreholes of the Derby Estates near Koster, Droogekraal on the Groot Marico River and at Vlakfontein 584.

Much of the clay consists of rock weathered in situ, below which are cores of more or less unaltered

diabase/....

diabase often reported as boulders. In this respect drilling conditions are similar to those encountered in the lavas of Ventersdorp age.

Where the decomposition goes down to exceptional depths and is presumably complete, the water supplies obtained are not large e.g. in the Marico Area. In the majority of boreholes yielding good supplies the soil and clay covering is seldom more than 20' or so thick often less.

It is suggested that as in the case of the lavas of Ventersdorp age some of the intrusive diabase sheets of Bushveld age in the Pretoria area, and also Karroo dolerites in the Eastern Transvaal, the small supplies of water obtained where decomposition penetrates deeply is due to the complete breaking down of the rock structure into an impervious clayey product, and this overlying the jointed and only partially sound rock has hindered infiltration into the formation.

Failures are comparatively rare except in the Marico area where decomposition as mentioned above is common.

In the Gatsrand area the average yields are good, the failures are low and the water is shallow, the area is well watered and replenishment of underground waters is thus facilitated apart from the annual rainfall of 25'.

COMPARISON OF AVERAGE DAILY YIELDS OBTAINED BY BORING IN THE ONGELUK LAVAS IN THE TRANSVAAL IN GALLONS PER PER DIEM PUMPING.

Witbank Middelburg area	Pretoria Area	Rustenburg Area	Marico Area	Gatsrand Area	Eastern Transvaal
27.600	36.000	17.200	26.200	28.400	14.400

The equivalent formation in Griqualand West known as the Ongeluk Diabase occurs associated with the jaspers. It gives an average yield of 13,000 gallons per borehole per day/...

day in the south, but further north in the Vryburg District it reappears from under the sand covering and outcrops from Mashowing laagte northwards to Heuning Vlei. Here these rocks give an average yield of 24,500 gallons per diem which struck at an average depth of 79 feet.

CONCULSIONS:

1. Good yields are obtained at shallow depths in this formation.

2. Successes are high particularly if

(a) the quartzites are avoided in the eastern area;
(b) the altered shales are avoided especially in the western area where the flat lying altered quartzite becomes the better aquifer.
(c) sites are selected wherever possible so as to cut or approach a shale-diabase contact at depths of 100-150' which is generally easy in view of the tilting of the strata and the frequency with which the intrusive sills occur.
(d) in the extreme west the banded ironstone and jaspers should be avoided especially when they are forming high ground.

3. The contemporaneous diabase or Ongeluk Lava also gives good returns similar to other stratified lavas described, so long as the very hard or very soft decomposed portions are avoided.

4. The influence of increase in the rainfall is apparent here especially in the well-bedded shales but is counteracted to a certain extent by metamorphism in the shales and topography in the case of the quartzites. In the east where the beds have been recently stripped of coverings of younger rocks the yields are not so good in spite of a large rainfall.

5. As the tables 2 & 3 show deep boring viz. depths greater than 300' have not been successful.

TABLE 11. AVERAGE RESULTS FROM THE PRETORIA SERIES IN THE GATSRAND AREA COMPRISING PORTIONS OF THE POTCHEFSTROOM, VENTERSDORP, VEREENIGING AND KRUGERSDORP DISTRICTS.

DISTRICT	Geological horizon.	Total No. of boreholes from which results were obtained.	Average total depth in feet.	Average depth at which water was struck.	Average depth to which water rises in feet rest level.	Average daily yield in gallons pumping.	General % of failure.	Total failures.	Water insufficient for practical use.	Holes not carried deep enough.	Holes deeper than 300'	Day	Water struck shallower than 300'	Water struck deeper than 300'.	Holes with yields above 100000 gals per diem.	Remarks.	Rainfall.
	Timeball Quartzite	9	74	57	32	10,000	30%										25"
	Timeball Shale	74	159	113	50	26,000	21%	12	5	4	5	2½	2½				
	Daspoort Quartzite	4	96	77	28	26,000											
	Daspoort Shale	34	121	79	18	28,400	6	3	3		6			6			
	Contemporaneous amygdaloidal andesite or Ongeluk Diabase	55	90	68	30	28,400	21	6	11	4	1		1				
	Intrusive Diabase of Bushveld age.	78	94	66	21	23,000	26	13	5	8	2		1	1			

AVERAGE RESULTS FROM THE PRETORIA SERIES IN THE EASTERN TRANSVAAL COMPRISING PORTIONS OF THE LYDENBURG AND CAROLINA DISTRICTS.

	Timeball Shale	5	138	89	45	16,100											20-30"
	Daspoort shale	2	83	27	13	26,000											
	Magaliesberg Quartzite	6	110	71	22	18,000											
	Magaliesberg shale.	3	110	51	16	25,000											
	Ongeluk					14,000											
	Bushveld Diabase	10	74	47	27	22,200	30%		30%								
Kurumam	Griquatown Sedimentaries	37	181	147	103	21,000	46%	27%	8%	10%	10%	8%	2%				
Kurumam	Griquatown Ongeluk Diabase	39	150	122	93	13,000	38%	7%	12%	9%	3%		3%				
Vryburg	"	9	110	79	42	24,500	20%	10%	10%								

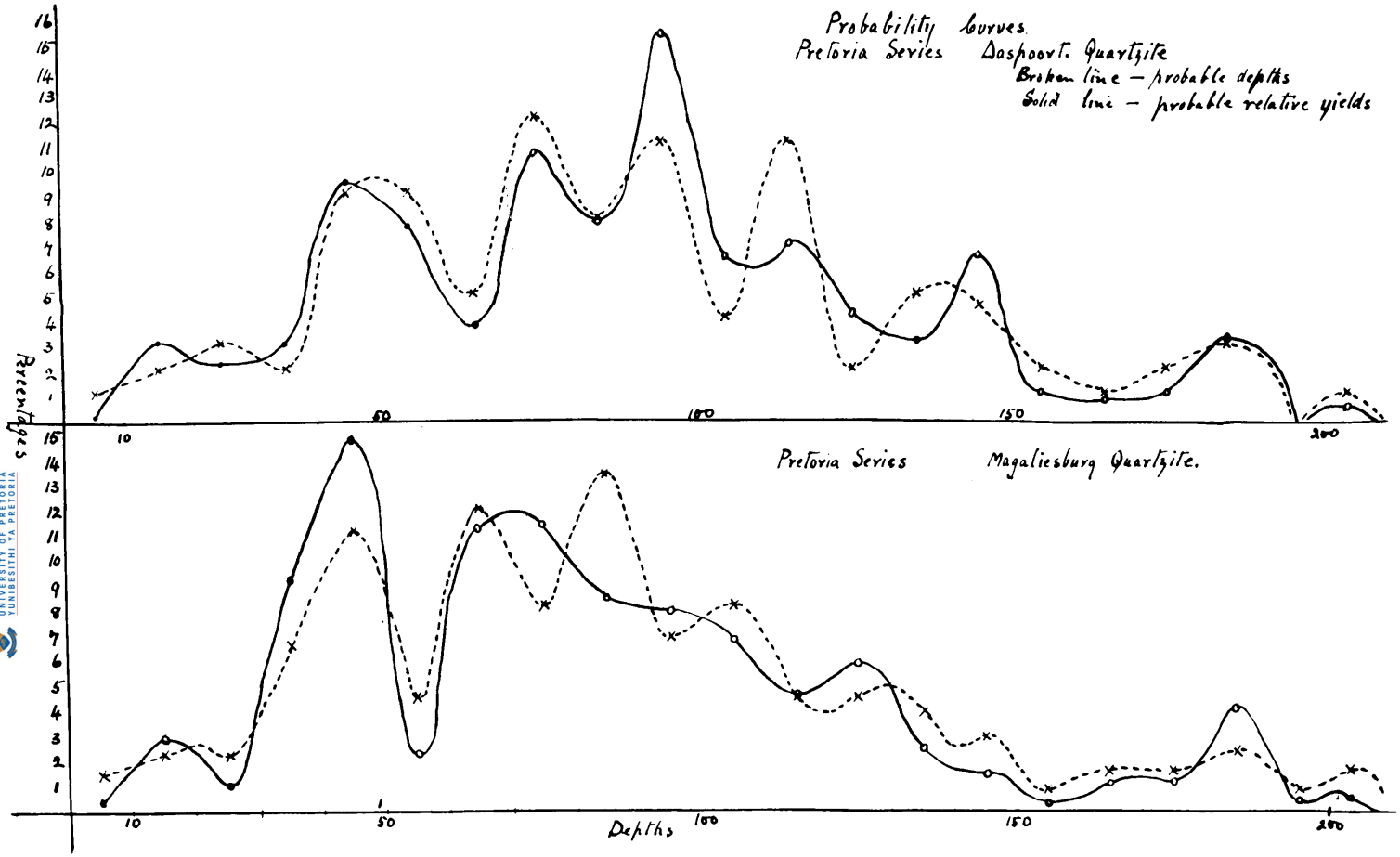


Fig. 11a

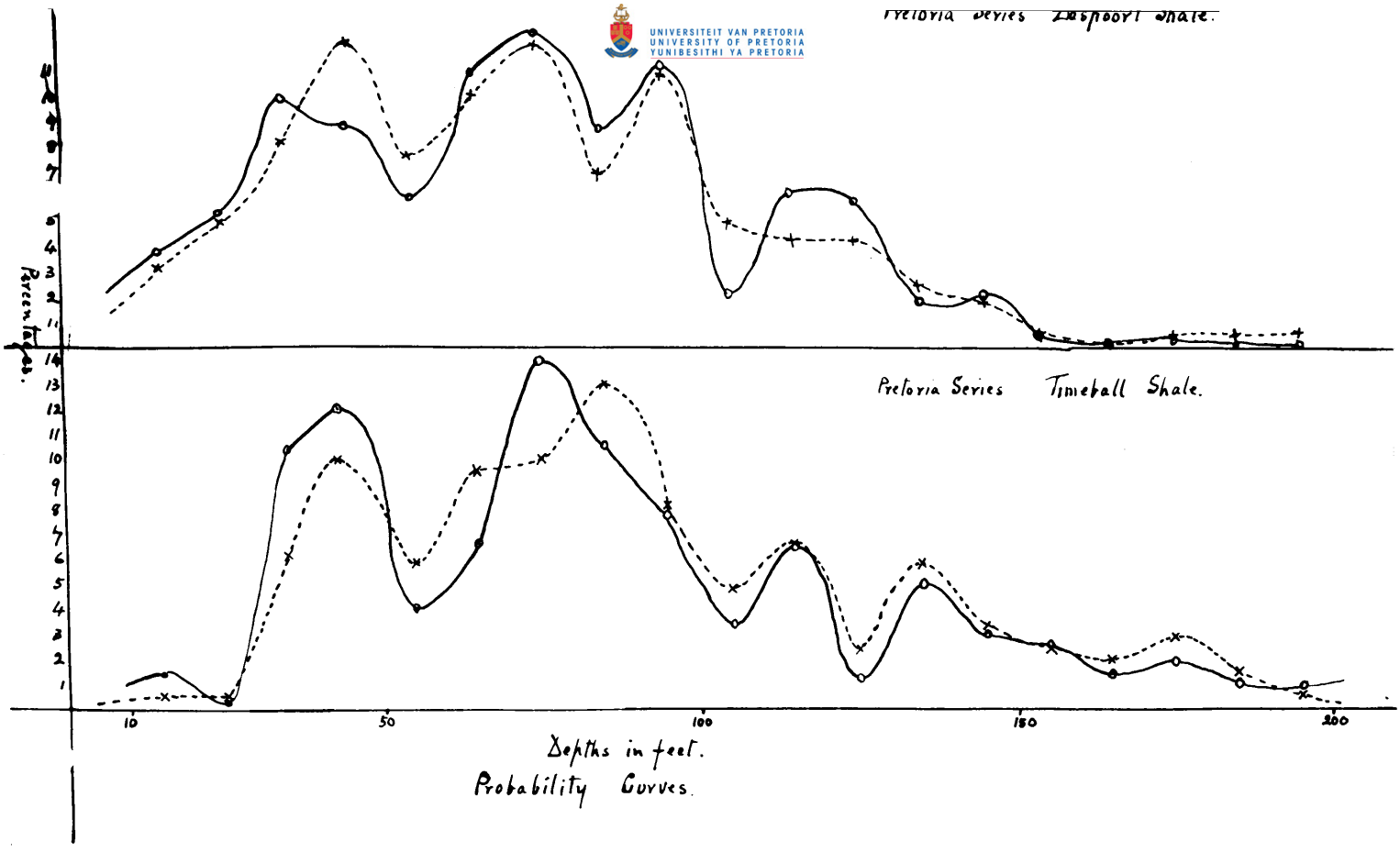


Fig. 11 b.

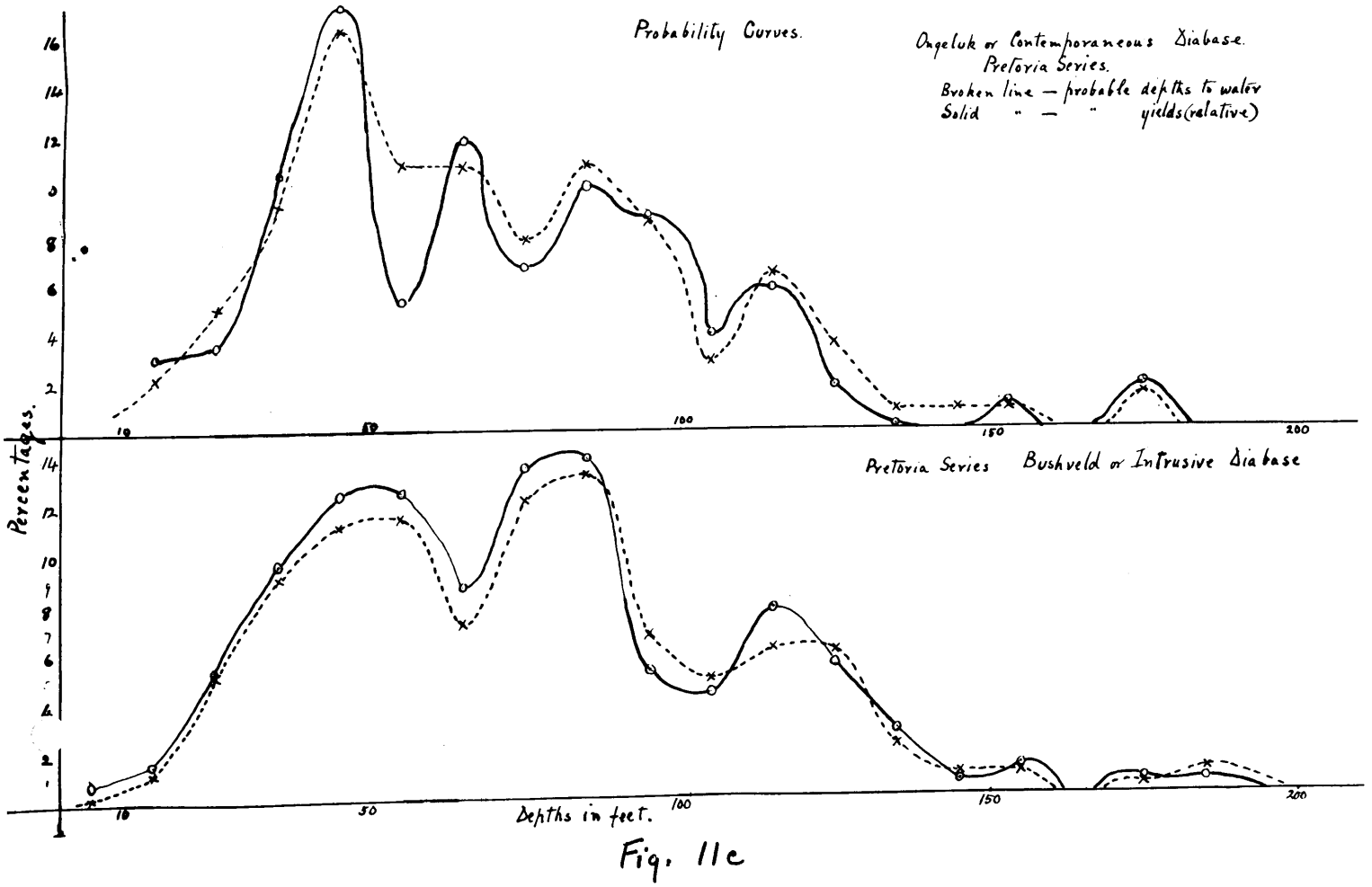


Fig. 11c

TABLE 3. AVERAGE RESULTS FROM BOREHOLES PRETORIA SERIES IN THE MIDDELBURG, WITBANK, PRETORIA, RUSTENBURG AND MARICO DISTRICTS.

DISTRICT	Geological Horizon	Total No. of boreholes from which results were obtained.	Average total depth in feet.	Average depth at which water was struck in feet.	Average depth to which water rises in feet rest level.	Average daily yield in gallons pumping	General % of failures	Total failures	Water insufficient for practical use.	Holes not carried deep enough	Holes deeper than 300'	DRY	Water struck shallower than 300'	Water struck deeper than 300'	Holes with yields above 100000 gals per diem.	Remarks	Rainfall.
Witbank																	30
Middelburg																	25-30
Pretoria	Timeball																
Rustenburg	Quartzite	22	130	97	53	26,880	42%	15%	19%	9%	Nil.				4%		25-30
Marico		38	117	85	56	31,400	24%	10%	7%	7%	2.5%		2.5%		5%		20-25
Witbank-																	
Middelburg																	
Pretoria	Timeball	29	182	116	51	40,400	7%	3.5%	3.5%	Nil	10%						
Rustenburg	Shale	80	144	102	60	20,000	23%	9%	8%	5%	4%		3%	1%	1%		
Marico		80	140	87	48	25,900	11.2%	4%	6.2%	1%	1%		1%				
Witbank-																	
Middelburg																	
Pretoria	Daspoort	39	145	112	47	16,400	25%	2.5%	12.5%	10%							
Rustenburg	Quartzite	63	109	81	47	18,500	22%	6.3%	6.3%	9.5%	1.6%		1.6%				
Marico		25	116	95	63	24,000	44%	20%	16%	8%	4%		4%				
Witbank-																	
Middelburg																	
Pretoria	Daspoort	91	136	80	34	30,500	8%	5%	1%	2%					?		
Rustenburg	Shale	57	107	78	53	32,000	30%	10%	5%	9%	2%		2%		2%		
Marico		14	147	98	75	29,390	28%	14%	7%	7%	Nil				Nil		
Witbank-																	
Middelburg																	
Pretoria	Magaliesberg	25	136	80	40	16,000	36%	12%	16%	8%	4%	4%					
Rustenburg	Quartzite	139	134	88	51	21,000	27%	10%	3%	14%	0.6%		0.6%				
Marico		23	160	120	71	27,200	30%	9%	18%	3%	4%		4%				
Witbank-																	
Middelburg		2	83	74	48	11,500											
Pretoria	Magaliesberg	8	106	72	30	18,000	12%										
Rustenburg	Shale	22	137	87	72	23,750	50%	25%	5%	20%	Nil				Nil		
Marico																	
Witbank-	Ongeluk Dia-	3	138	56	27	27,600	30%										
Middelburg	base of Con-																
Pretoria	temporaneous	14	169	92	52	36,000	14%	Nil	7%	7%	14%						
Rustenburg	Andesite	92	92	71	37	17,200	18%	5.4%	7.6%	5%	Nil						
Marico		24	143	112	72	26,200	50%	12%	4%	34%	4%		4%		Nil		

		obtained.		feet.	feet rest level.	pumping									per diem.	
Witbank																
Middelburg																30
Pretoria	Timeball															25-30
Rustenburg	Quartzite	22	130	97	53	26,880	42%	15%	19%	9%	Nil.				4%	25-30
Marico		38	117	85	56	31,400	24%	10%	7%	7%	2.5%		2.5%		5%	20-25
Witbank-																
Middelburg																
Pretoria	Timeball	29	182	116	51	40,400	7%	3.5%	3.5%	Nil	10%					
Rustenburg	Shale	80	144	102	60	20,000	23%	9%	8%	5%	4%		3%	1%	1%	
Marico		80	140	87	48	25,900	11.2%	4%	6.2%	1%	1%		1%			
Witbank-																
Middelburg																
Pretoria	Daspoort	39	145	112	47	16,400	25%	2.5%	12.5%	10%						
Rustenburg	Quartzite	63	109	81	47	18,500	22%	6.3%	6.3%	9.5%	1.6%		1.6%			
Marico		25	116	95	63	24,000	44%	20%	16%	8%	4%		4%			
Witbank-																
Middelburg																
Pretoria	Daspoort	91	136	80	34	30,500	8%	5%	1%	2%					?	
Rustenburg	Shale	57	107	78	53	32,000	30%	16%	5%	9%	2%		2%		2%	
Marico		14	147	98	75	29,390	28%	14%	7%	7%	Nil				Nil	
Witbank-																
Middelburg																
Pretoria	Magaliesberg	25	136	80	40	16,000	36%	12%	16%	8%	4%	4%				
Rustenburg	Quartzite	139	134	88	51	21,000	27%	10%	3%	14%	0.6%		0.6%			
Marico		23	160	120	71	27,200	30%	9%	18%	3%	4%		4%			
Witbank-																
Middelburg		2	83	74	48	11,500										
Pretoria	Magaliesberg	8	106	72	30	18,000	12%									
Rustenburg	Shale	22	137	87	72	23,750	50%	25%	5%	20%	Nil				Nil	
Marico																
Witbank-	Ongeluk Dia-	3	138	56	27	27,600	30%									
Middelburg	base of Con-															
Pretoria	temporaneous	14	169	92	52	36,000	14%	Nil	7%	7%	14%					
Rustenburg	Andesite	92	92	71	37	17,200	18%	5.4%	7.6%	5%	Nil					
Marico		24	143	112	72	26,200	50%	12%	4%	34%	4%		4%		Nil	
Witbank-	Intrusive	5	109	83	39	33,000										
Middelburg	diabase															
Pretoria	of bushveld	168	117	80	40	24,200	17.3%	7.8%	7.1%	2.4%	3.5%				0.6%	
Rustenburg	age	163	110	80	50	30,000	21%	8%	3%	10%	Nil				0.6%	
Marico		49	113	93	66	21,200	40%	16%	18%	6%	Nil				Nil	

CHAPTER VI.

UNDERGROUND WATER.

in the

KARROO SYSTEM.

GENERAL DESCRIPTION: (x)(X)

The Karroo formation occupies about half of the area of the Union. It extends 800 miles from Karroo Poort in the South Western Cape to the Middelburg District in the Transvaal and has its greatest width of 370 miles between Kimberley and East London except where it disappears beneath the sea on the south eastern coast and a narrow strip east of Vryheid it is surrounded by older rocks.

Apart from this main area extensive outliers occur in the Kalahari, the Transvaal Bushveld and the Limpopo valley.

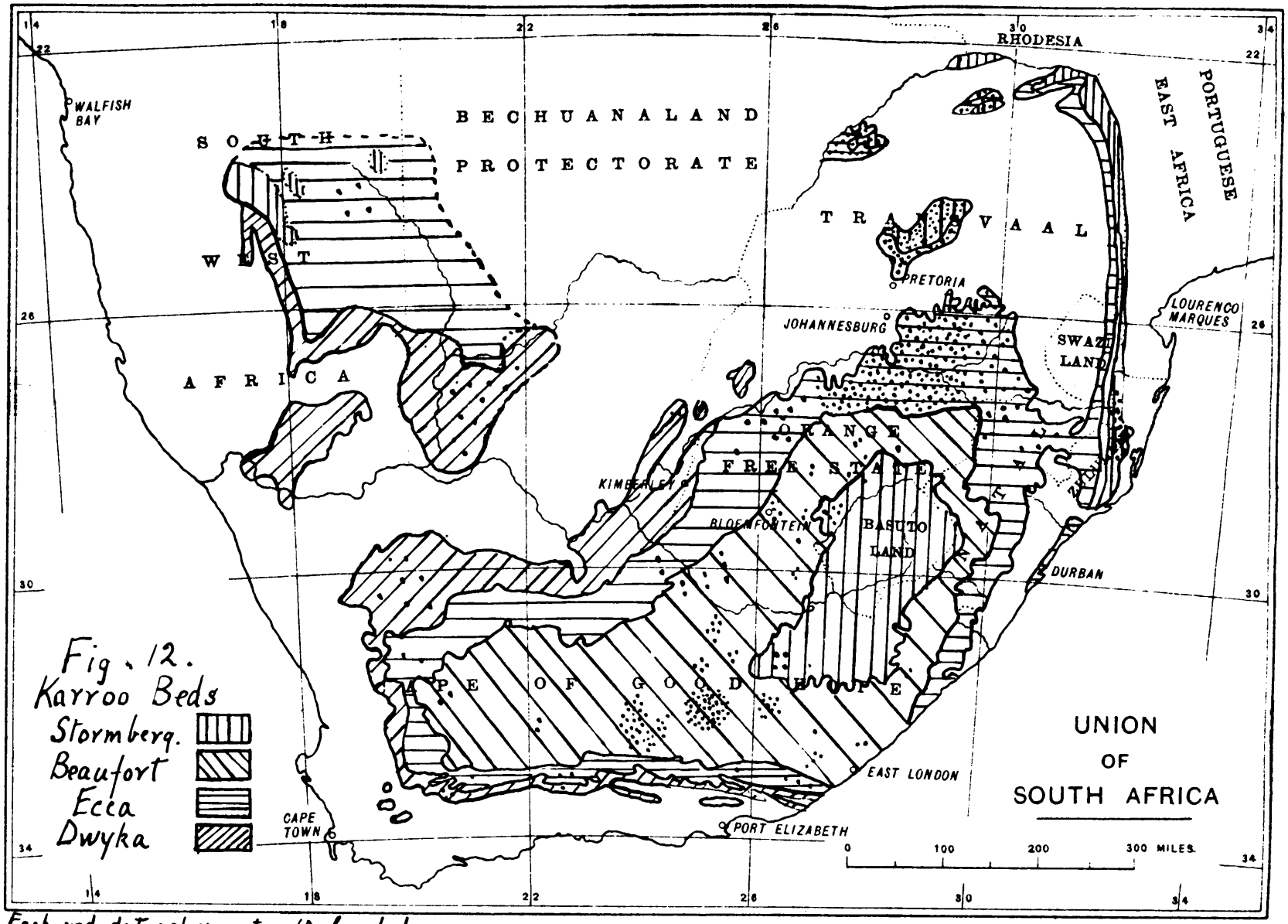
		CAPE (SOUTH)	TRANSVAAL (NORTH)
Karroo System.	Stormberg Series	Drakensberg Basalts	Bushveld Amygdaloid
		Cave Sandstone	" Sandstone
		Red Beds	" Marls.
		Molteno Beds.	
	Beaufort Series	Upper Middle Lower	Absent
	Ecca Series.	Upper Middle Lower	Upper Middle Coal Measures Lower
	Dwyka Series	Upper Shales Tillite Lower shales	Glacial Conglomerates

DWYKA LITHOLOGICAL.

The Lower Shales consist mainly of greenish and bluish shales and flagstones, but include hard green and grey sandstones and quartzites.

The tillite is a compact fine grained blue or green rock made of particles of sand and various minerals embedded in a fine-grained argillaceous matrix, in which are scattered irregularly pebbles and boulders of a large

(x) Handbuch der Regionalen Geologie - VII Band 7a Abteiling. The Union of South Africa.
(X) Du Toit. The Geology of South Africa.



Each red dot represents 10 Boreholes
Northern Area 2504
Southern Area 2100.

variety of rocks the majority of which can be recognised as having been derived from Pre Karroo formations. In the south the tillite is hard and blue and breaks through pebbles and matrix alike. In addition a rough cleavage has been developed parallel to the strike of the formation but at varying angles to its dip. Ih the north the pebbles can usually be easily removed from the matrix.

Other varieties generally subordinate to the unbedded type are the stratified "bedded Dwyka" where it has a more shaly matrix and layers poorer in inclusions, the boulder-shale an argillaceous rock in which inclusions are distributed erratically and at wide intervals, pure shales, calcareous hard brown weathering bands, lenses, and concretions, and masses of small fragments of rocks known as "gravel Dwyka".

The Upper Shales, are green but pass into a zone of black carbonaceous shale which weathers white on exposure called the "White Band".

THE ECCA:

In the Cape it is comparatively thin in the east, north and west and consists predominantly of blue and green shales. In the south it thickens and becomes more arenaceous.

In the Transvaal it is characterised by thick bands of sandstones and grits with softer layers and has shales above and below. The coals are carried in the middle Ecca.

THE BEAUFORT SERIES:

Consists of thick blue,green,red and purple shales with bands of fine to medium grained felspathic yellow sandstones. The colours become more brilliant going upwards in the succession.

THE STORMBERG SERIES:

is composed of coloured shales and sandstones

and/...

and is capped by the Drakensberg Volcanic Beds a succession of lavas including compact hard and amygdaloidal varieties.

Considering this tremendous extent of sediments with a maximum thickness of some 27,000 feet as a carrier of underground water, most of the information available is from borings in the Dwyka Ecca and Beaufort Series in the Cape and the Ecca and Bushveld series in the Transvaal. Intrusive dolerites occur in almost constant association with the strata of the Karroo System, where they play a great part in influencing the circulation of the Underground water, as the underflow is intercepted by the more dyke-like intrusions, and it has been known for a long time that boring behind or above such barriers is likely to prove successful.

(1) UNDERGROUND WATER IN THE KARROO IN THE NORTH. (TRANSVAAL AND O.F.S.)

The term coal-measures is applied to the series of strata more particularly associated with the coal seams, the Karroo system is represented chiefly by this horizon in the Transvaal. To the south of this exposure the upper beds appear, also there is a change in phase as well as horizon as the Beaufort series is approached.

Although, as mentioned before, the Karroo system is not so well developed in the Transvaal as in the Cape, it still occupies fairly large tracts of country. The greatest extent is situated along the south-eastern and eastern borders of the Province. The districts of Springs, Standerton, Bethal, Ermelo, Piet Retief and Wakkerstroom in the Transvaal and Frankfort and Heilbron in the Orange River Province are situated wholly on this formation, likewise the southern portions of Carolina and Middelburg and the south and south-eastern portions of Heidelberg and Vereeniging

Districts/...

Districts Transvaal.

In the Pretoria district except for a very small area in the extreme south-east, the Karroo beds are present as outliers lying unconformably on older floors of old granite, Red granite, Waterberg, Pretoria Bed, Dolomite and Witwatersrand beds, in the Aapies River, Pienaars River and Elands River Valleys.

The Springbok Flats area, comprising portions of the extreme Northern Pretoria District, Southern Waterberg, S.E.Rustenburg, and Potgietersrust Districts all in the Transvaal, has a Bushveld series of sediments and amygdaloid developed in addition to the Ecca beds.

In the northern portion of the Waterberg District and in the Zoutpansberg District these beds occur in addition to those above.

LITHOLOGICAL.

The most important member of this series in the Transvaal are the conglomerates which are of normal sedimentary origin and not glacial. The pebbles are usually 3-4 inches in diameter though they have been found up to 1-2 feet, they are generally derived from the older rocks on which the series is resting.

Succeeding the conglomerates and forming the lower and middle portions are the grits which are mostly felspathic white and purplish in colour darkening in the lower portions owing to ferruginous cement. The lowest part of the grits coarsen and merge into the conglomerate and similarly the higher portions become finer grained until they merge in places into the sandstones. These latter are white, thick bedded and massive when coarse grained, but thinly laminated and often micaceous when fine grained.

It is difficult to make a sharp distinction betwee

the/....

the sandstones and the shales above them, as the latter are sandy in character and often carbonaceous they can be called finely laminated sandstones. When coal is present it is usually found along with the shales. The higher portions of the series consist of another thick layer of sandstones and grits.

There are present also intrusive dolerites mostly in the form of sheets, more rarely dykes.

This series gives rise to a typical landscape, whose chief physical features are broad undulations with shallow valleys, marshy and ill-defined stream courses originating in boggy springs. The whole surface is covered by yellow or red sandy soil generally passing downwards into beds of "ouklip" or laterite. The country is grass covered and trees are rare.

The fairly thick carpet of sandy soil covering the rock has the property of rapidly absorbing the rainfall, hence the run-off is small and accordingly the streams have slight erosive powers. This rapid absorption, however, is somewhat counteracted by the low porosity of the underlying rocks, and the resulting underground supplies are chiefly obtained from joints, fissures, contacts with dolerite and the layers of highest porosity as the grits and coarse sandstone, is consistent but not of great magnitude. The flow underground is aided by the generally horizontal nature of the beds and their position as elevated outliers with free marginal outlets. Hence in addition to the usual surface weathering a considerable amount of subsurface decomposition, solution, and denudation of various layers especially those of carbonaceous nature and their accompanying soft clays and sandy shales; accordingly the conditions are favourable for the formation of small subterranean reservoirs and streams, the latter pursuing their slow

course/...

courses in the channels of subsurface erosion. The sills, sheets, and rare dykes of dolerite conserve the waters and concentrate their volumes locally.

WATER BEARING PROPERTIES:

A considerable amount of boring for water has taken place in these beds in this area and for this account the records of 2,500 boreholes have been critically examined.

The majority of these bores have been carried out in the main body of the Karroo system situated in the south-eastern corner of the Transvaal, and which is connected with that of both the Cape and Natal, but 109 are situated in the outliers of the Transvaal Bushveld, 500 are in the Springbok flats area and 170 are in the Northern Waterberg and 100 are in the Zoutpansberg District.

For the purpose of this examination the records have been divided into the following groupings. Those in the main group comprising the districts of Heidelberg, Springs, Middelburg, Standerton, Witbank, Bethal, Ermelo, Wakkerstroom, Piet Retief, Carolina, Paulpietersburg, and Volksrust, have been further divided into areas of equal rainfall, as the lithological uniformity is so striking.

Comparison of the results for the Ecca beds is as follows:-

GROUP	No.of bore-holes.	Average total Depth in ft.	Rain-fall.	Average depth of water in feet.	Average daily quantity in gallons.	Percentage of total failures.
1. Ermelo Wakker-stroom, Piet Retief, Paul-pietersburg, Carolina, Volksrust.	258	136	30-40"	75	21,600	6.2%
2. Springs, Bethal, Heidelberg, Witbank, Middelburg, Stand-erton, Frankfort, Heilbron.	1,389	156	25-30"	87	13,(	
3. Vredefort, Hoop-stad, Kroonstad.	83	120	20-25"	80	9,370	9%

A further study of these records in order to ascertain the horizon which carried the water and at what depth it was, showed that the water bearing properties are fairly equally divided between the coals and coal shales, (2) the sandstone above the coal, (3) the sandstone below the coal and (4) the igneous intrusions. Very few supplies are struck below the Karroo beds on the pre-Karroo floors except on the edges of the formation.

In a general consideration of the results it is seen that the supplies are moderate in size but fairly consistent and are to be obtained at a reasonably shallow depth from any horizon in the series. The latter fact would seem to point to the water being carried in the zone of weathering and not in any particular horizon.

The series carries members i.e. the sandstones and grits which have the highest average porosity of all the formations considered and being the youngest in age and mostly lying horizontal the question of jointing and fissuring does not play such a prominent part as in others.

TABLE OF POROSITY PER CENT.

Karroo Rocks.

Northern Ecca Coal Measure Sandstone.

	According to Wybergh.	According to du Toit.
Steenpan Stone	15.64	13.9 - 14.6
Flatpan "	14.8 - 15.1	9.2 - 13.3
Balmoral "	12-15	12.6 - 15
Ermelo "	9.72	8.2
Hamanskraal "		14.6 - 16.9
Waterval "	15	11.9
Stinkwater "	17.4 - 19.04	13.6
Vereeniging "	9.75- 33.93	12.7 - 32.8
Bethal "	7.6 - 12.8	
Elands River"	8.1	6.2 - 7.8
Bushveld Sandstones		
Buiskop	20.81	9.7 - 13.6
Mapani	19.53	

Upper/...

TABLE OF POROSITY PER CENT (Contd)

Upper Beaufort Sandstones

	According to Wybergh.	According to du Toit.
Cathcart	7.2	3.3 - 4.8
Cradock	4.2	6 - 8.3
Queenstown	5.6 - 6.9	6.8 - 7.3

Owing to this porosity it is possible that a true water table may be developed here, in places where thick beds of sandstone and grits outcrop or are near the surface.

The formation gives increasing yields with higher rainfall as do others.

THE ECCA SERIES IN THE NORTH

See Table 5.

Looking at the district results it is noticed that there is a variation in the averages showing the different effects of slight variations in local altitudes and rainfall, though it is possible that this divergence is not due to this alone. The presence in the more southern areas of the upper division of the Ecca which is more argillaceous in nature may explain a drop in the yield per day. The south-eastern portion of Standerton and almost the whole of Bethal and Wakkerstroom are situated in this horizon. Moreover in such a large area a change of "phase" as well as of horizon may play its part.

GROUP 4. Next under consideration are the outliers both large and small all near Pretoria in the districts of Pretoria, Brits, Rustenburg, Southern Waterberg and N.W. Middelburg.

These occurrences nearly all form gently rising ground or low "bults" and mostly fill shallow basins in the older rocks.

To the North of Pretoria some are situated on the

farms/....

THE ECCA SERIES IN THE NORTH

	Number of Holes	Average Total Depth.	Average depth at which water is struck.	Average depth to which water rises.	Average daily yield in gallons.	Percentage of failures.
Group I. under 30-40" of rain (Annual Average).						
Paulpietersburg	15	123	70	48	33,600	13%
Piet Retief	54	112	81	36	23,200	15%
Wakkerstroom	28	165	74	40	14,100	17%
Volksrust	5	140	118	22	43,500	-
Carolina	14	93	54	27	20,600	35%
Ermelo	175	143	72	32	20,400	13%
Group II. 25-30" Annual Average Rainfall.						
Springs & Benoni	186	174	95	30	11,000	4%
Heidelberg	50	112	72	26	12,600	18%
Bethal	305	133	82	35	10,700	24%
Witbank & Middelburg	170	133	77	34	18,000	15%
Standerton	459	178	93	37	11,500	24%
Frankfort & Heilbron	18	105	64	40	12,000	27%
Group III. 20-25" Annual Average Rainfall.						
Vredefort	56	112	72	45	8,460	26%
Kroonstad	11	133	97	41	19,000	45%
Hoopstad	16	144	95	64	3,980	40%

DOLERITE ONLY.

14	134	98	32	19,500	nil
72	107	57	28	10,300	34%
15				14,500	

TABLE 5.

farms Kameelfontein 164, Buffelsdrift 337, Wolmansthal 116, Paardefontein 338, Haakdoornfohtein 492, Boekenhoutkloof 146, Klopperbosch 516, Klipdrift 123, 227, and 302, Stinkwater 585 and Sterkwater 213. Large areas occur in the Valleys of the Aapies, Pienaars and Elands Rivers which are difficult to delimit but have been proved by boring at Makapanstad, Hammanskraal, and Matibiestad.

To the East Schoongezicht 316, Valschspruit 103, Elandsfontein 245, Nooitgedacht 135, Loop Spruit 673, are the situations of small outliers.

These occurrences should form ideal reservoirs for the storage of underground water as their shape is basinlike and they are filled with porous sandstones and grits. Unfortunately however their restricted size, their limited catchment and probably underground leakage along joints and fissures in the underlying older rocks, limits the amount of input and the storage, consequently, the average daily output is low, and the percentage of failures high. Thus in this case the high annual average rainfall of 30" is negatived by the conditions under which the rocks occur. (For average results see Table 6).

The water was generally struck in the sandstones and grits just above the coal horizon in the majority of cases, less frequently it occurred at the base of the deposits just above or on the pre-Karroo floor, thus differing from the rocks in the south where the water bearing horizons were more widely distributed.

GROUP 5. In the Ecca beds fringing the southern edge of the Springbok Flats area results have been very poor in spite of the annual average rainfall of 25". The water-table is the same as in the previous group but the average daily yield is low and the failures are many (see Table 6). It is thought that the extreme flatness of this area coupled

with/...

with the thick deposits of red and black turf and surface limestone which cover it, also the absence of intrusive dolerites, are the cause. The thick covering insulating the rock from the rainfall, and the absence of dolerite means no subterranean barriers to concentrate the water.

GROUP 6. In the Northern Waterberg District the Ecca beds form part of an occurrence of Karroo extending from the Rooibok Hills in the South to the Limpopo River and across into the Bechuanaland Protectorate where it has also been exploited for producing underground water. The series underlies gently undulating country covered by red and white sandy soil. The soil mantles the geology and it is only from isolated exposures in pans and watercourses that information can be obtained. The borehole records have been of great value in determining the extent of the occurrence.

It is similar to the more southern occurrences in that it is composed of almost horizontal beds of sandstones, grits, and shales, which are dipping on the right bank of the Limpopo below the junction with the Matlabas River.

Boring for water in this area has proved very fruitful both in the Union and the Protectorate. The average daily yield is comparatively high and failures are only one in five. (See Table 6). The celebrated borehole at Artesia in the Protectorate is in this area. The depth to the water is greater here than elsewhere. The water bearing horizon in this area is generally the shales.

GROUP 7. In the Zoutpansberg District the Karroo beds are developed in the East, but have not been bored for water. The occurrence further west which extends from east of Sulphur Springs on the Messina Road across the railway to the north of the Blaauwberg in a narrow band, is the area

which/...

which has been exploited for underground water. In addition a few small outliers occur to the north on the Messina Road, and the southern portion of the Palapye belt crosses the Limpopo above Rhode's Drift and recrosses some distance above Messina.

Grits sandstones and coals of the Ecca, Bushveld sandstone and amygdaloids make up the occurrences which are mostly concealed by red sand and soil.

The boring operations are mostly distributed around the railway, north of the Zoutpansberg, none having taken place to the east and very few in the north along the Limpopo.

The boring results (See Table 6) in the sediments (it has not been possible to separate Ecca from Bushveld series) give good average yields, but the water is deep and one hole in five gave brack water.

Overlying the Ecca beds in the Springbok flats area Northern Waterberg and Zoutpansberg are the Bushveld marls (x) and Sandstones.

The former have been avoided as far as possible for drilling because as du Toit says "the dominant clayey nature of the material and the general absence of porous layers, or dolerite, supplies are scanty and erratic while caving is not uncommon. Deep drilling is of no advantage as they are underlain by the tight upper Ecca Shales. Water supplies when obtained are small".

GROUP 8 & 9. The ywllow or pink Bushveld sandstone corelated with the Cave sandstone in the south overlies the unproductive marls. The areas underlain by this rock are well timbered and are covered by thick pale sand formed from

the/...

(x) A.L.du Toit. Borehole water supplies in the Union of S.Africa. Trans.Mines Proc.of the S.Af.Soc.C.E.1928.

the wash from the rock. The results from drilling in this rock are fairly good. (8 and 9 Table 5.) though the water is deep; care must be exercised in selecting sites that the marls are not reached at too shallow a depth or a dry hole may result.

GROUP 9 & 10. The amygdaloidal basalts form country which is wooded in the "laagtes" and bare on the "bults" generally covered with black turf and red soil and surface limestone. Outcrops are scarce and generally in a decomposed crumbling state. As these basalts are lava flows, the remarks made about the Ventersdorp amygdaloid and the Ongeluk lavas q.v. also apply here, and the good results consequent on drilling into a series of flows are also obtained here.

Most of the drilling has been carried out in the Springbok flats area and a little in the Zoutpansberg. The results are tabulated in Table 6.

(2) UNDERGROUND WATER IN THE KARROO BEDS IN THE SOUTH:

1. DWYKA:

This series has been divided into Upper Shales with the white band at the top, Tillite, and Lower Shales, the latter not always present when the Tillite rests unconformably on pre-Karroo rocks.

In the south the beds have been tilted at high angles due to folding and owing to the severe compression experienced the tillite in this area though harder displays conspicuous cleavage and jointing which influences the flow and storage of underground water. This in the narrow belt extending from the mouth of the Great Fish River in the east to Karroo Poort in the west.

After this it turns northward, the dip decreases and the outcrop widens viz. from Doorn River through Bushmanland and past Prieska and Kimberley up to Vryburg.

In/...

In Gordonia lies another large area which is buried under the sands, etc. of the Kalahari.

WATER BEARING PROPERTIES:

In the areas affected by the folding the results are good but variable, e.g.

	Laingsburg.	Prince Albert.
Number of boreholes	27	13
Average depth of borehole in feet	132	160
Average depth at which water is struck in feet.	63	48
" " to " " rises in feet.	32	32
Average daily yield in gallons per 24 hrs pumping.	40,000	15,000
Percentage of failures		
(a) Insufficient water	7	-
(b) Total failures	13	-
Percentage of deep holes	3	-
Percentage of flowing holes	3	-
Rainfall	5-10"	5-10"

In Calvinia, Kenhardt and Bushmanland the results are lower as the beds are horizontal and uncleaved and the water is generally saline, but good yields can be counted on if sites are judiciously selected.

The average results are as follows:

Number of boreholes	67
Average total depth of boreholes in feet	121
" depth at which water was struck in feet	80
" " to which water rises rest level in feet	30
" yield per 24 hours pumping in gallons	27,000
Percentage of failures	
(a) Insufficient water (less than 1000 g.p.d.)	19%
(b) Total failures	12%
Percentage of deep holes (a) Dry	3%
(b) Striking water shallower than 300'	10%
Percentage of deep holes (c) Striking water deeper than 300'	7%
Percentage of brack supplies	10%
Rainfall	5-10"

At Vryburg the Dwyka is deposited on an uneven floor, with ridges and peaks of older rocks jutting through. A fairly thick sandy covering aids infiltration. The averages are as follows:

Number of boreholes	54
Average total depth in feet	120
" depth at which water is struck in feet	74

Average/...

Average depth to which water rises (rest level) in feet	51
Average yield per 24 hours in gallons pumping	18,000
Percentage of failures (a) Insuff.water i.e.less than 1,000 g.p.d.	5%
(b) Total failures	26%
Percentage of deep holes. All dry.	7%
Rainfall	15"-20"

In Gordonia (1) the Tillite and overlying shales are to be found outcropping in places between Upington and Rietfontein, and under the sand between Upington and Molopo Rivers. (2) The shales are undoubtedly marine in origin here.

In Gordonia the depths to the water are great which is characteristic of the fringes of the Kalahari vide the results from the Crystalline rocks in Northern Mafeking, etc., and the supplies are not large, further the great drawback is the saline quality fo the water, similar to Calvinia but more extensive.

The averages are as follows:

Number of boreholes	115
Average total depth of boreholes in feet	293
" depth at which water is struck in feet	185
" " to " " rises rest level in feet.	160
" yield per 24 hours in gallons pumping	11,500
Percentage of failures (a) Insuff.water viz.less than 1,000 g.p.d.	11
(b) Holes not deep enough	2
(c) Total failures	31
Percentage of Deep holes viz. over 300'. (a) Dry	18
(b) Strike water below 300'	20
(c) " " above 300'	8%
Percentage of holes with brack water	30
Rainfall	5-10"

(3)
THE EUCA: Here it forms a belt inside the outcrop of the Dwyka extending from Peddie in the south east past Jansenville, Prince Albert, and Laingsburg to Karroo Poort, thence due north to Calvinia, and after that in a general north-easterly direction past Britstown, Luckhoff, Boshoff, and

Hoopstad./...

---

(1) A.L.du Toit. Karroo System in the S.Kalahari.T.G.S.S.A. 1916 XIX.1.
(2) S.H.Haughton & H.F.Frommurze. The Karroo Beds of the Warmbad Dist. S.W.Africa T.G.S.S.A. 1927 XXX.
(3) H.F.Frommurze: Flowing Boreholes in the Rehoboth Gibeon and Gobabis Districts. S.W.Africa. T.G.S.S.A. XXXIV.

Hoopstad. In Pondoland from close to the Umtata River mouth it extends north eastwards into Natal".

The width of the outcrop varies but averages from 10 to 40 miles, the strata dipping inwards - towards the axis of the basin - at low angle.

LITHOLOGY:

Farm Boshof to van Wyks Vlei the beds are almost entirely bluish and greenish shales. At Calvinia however thin sandstones make their appearance in the middle part of the group, these thicken both individually and collectively to the South.

In the Southern Karroo the sandstones thicken up to Grahamstown and even in the lowest division lenses and nodules of sandstone appear.

In Pondoland the succession is identical with that of the northern Karroo, mainly argillaceous, but proceeding northwards the arenaceous character increases and the series develops into the Natal Coal Measures, in the same way as the rocks of the northern Karroo pass into the Transvaal Coal Measures.

In South West Africa (x) the Series outcrops in the Keetmanshoop Gibeon, Rehoboth, and Gobabis Districts to the north east of Marienthal and in the Auob,Olifants and Nossob Rivers and near Keetmanshoop. The strata consist of calcareous grit, succeeded by blue, green, red and purple shales and flagstones, brown micaceous sometimes calcareous sandstones, and brown sandy limestones, types of deposits not seen elsewhere in the Karroo System.

The white and brown sandstones and grits lying between shales is the aquifer for the artesian water in this region, a number of boreholes penetrating it yield flowing supplies particularly around Stamprietfontein on the Anob river and also on the Nossob River.

THE/...

(x) H.F.Frommurze: Flowing Boreholes in the Rehoboth Gibeon and Gobabis Districts, S.W.Africa. T.G.S.S.Af. XXXIV.

THE WATER BEARING PROPERTIES OF THE ECCA:

Starting with the south-eastern Karroo, where the series has a greater development of hard fine-grained arenaceous rocks, a rainfall of up to 20-25 inches, but where the intrusive dolerites are absent the following results are obtained:

	Districts.			
	Bedford & Peddie	Somerset E. & Pearston.	Prince Albert	Laings-burg.
Number of boreholes	26	10	18	11
Average total depth in feet	164	181	81	118
Average depth at which water is s struck in feet.	142	120	44	70
Average depth to which water rises rest level in feet.	112	74	26	44
Average yield per 24 hours pumping in gallons	22,500	15,000	26,600	32,400
Percentage of failures				
(a) Insufficient water	16		-	
(b) Totally dry	29	40	-	10%
Percentage of holes deeper than 300'	nil	nil	-	
Rainfall in inches	20-25"	10-15"	5-10"	5-10"

The variation is surprising in view of the rainfall but the absence of the usual impervious dolerite dykes and sheets undoubtedly plays a large part. Further the amount of tilting and folding to which the beds have been subjected must also have an influence on the subterranean flow and storage, this varies in degree from place to place, and the correspondingly amoount of acquired jointing and cleavage, which explains the increase in yield in Laingsburg and Prince Albert Districts.

Proceeding westwards and northwards the beds become more shaly and horizontal and the intrusive dolerites make their appearance in abundance both as sheets cutting across the bedding of the strata and narrow vertical dykes which may run for long distances. This is the outcrop which extends from Sutherland up to Hoopstad and the drilling results have averaged as follows.

Number/....

	Sutherland & Calvinia.	Phillipstown	Hoopstad.
Number of boreholes	16	20	16
Average total Depth in feet	115	72	144
Average depth at which water is struck in feet.	62	37	95
Average depth to which water rises rest level in feet.	14	15	64
Average yield per 24 hrs.pumping in gallons	44,700	35,000	3,980
Percentage of failures			
(a) Sufficient Water	12	20	18
(b) Total	12	15	6
(c) Not deep enough			12
Percentage of deep holes			
(a) Dry	6	Nil	
(b) Water struck deeper than 300'	12		6
(c) Water struck shallower than 300'	6		18
Rainfall in inches	5-10"	10-15"	20"

Here also the variability of the yield is very pronounced, being in inverse ratio to the rainfall which is unusual, but undoubtedly the increase of the argillaceous content of the series accounts for this. Careful selection of sites in relation to the intrusive dolerite sheets abd dykes probably account for the high average yields in the first two cases.

In South West Africa the artesian conditions which exist in the Ecca beds (described before) have had an extraordinary effect on the underground storage of the water and the yields are exceptional and the depths higher. The averages from 40 non-flowing holes in this area are as follows:

Average total depth of boreholes in feet	312
" depth to first water in feet	81
" " to 2nd. " " "	242
" " to which water rises in feet rest level.	50
Average yield per 24 hours in gallons pumping	42,000

There have been practically no failures in this area.

THE BEAUFORT BEDS:

This series follows the Ecca conformably and makes a large oval extending from the Tanqua, Karroo, to

Wakkerstroom/...

Wakkerstroom and from East London across to De Aar, an area 800 miles in length by 300 miles in breadth, bounded on the south east for a relatively short distance by the Indian Ocean. The structure conforming with the underlying Ecca is a shallow basin with its southern margin determined by folding though dips are moderate except at Prince Albert.

In Pondoland the succession is bent over to dip eastwards and north of Port St.Johns it is affected by faulting. The beds continue to the north of Zululand dipping seawards. Intrusive dolerite is found throughout the series except in the folded region in the extreme south.

The series has been zoned paleontologically but is for the purposes of this account treated as a whole.

LITHOLOGICALLY

the series consists of alternating thick beds of blue-green and occasionally red badly laminated mudstones and white to yellow medium to fine grained sandstone, the colours brightening and varying more considerably going upwards.

Local variations are numerous such as small unconformities, false bedding, limestone lenticles, etc. The water bearing properties are also variable depending on the topography and the rainfall.(1)

In the Central and southwestern Karroo are obtained the highest average daily yields which the series has given, as the country is fairly flat-lying with a persistent inward dip, and advantage can be taken of the numerous dolerite intrusions in selecting sites. The rainfall appears to have had no influence in the South-western corner as the average yields here under a 5" annual average rainfall is equal to those obtained in areas with 15-20" annual average in the central area.

Generally these areas have given consistent results for many years though there has been a drop in the average

daily/....

(1) A.L.du Toit Borehole Water Supplies in the Union of S.A. Trans & Mins. Proc of S.A.Soc.E. 1928.

daily yields during recent years which du Toit[2] attributes, not to depletion or over pumping, but merely to the exhaustion of the more favourable sites, usually situated near springs, on drainage lines and behind dykes. He also draws attention to the fact that it would appear that the average daily yields for boreholes drilled in Aberdeen, Graaff Reinet, Victoria West, Hanover, Cradock and Tarka, when considered annually, show variations in relation to the rainfall for the years reviewed, the average depth to the water remaining about the same however.

Comparing this with the results obtained in the Ecca Beds in the North, there is a similarity as higher daily average yields seem to be obtained after periods of good precipitation[3]. There is no evidence of any lowering of yields yet in this area, probably because drilling has not been continued for so long a period.

In the eastern and northeastern portion the greatly dissected nature of the country has had an adverse influence on the underground water storing capacity of the strata, and has resulted in a large number of small perched water tables offering limited yields to the holes drilled into them. Results here could probably be improved by very careful selection of sites and in some cases deeper boring as has been done at De Wetsdorp. Generally,however, deep boring has been no remedy as pointed out by du Toit[2] and as borne out by the analysis of the holes deeper than 300' drilled in each area (see tables and analyses). In consider ing the question of flowing supplies which were frequently obtained at shallow depths from these beds in the Central and Western Karroo, and which today are seldom recorded,

it/...

(2) Boreholes water supplies in the Union of S.Af. T.M.R.S. A.S.C.E.1928. A.L.du Toit.
(3) Explanation to the Bethal Sheet. Chapter on underground water. H.F.Frommurze.

it is suggested that apart from the fact that the sites are not so favourably situated to-day, there are not so many records coming from these parts. In an investigation in the Richmond District recently it was observed that a number of flowing supplies had been opened recently along a long main dyke. The results from Graaff Reinet where the Government Drills were called upon to do a considerable amount of drilling showed that flowing supplies were still available even to-day. (See Table 7.)

THE UPPER KARROO BEDS (MOLTENO AND STORMBERG SERIES)

These series form highly dissected mountainous country on the borders of Basutoland and are generally well watered by numerous small springs and vleis. The beds consist of various coloured shales and coarse and fine grained yellow sandstones. They have not been drilled into very much on account of the natural supplies but records show that they are not very good aquifers particularly the argillaceous divisions. The records available are confined to the north and souht-western portions of the outcrop comprising the districts of Ficksburg, Ladybrand and Wodehous These average as follows:

	Ficksburg.	Ladybrand.	Wodehouse
Total number of boreholes	6	62	44
Average total depth in feet	204	205	140
" depth at which water is struck in feet.	99	91	84
Average depth to which water rises (rest level) in feet.	65	41	42
Average yield per 24 hours pumping in gallons	9,200	17,500	8,600
Percentage of failures			
(a) Total	25	16	5
(b) Holes not deep enough	-	6	-
(c) Holes with insufficient water	-	3	14
Percentage of Deep holes i.e. deeper than 300'			
(a) Dry	-	6	-
(b) Water struck shallower than 300'	-	11	2
(c) Water struck deeper than 300'	-		2
Average annual rainfall	30"	26"	20-25"

The/....

THE STORMBERG VOLCANICS:

This great area of lavas, tuffs, and agglomerates has not as far as is known been touched by the drill in the central or Basutoland area. In the Lebombo area,however, where the volcanics stretch from the Umfolosi River northwards up to the Limpopo and beyond a considerable amount of drilling for water has taken place in these rocks in the Hlabisa, Nongoma and N'gtosche districts in Northern Natal for the purpose of land settlement. Here the basalts dipping eastwards, compose the prevailing formation, but they are intersected by a system of vertical parallel dykes striking north and south. These dykes are difficult to distinguish from the basalts and they occur very close together often not more than 50' apart. They have the effect of dividing the stratified lavas into narrow strips so that a borehole is taking its supply from elongated compartments which are separated from each other by the impervious dykes. Thus the volcanics, which in the north are fairly high yielders of underground water, have not proved to be a good aquifer in this area.

The average results are as follows:-

Number of boreholes from which information was taken.		150
Average total depth of boreholes in feet		186
" depth to which water was struck in feet		116
" " to " " rises rest level in feet.		60
" yield per 24 hours pumping in gallons		15,000
Percentage of failures	(a) Total failures	17
	(b) Holes not deep enough	4
	(c) Holes with insufficient water to pump.	8
Percentage of deep holes		
	(a) Dry	4
	(b) Water struck shallower than 300'	8
	(c) " " deeper than 300'	2
Percentage of brack water		20
Average Annual rainfall		

Thus it can be seen that one in every three holes fails to strike water and one in every five delivers brack water. Owing to the dykes mentioned above both the catchment areas and the underground storage space for each

borehole/...

borehole is limited, consequently on pumping many of these supplies diminish in quantity or are completely exhausted. There is no means of overcoming this combination of natural phenomena which makes itself felt even in seasons of normal rainfall, in dry years it is much worse.

It is thought that numbers of small conservation dams founded on the dykes would furnish additional replenishment to that from meteoric sources, and at the same time lessen the shortage of water. If this is put into practice it will be interesting to see what effect this surface storage will have on the water-table.

SUMMARY OF BORING FOR WATER IN THE STORMBERG VOLCANICS NORTHERN NATAL.

Depth in feet.

Yields in gallons per 24 hours.	1-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	Totals.
Up to 1000	4	8	4	6	2	2			26
1000-10,000	10	20	7	10	5	6	2	1	61
10,000-20,000	5	12	7	5	1	1		1	32
20,000-30,000	6	4	3	2	1				16
30,000-40,000	3	3	1		1		1		9
40,000-50,000	5	2			1				8
50,000-60,000		2			1				3
60,000-70,000									
70,000-80,000	2	1							3
80,000-90,000	1								1
TOTALS.	36	52	22	23	12	9	3	2	159

THE ECCA SERIES IN NATAL:

This series is the southward and eastward continuation of the Transvaal Ecca. It has been divided into Lower, chiefly argillaceous, Middle chiefly arenaceous, and Upper mostly shales again;

They build highly dissected country from the Transvaal border eastwards to about Magut, and though naturally well supplied with surface waters as springs they do not contain large quantities of underground water owing to the dissection except along drainage lines where naturall

boreholes/...

boreholes will not be required. Most of the drilling takes place on the large isolated blocks with free marginal outlets where extra water supplies are required for stock and homesteads, etc.

The following figures show the average obtained from holes drilled in the Vryheid, Dundee, Helpmekaar, Nqutu and Mgotsche Districts.

Total number of holes		35
Average total depth in feet		163
" depth at which water is struck in feet		110
" " to " " rises rest level in feet		45
" quantity per 24 hours pumping in gallons		12,500
Percentage of failures	(a) Total	22
	(b) Holes not deep enough	-
	(c) Insufficient water	11
Percentage of Deep holes		
	(a) Dry	11
	(b) Water struck shallower than 300'	8
	(c) Water struck deeper than 300'	-
Annual Average rainfall		30-40"

CONCLUSIONS:

The fact that structure and rainfall are responsible for the success and amount of water to be obtained by boring is well brought out by a study of the averages obtained in the Karroo. In long stretches of rocks of a similar composition as the Ecca in the north the yields respond directly to the rainfall.

The Basalts give excellent results in the north as would be expected from a rock with their structure under a good rainfall, but in Zululand where the structure is interfered with by many intrusions the yields decrease considerably.

The change from the predominantly arenaceous rock to the predominantly argillaceous one is seen in the drop in the yield from the Ecca beds proceeding southwards.

In the central areas the Beaufort Beds give comparatively good yields under a moderate rainfall, to the east the rainfall increases but the average yield drops,

due/,,.

due it is thought to the dissected nature of the country.

In the western areas the Dwyka produces surprising yields under a low rainfall e.g. Laingsburg and Calvinia. Here, however, the rocks are highly cleaved and fissile due to their having taken part in the Cape folding.

The intrusive dolerites of course have almost the largest part in influencing the movement and storage of the underground water throughout the portion of the Karroo where they occur. They often carry water themselves, especially the sheets, but results are more erratic when the drilling takes place in the dolerite itself.

In general the results obtained are comparatively good and probably could be greatly improved by careful selection and a little deeper drilling in some parts.

TABLE 6

ECCA BEDS - NORTHERN AREA - HOOPSTAD - PAULPIETERSBURG and N.WATERBERG - SPRINGBOKFLATS AND ZOUTPANSBERG.

DISTRICT	Number of bore-holes.	Average total Depth in ft.	Average depth at which water is struck.	Average depth to which water rises.	Average daily yield.	Percent-age of failures.	Total failures	Water in-sufficient for practic-al use.	Holes not carried deep enough	Except. supplies i.e.over 100,000 gpd.	Holes deeper than 300'	DRY	Water struck shallower than 300'	Water struck deeper than 300'	Rainfall
GROUP 1. Ermelo, Wakkerstroom Piet Retief, Paulpietersbg, Carolina, Volksrust.	258	136	75	44	21,600	16%	6.2%	5%	4.8%	0.8%	5%	0.8%	3.9%	1.1%	30-40"
GROUP 2. Springs, Bethal, Heidelberg, Witbank, Middel-burg, Standerton, Frankfort, Heilbron.	1389	156	87	34	12,800	15.4%	5.7%	2.3%	7.4%	0.2%	3.5%	1%	2%	.5%	25-30"
GROUP 3. Vredefort, Hoopstad, Kroonstad.	83	120	80	37	9,370	27%	9%	9%	9%	-	8%	-	7%	1%	20-25"
GROUP 4. Outliers, Pretoria, Brits.	109	173	104	54	14,000	41%	22%	17%	2%		22%	7.3%	10%	4.7%	30"
GROUP 5. Springbokflats area	58	145	105	74	10,000	50%	26%	20%	4%		22%	5%	10%	7%	25"
GROUP 6. N.W.Ecca.	120	225	138	77	16,200	20%	16.7%	3.3%	-		22.5%	9.1%	13.4%	-	20"
GROUP 7. Zoutpansberg, Karroo Sediments.	79	180	115	60	20	36%	12%	21%	3%		14%	7.6%	6.4%	-	15-20"
						STORMBERG OR BUSHVELD SANDSTONE.									
GROUP 8. N.Waterberg Bushveld Sandstone.	43	207	132	77	12,300	23%	20%	3%	-		14%	11%	5%		20"
GROUP 9. Springbokflats, Bushveld Sandstone.	153	180	110	68	17,400	20%	7.7%	7.7%	4.6		6.4%	2%	2%	2%	25"
						BASALTS									
GROUP 10. Springbokflats	274	122	83	51	29,000	30%	15%	13%	2%		8.6%	2.8%	4.2%	1.6%	
GROUP 11. Zoutpansberg	17	156	122	71	27,500										

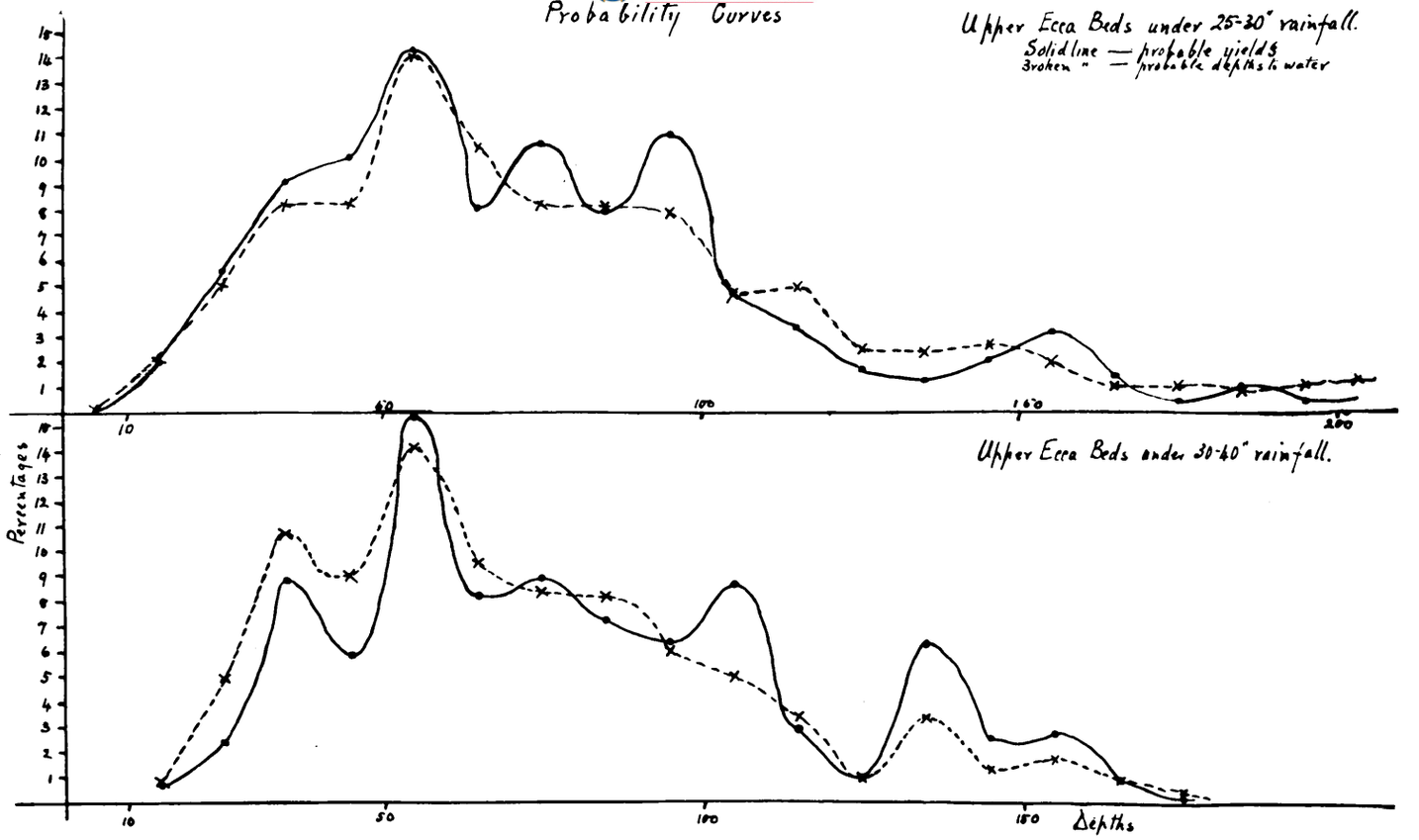


Fig. 12a

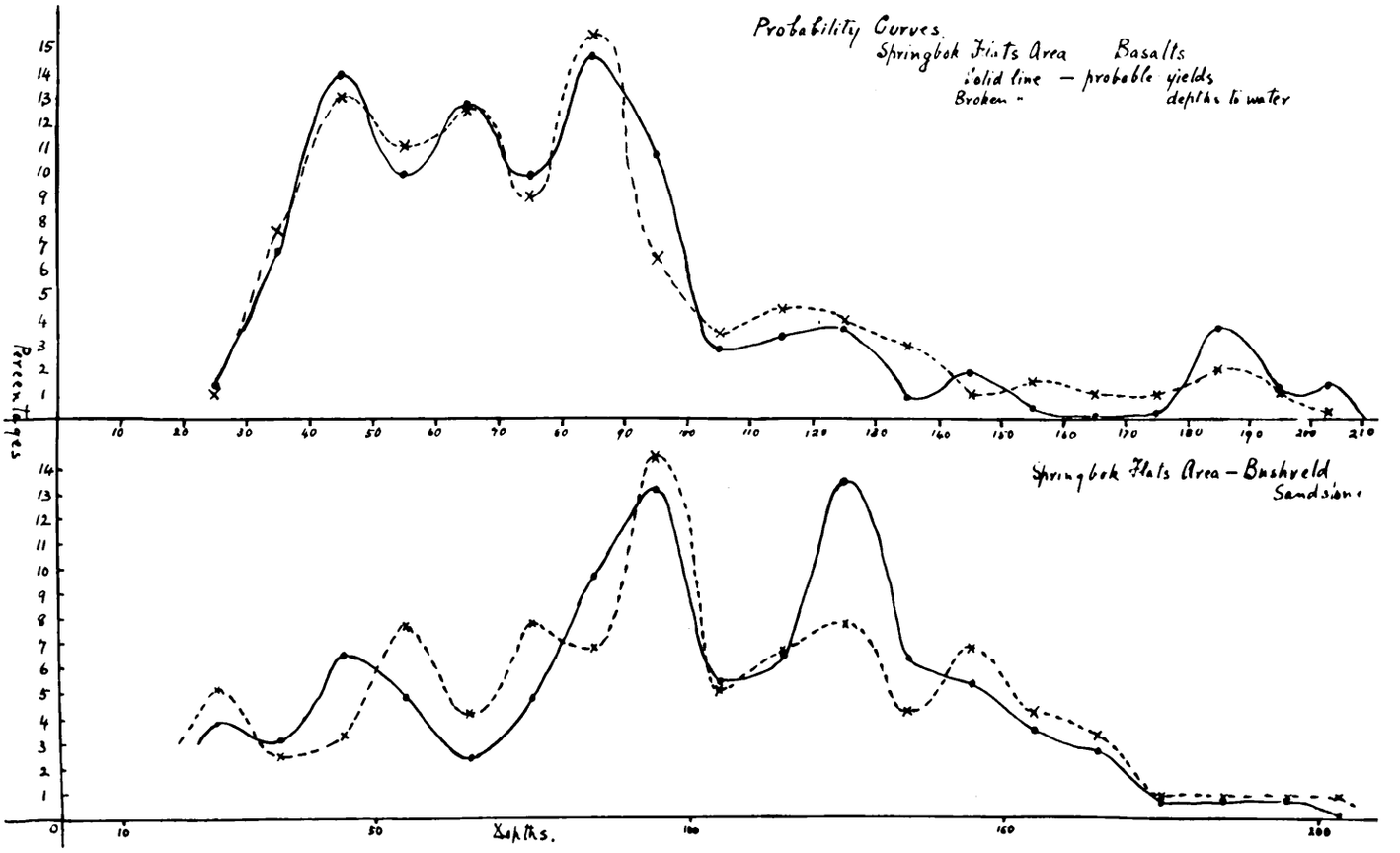


Fig. 12b.

TABLE 6

ECCA BEDS - NORTHERN AREA - HOOPSTAD - PAULPIETERSBURG and N.WATERBERG - SPRINGBOKFLATS AND ZOUTPANSBERG.

DISTRICT	Number of bore-holes.	Average total Depth in ft.	Average depth at which water is struck.	Average depth to which water rises.	Average daily yield.	Percent-age of failures.	Total failures	Water in-sufficient for practic-al use.	Holes not carried deep enough	Except. supplies i.e.over 100,000 gpd.	Holes deeper than 300'	DRY	Water struck shallower than 300'	Water struck deeper than 300'	Rainfall
GROUP 1. Ermelo, Wakkerstroom Piet Retief, Paulpietersbg, Carolina, Volksrust.	258	136	75	44	21,600	16%	6.2%	5%	4.8%	0.8%	5%	0.8%	3.9%	1.1%	30-40"
GROUP 2. Springs, Bethal, Heidelberg, Witbank, Middel-burg, Standerton, Frankfort, Heilbron.	1389	156	87	34	12,800	15.4%	5.7%	2.3%	7.4%	0.2%	3.5%	1%	2%	.5%	25-30"
GROUP 3. Vredefort, Hoopstad, Kroonstad.	83	120	80	37	9,370	27%	9%	9%	9%	-	8%	-	7%	1%	20-25"
GROUP 4. Outliers, Pretoria, Brits.	109	173	104	54	14,000	41%	22%	17%	2%		22%	7.3%	10%	4.7%	30"
GROUP 5. Springbokflats area	58	145	105	74	10,000	50%	26%	20%	4%		22%	5%	10%	7%	25"
GROUP 6. N.W.Ecca.	120	225	138	77	16,200	20%	16.7%	3.3%	-		22.5%	9.1%	13.4%	-	20"
GROUP 7. Zoutpansberg, Karroo Sediments.	79	180	115	60	20	36%	12%	21%	3%		14%	7.6%	6.4%	-	15-20"
						STORMBERG OR BUSHVELD SANDSTONE.									
GROUP 8. N. Waterberg Bushveld Sandstone.	43	207	132	77	12,300	23%	20%	3%	-		14%	11%	5%		20"
GROUP 9. Springbokflats, Bushveld Sandstone.	153	180	110	68	17,400	20%	7.7%	7.7%	4.6		6.4%	2%	2%	2%	25"
						BASALTS									
GROUP 10. Springbokflats	274	122	83	51	29,000	30%	15%	13%	2%		8.6%	2.8%	4.2%	1.6%	
GROUP 11. Zoutpansberg	17	156	122	71	27,500										

Probability Curves

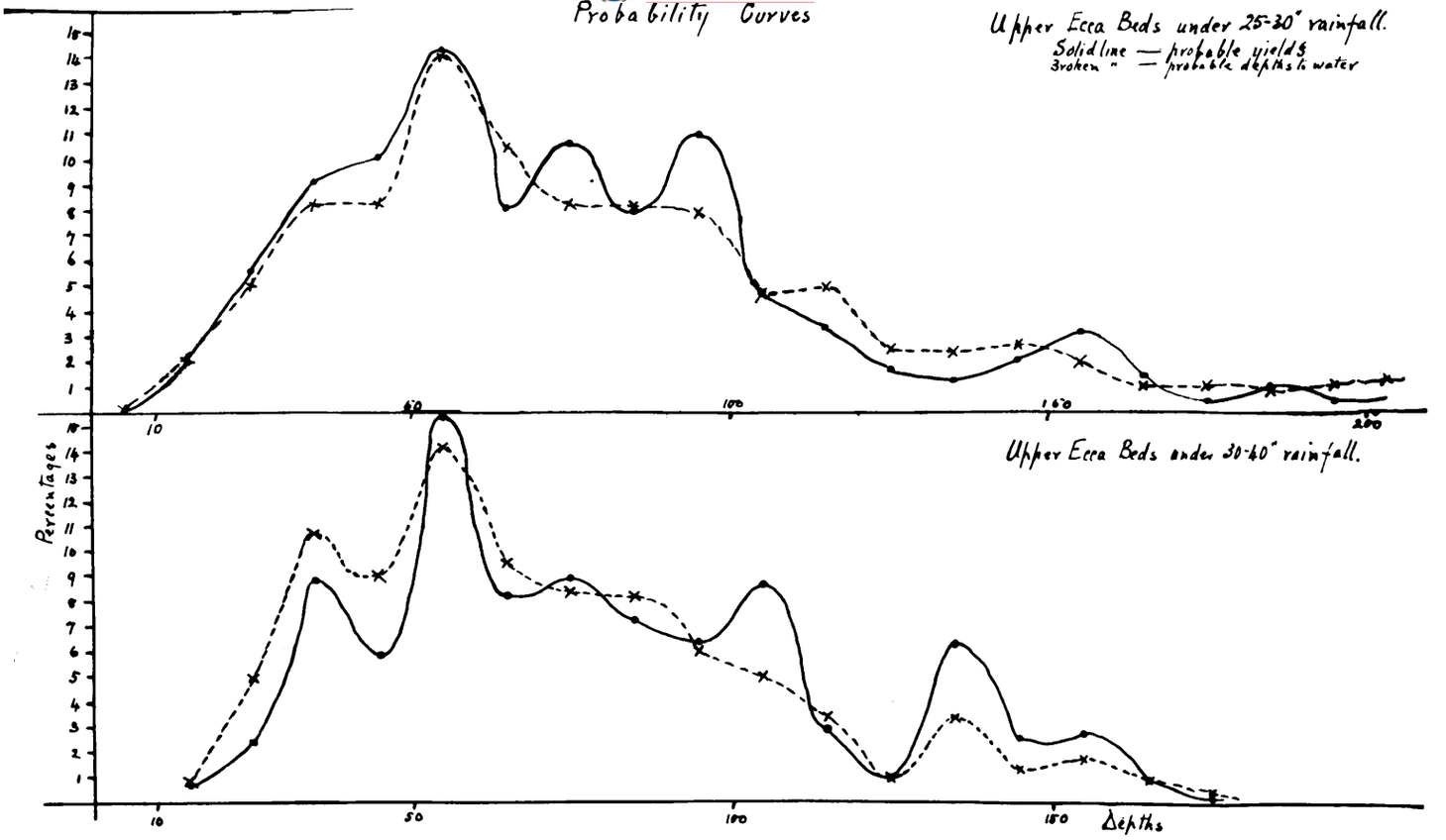


Fig. 12a

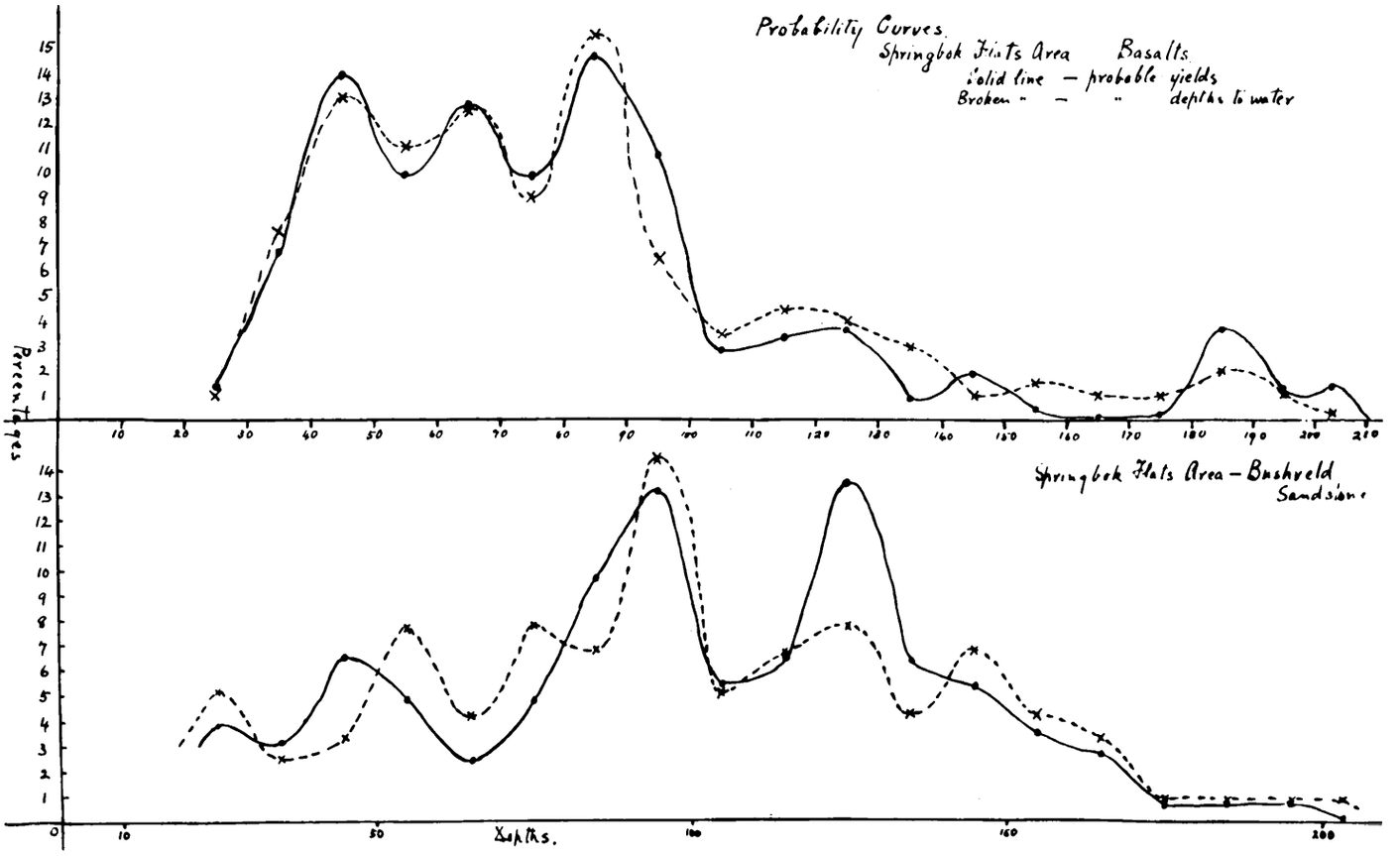


Fig. 12b.

TABLE 7.

BEAUFORT BEDS.

SOUTH WESTERN GROUPS.

Number of boreholes	Average Total Depth	Average Depth to water	Water rises to.	Quantity	Rainfall	District or Locality	Failure per cent			Deep Holes %			Exceptional Yields.	Flowing Holes.
							Total	Not deep enough.	Insufficient water.	Dry	Water Shallower than 300'	Water Deeper than 300'		
22	101	73	29	36,786	5	Calvinia and Sutherland.			5%					5%
25	119	69	38	20,000	5-10"	Beaufort West	16		9					
						NORTH WESTERN GROUP								
20	69	38	12	35,000		Phillipstown	15		25					
34	134	75	30	28,320	10-15"	Phillipolos	23	6	6		6		4	
28	91	43	22	20,000		Fauresmith	50%							
						CENTRAL GROUP								
72	155	116	55	19,700	15"	Colesberg	8	13	20	1	1			
28	156	83	41	25,000	15-20"	Steynsburg	21		7					
40	105	53	38	20,900	10-15"	Middelburg	15	5	25					
87	119	79	52	20,600	15"	Cradock	16	7	15	2				
450	78	43	22	24,700		Pre Union "	20							
11	93	85	46	14,830		Tarka								
110	94	60	25	37,900	18"	Pre Union "	21							
68	147	107	55	25,560	15-20"	Pearston	22		11					
189	132	99	49	27,500	15-20"	Graaff Reinet	16	7	19	1.5	1.5		1	
113	102	72	27	26,700		" Pre Union	7							
73	146	91	47	22,000	20'	Somerset East	11	1	12		1			
37	134	94	23	31,700	15-20"	Smithfield	35		5		2	2		
49	160	96	54	14,700	20"	Bloemfontein	20		4		4			
18	143	88	51	12,200	23"	Winburg	33			5				
19	144	87	51	23,300	24"	Lindley	15		5					
15	178	78	40	6,760	25"	Bethlehem	16		16					
						EASTERN GROUP								
26	120	61	41	10,000	25-30"	Senekal	35		5					
20	130	80	37	19,000	20-25"	Thaba N'Chu	18							
14				25,000		De Wetsdorp	8				12	6		
43	116	82	41	12,600	20-30	Kingwilliamstown	26		18	26				
23	170	143	53	7,300	"	and Konga Pre-Union.								
15	111	64	45	3,430	25-30	Stutterheim	33		20					
17	199	145	53	13,000	30	Umtata	5		18		3	30		
						MOLTENO BEDS.								
62	205	91	41	17,500	26"	Ladybrand	16	6	3	6	11			
6	204	99	65	9,200	30	Ficksburg	25							
44	140	84	42	8,600	20-25	Wodehouse	5		14		2	2		
						STORMBERG. VOLCANIC NATAL.								
148	186	116	60	15,000		Ubombo Ngotsche	17%	4	8	4	8	2		20% brack waters.