THE GEOLOGY OF SOUTH AFRICA

BY

ALEX. L. DU TOIT
D.Sc., F.G.S., F.R.S.

WITH 41 PLATES, 73 TEXT-FIGURES, AND
A GEOLOGICAL MAP

THIRD EDITION
REVISED AND ENLARGED

EDITED AND PREPARED FOR PUBLICATION
BY

S. H. HAUGHTON
D.Sc., Hon.LL.D., F.G.S., F.R.S.S.Af.

OLIVER AND BOYD
EDINBURGH: TWEEDDALE COURT
LONDON: 98 GREAT RUSSELL STREET, W.C.
1954

Water.—An uncommonly large proportion of this country is without supplies of surface water except for a limited period during the rainy season, while perennial streams are few. Although advantage has been taken by the settler of springs and shallow wells, it is through boring that the salvation of South Africa has been effected. Wide regions in South-West Africa, Bechuanaland, and the south-western and northern Transvaal have been opened up almost entirely by means of the drill, and vast areas still await their turn. Recently considerable benefits have followed the use of geophysical methods of water-location.

A. SPRINGS. *Warm Springs.*—In addition to a multitude of cold springs there are a considerable number of warm ones with various temperatures. The Zongola Geyser and the Kapesa Hot Spring within the Zambezi trough, not far from the junctions with the Gwaai and the Sanyati respectively, yield water at 206° F. and 133° F., but the majority range between 70° and 90° F. Some of them are perfectly fresh, others are highly mineralised, while they are generally not connected with any particular formation, nor confined to any special belts of country, nor closely associated with recent volcanic rocks. With few exceptions those furnishing sulphuretted waters issue from beds of the Karroo System, *e.g.* Aliwal North, or Bokkeveld, the gas being derived from pyrite or marcasite in the strata.

In regard to their location many appear at the junction of dissimilar formations, the contact surface making a water-plane. The warm springs at Caledon, Warmwater Berg, Montagu and Olifants River (Oudtshoorn) issue on the flanks or ends of anticlinal ranges, where the Table Mountain sandstones pass beneath the Bokkeveld slates; that at Brandvlei, Worcester, has a temperature of 147° F. Frequently they have been determined by igneous dykes or inclined sheets, as is indeed most common throughout the region occupied by Karroo beds and intrusive dolerite. At other times a line of faulting has been responsible, as in the six hot springs (up to 175° F.) [1] which provide the town of Windhoek with its supply (in mica schist), at Kuibis (in quartzite and limestone), Warmbaths in the Transvaal (in Red Granite), Tugela Ferry, and Lilani near Greytown in Natal [2] (in amphibolite), the Letaba River (106° F.) (in Old Granite) and Loubad near Nylstroom [3] (in Waterberg). Connected with post-Karroo fault-lines are most of the Rhodesian springs, many of them warm, for example those within the broad belt trending north-eastwards from Wankie down the Zambezi.[4] In other cases, however, there are no obvious structural features with which they can be correlated, *e.g.* Warmbad in South-

[1] For details see T. W. Gevers, *T.G.S.S.A.*, 1933, xxxv, 1.

[2] T. W. Gevers, *T.G.S.S.A.*, 1943, xlv, 43.

[3] L. E. Kent, *T.R.S.S.A.*, 1942, xxix, 35.

[4] See H. B. Maufe, *S. Rhod. G.S.*, 1933, Bull. 23.

West Africa and Badplaats east of Carolina (in the Old Granite), Machadodorp (in diabase), and Aliwal North and Tarka Bridge near Cradock (in Karroo beds).

At the last place saline water at a temperature of about 80° F. issues from four shallow boreholes and, most remarkably, its level rises and falls at twelve and a half hour intervals as with the oceanic tides. The boreholes clearly draw their supplies from the same underground source, for the composition and temperature is the same in all, while the pumping of one hole affects the discharge from the others.

(2) *Cold Springs.*—The Dolomite is responsible for the cold ones in South-West Africa, the Transvaal, and Griqualand West, while several large open sink-holes are known with standing permanent water, *e.g.* the Wondergat just east of Mafeking, Lake Otjikoto near Tsumeb, and Sinoia Cave.

The water may appear just above the Black Reef, as at the " eye " of the Mooi River or at Ventersdorp, or at its contact with the underlying granite, as at Motiton, west of Vryburg ; where the dolomite dips beneath the Pretoria beds, as at Steenkoppies west of Krugersdorp and at Pretoria ; above syenitic dykes, as in the Wonderfontein Loop between Randfontein and Potchefstroom. As is so common in limestone regions, the springs may issue from solution-channels without any relation to structural or other features, as in the Molopo Eye in Marico, at Kuruman and at Otavifontein in South-West Africa ; minor examples of such are abundant. The larger springs in the Dolomite are rather constant in their yields, with outputs of from 4 to 13 millions of gallons per diem, though the discharge may lag behind the rainfall by from six months to two years ; the biggest is the Gerhardminnebron near Potchefstroom. These waters are naturally charged with carbonates of lime and magnesia, the proportion of such solids ranging from 14 to 24 parts per 100,000, with an average of 20, the pH value ranging from 7·0 to 8·0. The Newlands and Albion Springs near Cape Town emerge along a fault-line in slates. Those at Kokstad, from dolerite, yield about a million gallons daily. Fresh water issues during low tides at Osterwal in Saldanha Bay and at the mouth of the Coega River.

B. Wells and Boreholes.—*Truly artesian* supplies are all but confined to two regions.

To the north-east of Mariental in South-West Africa a number of boreholes from 300 to 600 feet deep sunk along and outside the dry troughs of the Auob River around Hofmeyr and Stampried, and of the Nossob above and below Pretorius, yield huge flowing supplies of good quality, the water-horizon belonging to the Karroo System and consisting of beds of porous sandstone averaging from about 50 to 175 feet thick sandwiched between blue shales.

Quite a number have gushed at the rate of over half a million gallons per day, and a couple—Österode and Nabas—at about three-quarters of a million, while static pressures up to 32 lb. to the square inch have been measured; the outputs are, however, being controlled by stop-valves, since some large decreases have already been observed. There are also many non-flowing holes. The intake is mainly the ground sloping southwards from the base of the ranges between Rehoboth and Gobabis. The "aquifer" or artesian stratum is dropping gently towards the south-east, the limit of the basin down the Nossob being 30 miles from the Cape border.

Another artesian area exists in the north, the borehole 532 feet deep at Andoni on the northern side of the Etosha Pan furnishing about half a million gallons a day at nearly 30 lb. pressure.

In the Uitenhage district porous pebbly sandstones of the Cretaceous have a sporadic development, filling hollows in the Cape rocks and dipping beneath the Variegated Marls (see p. 378). A number of boreholes in the Elands Valley close to Uitenhage yield flowing supplies, but unfortunately of water rather high in mineral matter, notably sulphate of iron from pyrite or marcasite in the water-bearing beds. At Zwartkops water issuing from this zone at a depth of 3600 feet with a temperature of 130° F. is chalybeate and valuable medicinally. At Balmoral, near Uitenhage, the water pours out at from 200,000 to 300,000 gallons a day from boreholes piercing the jointed Table Mountain Sandstone beneath the impervious covering of Cretaceous clays. Flowing holes occur on Disco near Addo and Klipfontein in Baviaans Kloof.

The Springbok Flats has been regarded as a possible artesian basin and certainly possesses the requisite structure; on the other hand, the "intake" on the north may be insufficient, the beds themselves are not conspicuous for permeability, and 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 1564-feet borehole on the farm Diepsloot, while practically all the other deep borings, from 500 to over 800 feet, 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 very low, while the formation is intersected by a maze of dolerite intrusions, which would act as barriers to underground circulation.

With regard to ground-water generally there is commonly no real "water-table," for the reason that owing to the lack of pervious strata the underground water circulates mainly by means of the bedding-planes, joints, and fissures in the rocks and consequently in, or just below, the zone of weathering; this explains why there are productive wells even in solid granite and other crystalline rocks. The supply in all cases is maintained by infiltration from the annual rainfall and is usually of local and not far-travelled origin, but the extraordinary feature is that the yields are to so great an extent almost independent of the magnitude of the seasonal precipitation. There is, for instance, less difficulty in obtaining water in the semi-arid Karroo, say about Laingsburg, Willowmore, Cookhouse, etc., than over much of the Transvaal or Natal with treble the rainfall. Apparently the more clayey character of the soils as developed in the wetter region tends to prevent the ingress of the surface waters as freely as in the drier one. In the case of the flat-lying Dolomite near the Rand with its covering of absorbent sand the infiltration amounts to as much as 11 per cent. of the rainfall, but on other formations this coefficient, and consequently the yield, must be much lower. When the rocks are foliated, tilted, or cleaved, so that the ingress of rain water is facilitated, the yields are usually higher than when they are homogeneous or flat-lying. Consequently the gneisses, cleaved greenstones, and phyllites, are better producers than the massive granites, felsites, quartz porphyries, epidiorites or amphibolites, and the tilted Pretoria beds or jointed Dwyka tillite than the horizontal Karroo strata. Quartzites, though hard to drill, often furnish satisfactory supplies, *e.g.* the Timeball Hill Group of the Pretoria Series. In the amygdaloidal diabase of the Ventersdorp System or the Ongeluk (Pretoria) lavas drilling is comparatively easy and the yields generally satisfactory.

In the great dry sandy region of the Kalahari the scanty groundwater is so held by the deep sand that it is not generally available for collection in wells. Where the covering is shallow, say up to about 100 feet, water can generally be got without much difficulty in the underlying formation, for example in Mafeking, Vryburg, Gordonia, Keetmanshoop, etc., in the Granite, Nama, or Dwyka Series; with a thicker covering the results are more variable. Many boreholes in the porous Kalahari limestone and sandstone have been successful, as for instance along the lower Auob or the lower Kuruman River, but others in Bechuanaland to the north-east and west of Kuruman have penetrated the red marls, and a goodly proportion have been failures.

The *contact* of two dissimilar rocks is frequently a water-plane, either (1) an unconformable one upon an older formation, *e.g.* the base of the Dwyka Tillite or Black Reef or Alexandria limestones, (2) a lithological discontinuity, *e.g.* a sandstone bed on shale or a band of slates on quartzite, or (3) an igneous contact, *e.g.* those of the numerous diabase sheets of the Pretoria Series or of dolerite in the Karroo, both the upper and lower boundaries being commonly available, though the former is the better generally. It has been a kind of unwritten law to avoid drilling in dolerite or diabase yet, with the aid of heavier drills, such intrusions are nowadays repeatedly being pierced or bored into for some distance and water obtained. The underflow is intercepted by the more dyke-like intrusions in the gneisses or sediments and may be even brought up to the surface as a spring. Boring behind (above) such barriers is commonly successful and is the general policy in the Karroo region; even in the case of hard crystalline rocks such as granite the presence of such dykes has been of advantage, more particularly in Rhodesia. The kimberlite dykes and pipes give large and usually shallow supplies. As a rule, the deeper the weathering of the rock the better the supply; the worst producers in the Union are the Bushveld norite and red granite—both rather " solid " formations. In the dolomitic groups, on the contrary, the rock itself is practically impervious, the water travelling along solution joints and fissures, consequently the yields are erratic.

Depth.—In much of the Karroo, the folded belt and south-west of the Cape, the Orange Free State, and south-western Transvaal shallow holes are the rule, water being struck at from 40 to 100 feet, rising thereafter to a certain distance in the borehole. In the Coal Measures of the south-eastern Transvaal about 150 feet is usual; but in the Old Granite of the Transvaal and of Rhodesia from 150 to 200 feet is common, while in the Koranna Berg and north-west Mafeking over 250 feet is almost the rule and up to 300 feet frequent.

After the general depth for the district or formation is exceeded, a falling-off in yield is to be found. It is rather rare to have good supplies furnished by holes well in excess of the average depth, say from 300 feet onwards, because the rocks have become more solid down below; progressing beyond 500 feet can hardly ever be recommended, a second trial elsewhere being usually more satisfactory. Of those exceeding 400 feet the majority derive their supply in great part from the upper strata or are low in their output; as stated earlier, the lack of porosity militates against the presence of deep-seated water in synclinal or monoclinal structures in this country.

Yields.—In the majority of formations the successful holes give on test anything up to about 30,000 gallons per day but, where the conditions are more favourable, up to 80,000 may be obtained; instances of over 100,000 are distinctly uncommon. In the Dolomite, even under continuous pumping, some large yields have been got, *e.g.* in the Klip River Valley and at Zuurbekom near Johannesburg—up to a million or more gallons from a well or large diameter borehole. The artesian flows in South-West Africa have already been cited.

Salinity.—To a large extent this character is dependent on the local rainfall, climate, and topography, consequently the prevailing salinity of the waters at such places as Walvis, Lüderitz, and Saldanha Bay is only to be expected. Siliceous formations tend naturally to yield fresh waters in the majority of situations, for example the Table Mountain Sandstone, Molteno beds, and most granites and gneisses. The Table Mountain Sandstone yields " acid " waters with a pH value of 4·5 to 6.

The Bokkeveld and Malmesbury slates furnish brackish waters, which in the case of the latter are frequently rich in magnesium salts. From the fact that in the west and north of the Cape and in South-West Africa the bulk of the saltpans are located on the Dwyka tillite or shales, it will not be surprising to learn that the water in wells in those particular formations is generally brackish, high in sulphates, and often undrinkable. In Natal, on the contrary, the tillite, though not so productive, is only slightly saline. The waters of the Lower Beaufort beds contain some chlorides, but those of the Middle and Upper divisions are distinctly alkaline owing to sodium bicarbonate and may have pH values as high as 6·2. The supplies from the Uitenhage beds in the Oudtshoorn and Uitenhage districts are frequently very salt and sometimes charged with sulphate of lime or of iron. The waters from the Dolomite contain merely carbonates of lime and magnesia, in the proportion usually from 14 to 24 parts per 100,000, which confer on them " temporary hardness " ; those from the Ventersdorp lavas not uncommonly carry a fair amount of carbonate of lime also, and naturally the same would be the case in the Kalahari or Alexandria limestones.[1]

Zinc.—See Lead.

[1] Further information will be obtained in the following papers :—

A. L. du Toit, " The Geology of Underground Water Supply," *Min. Proc. S.A. Soc. Civil Eng.*, 1913, 7 ; " Porosity of Rocks of the Karroo System," *T.R.S.S.A.*, 1915, iv, 169 ; " Borehole Water Supplies in the Union of S.A.," *Min. Proc. S.A.C.E.*, 1928, xxvi, 74.

E. Kaiser and W. Beetz, " Die Wasserschliessung in der südlichen Namib," *Zeits. Prakt. Geol.*, 1919, xxvii, 165.

H. B. Maufe, " The Geology of Underground Water in South Rhodesia," *Proc. Rhod. Sci. Assoc.*, 1921, xix, 23.

M. Rindl, " The Medicinal Springs of S.A.," *S.A.J.S.*, 1917, 528 ; *ibid.*, 1918, 217.

H. F. Frommurze, " Flowing Boreholes in the Gibeon, Rehoboth and Gobabis Districts, S.-W. A.," *T.G.S.S.A.*, 1931, xxxiv, 129 ; " The Water-bearing Properties of the more Important Geological Formations in the Union S.A.," *Union S.A.G.S.*, 1937, Mem. 34 ; " Scientific Methods of Water Finding," *P.G.S.S.A.*, 1944, xlvi, p. xxiii.

F. Dixey, *A Practical Handbook of Water Supply*, London, 1931.

G. W. Bond, " A Geochemical Survey of the Underground Water Supplies of the Union of S.A.," *Union S.A.G.S.*, 1946, Mem. 41.