UNION OF SOUTH AFRICA

DEPARTMENT OF MINES AND INDUSTRIES

GEOLOGICAL SURVEY

THE GEOLOGY

OF THE

COUNTRY BETWEEN GRAHAMSTOWN AND PORT ELIZABETH

An Explanation of Cape Sheet No. 9 (Port Elizabeth)

BY

S. H. HAUGHTON, B.A., D.Sc., F.G.S.

With a Chapter on Underground Water Resources of the Uitenhage Region by ALEX. L. DU TOIT, D.Sc., F.G.S., late Geologist to the Irrigation Department

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The Geology of the Country between Grahamstown and Port Elizabeth.

I.—Physiography and Structural Features.

The area represented on Sheet 9 includes 3,855 square miles of country with a somewhat varied topography and of great geologic interest. It comprises the eastern end of the Cape Folded Belt; but superimposed upon this lower end of the Folded Ranges are the deposits of the Uitenhage Basin and the subsequent peneplanation and deposition of late Cretaceous and Tertiary times. This peneplanation affected the exposed parts of the Folded Belt; and, in consequence, there are within the area no outstanding mountain peaks.

To the west of the area, the hard Table Mountain Series forms the ranges of the Van Stadens Mountains and the Winterhoek (the latter culminating in Cockscomb); but in the area covered by the Sheet the hills made of this series are insignificant. The Van Stadens Mountains are continued as a low peneplain which at its eastern end juts into the sea at Cape Recife; the Winterhoek range sinks rapidly eastwards and is buried under the sediments of the Uitenhage basin, jutting through these as a few small inliers between the Zwartkops and Coega Rivers, of which Coega Kop is the most prominent. The islands of Jahleel and St. Croix are continuations of this ridge, which is faulted on its southern face.

The chief mountain feature of the area is the Zuurberg, a peneplaned broad ridge, with a general height of about 2,600 feet, mainly composed of Witteberg rocks, but containing Karroo Beds folded into it. Owing to the easterly pitch of the folds there are, in Albany, one or two subsidiary ranges north of the main mass.

Between the Great Fish and Koonap Rivers the Fish River Rand, composed of slightly folded Ecca Beds, is a grassy broad rounded ridge.

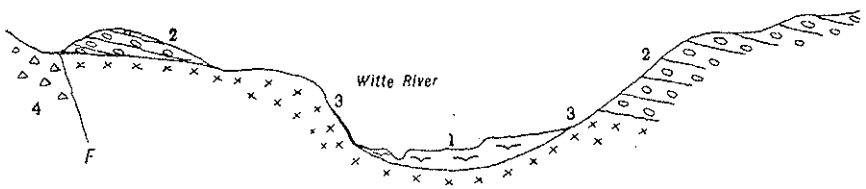
The Zwartkops and Coega Rivers begin in strike valleys in the Cape folded rocks and, on reaching the Uitenhage Beds, continue in the same general direction to the sea in fairly broad plains of alluvium bounded by gentle ridges. The Sundays River cuts a deep winding transverse gorge through the Zuurberg and then runs in a general south-easterly direction, with numerous big winding curves, through a broad alluvial valley. The Bushmans River rises to the north of the Zuurberg, meanders along a strike valley through the Karroo Beds, turns south at Alicedale and cuts through the Zuurberg,

runs in a deeply cut meandering valley southwards to Hillary, and then abruptly turns eastwards to run in an entrenched meander to the sea. The Kariega River is a meandering strike stream for some distance; at Sweetmans Location it turns southward and flows to the sea in an entrenched meander. The Great Fish River in our area is an easterly flowing entrenched meandering stream.

All the rock-series up to and including the Ecca Beds are thrown into a series of folds striking approximately E. 10° S., the northern limb of each fold (except along the northern edge of the map) being usually steeper than the southern. The folding of the Cape ranges is complicated by faulting and by subsequent peneplanation. Before Uitenhage times most of the area must have been at or near sea-level, and it is probable that much denudation and peneplanation had gone on in the interval between the initiation of the folds and the eruption of the Drakensberg lavas. The nature of the surface over which the latter flowed is obscure; but the presence of some red sediments under the volcanics in the down-faulted area in Steytlerville (west of the sheet) is of interest as showing the probable extension of both Stormberg sediments and Stormberg volcanics to this region.

Diagrammatic Section across Witte River Valley East of Enon.

N. S.



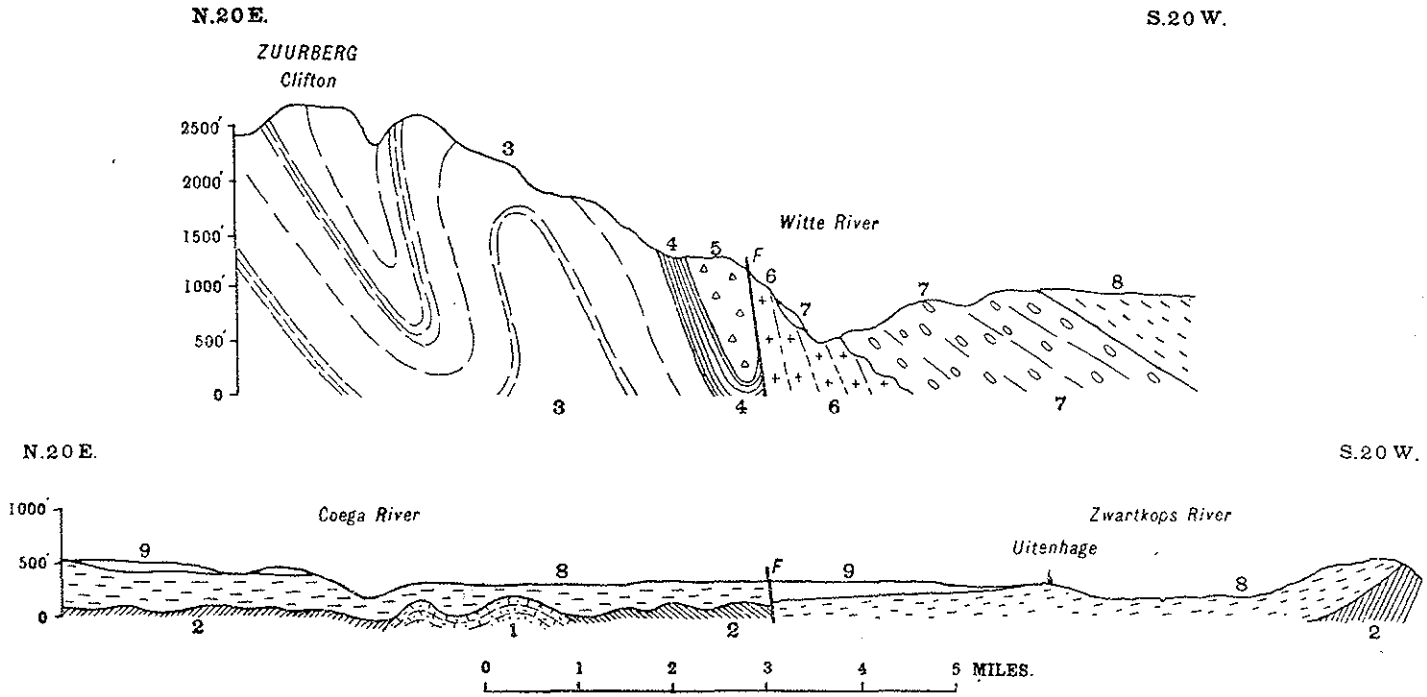
1. Alluvium. 2. Enon Conglomerate. 3. Basalts and Tuff—presumably Stromberg. 4. Dwyka Tillite

Fig. 1.

Upon a more or less flat surface, at least partly covered with Stormberg lavas, the Uitenhage Beds were deposited as sediments laid down in a large sinking delta fed by several streams, upon which the sea encroached from the south. At the end of this deposition the region suffered faulting. The largest fault is that known as the Zuurberg fault which now forms the northern boundary of the Uitenhage Basin. This cut athwart the strike of the folded rocks and let down the beds on its southern side. The fault plane is not straight, but is bowed at its eastern end, with concave side facing the south, and is broken near the Bushmans River by a series of step-faults which throw it to the south on the eastern side.

A fault with a similar strike affects the southern side of the eastern end of the Winterhoek and cuts the Uitenhage Beds, with downthrow to the south. A minor fault with a small downthrow to the north is traceable from Centlivres to the Sundays River at Penshurst.

SECTIONS ACROSS UITENHAGE BASIN.



1. Table Mountain Sandstone. 2. Bokkeveld Beds. 3. Witteberg Beds. 4. Lower Dwyka Shales. 5. Dwyka Tillite. 6. Pre-Cretaceous (Stormberg?) Volcanics. 7. Enon Conglomerates. 8. Variegated Marls. 9. Sundays River Marine Beds. F. Faults.

Fig. 2.

After this faulting some uplift and peneplanation set in, the latter continuing throughout Upper Cretaceous times. This resulted in the formation of a large coastal plain, out of which—to the west of our area—stood the higher peaks of the folded ranges. On this plain were deposited, owing to a certain amount of subsidence at the end of the Cretaceous Period, the limestones and terrestrial deposits which are collectively grouped as the Alexandria Beds.

Before the deposition of the limestones the plain must have had a very gentle slope over which the rivers flowed in broad meandering valleys. Along the coast inshore dunes were deposited, behind which the rivers twisted in order to find a way through to the sea. Gradually the sea retreated south-eastwards over a gently rising area, and the belt of dunes became gradually broader. As uplift proceeded the sea retreated, the rivers cut down their meandering channels into the plain, and partial recrystallization of the dune-deposits went on. On this supposition those portions of the Alexandria formation nearest the present coast-line are the most recent in age; but the formation is a unit and apparently indivisible, save for a time break represented by the 900 feet terrace at Sundays River Poort, the loose gravels along the lower part of the Sundays River, and along the lower terraces of the Bushmans River and its tributaries in Albany.

The peneplain on which the limestones and surface deposits rest, is a continuous one from Sandflats to the sea in the middle of the area. Mr. Wybergh considered that in the Bredasdorp area this plain was one of marine erosion; Dr. Rogers pointed out that such a marine plain should have a northern boundary showing a level beach mark at the foot of the mountains. Such a step is apparently to be found at one or two points. For example, north of Sandflats the land rises fairly abruptly from a height of 1,100 feet to one of 1,600 feet at Bellevue (which stands on the peneplain, but not at its edge); again, the plain at the east end of the Winterhoek is at 1,500 feet, but the base of the limestones at Grass Ridge and the neighbouring farms is not above 900 feet. To the west of the Gamtoos, however, where limestones do not occur, there is no such sudden fall, but a gradual slope of the peneplain almost to sea-level; and in the south-west corner of Albany the limestones and silcretes occur side by side with no apparent break in the slope of the surface on which they rest. It would appear as if the plain were, therefore, in part sub-aerial in origin and in part wave-cut.

II.—Pre-Cape Rocks.

Malmesbury Series.—Rocks which are tentatively assigned to this series crop out along the shore on Sea View and Bushy Park, and in a narrow patch just north of the Uitenhage Fault on Klip Rivier. In the shore section the general strike is E.S.E.-W.N.W. and the dip is southwards at an average angle of 45°. The strike is, however, somewhat variable, occasionally changing for short distances to almost N.-S., the dip then veering to the west. The

rocks consist largely of quartz-schists, sheared quartzites, arkoses, felspathic grits, and conglomerates containing pebbles of shale and grit; the quartz-schists, quartzites and grits all contain a small amount of dolomite, which occurs as small grains in the groundmass. Phyllites, schists and quartz-schists occur to the west on Sea View, where they are heavily shot with quartz veins, the latter reaching a maximum thickness of 3 feet in places and containing marcasite, pyrites and other minerals in small quantity. Cubes of pyrites also occur in a sheared grit on Sea View (775 S.H.). This occurrence of Malmesbury Beds is the extreme eastern end of the large mass which outcrops to the west in the Gamtoos Valley.

III.—The Cape System.

(*a*) The *Table Mountain Series* occupies only a small area on the map. It forms most of the peneplaned country lying south of the Zwartkops River Valley forming the coast-line between Bushy Park and Port Elizabeth; an outlier of the Elands River Mountains occurs on Kruis Rivier; and the extreme eastern end of the Winterhoek Range appears west of the railway at Sandfontein and as a series of inliers protruding through the Cretaceous Beds on Sandfontein, at Coega Kop, and Jahleel and St. Croix Islands. The rock is typically a quartzitic sandstone, rather heavily jointed. Near Schoenmakers Kop there is a local occurrence of shales and of a conglomerate band. The formation is of some considerable importance as a source of water in the Uitenhage area.

(*b*) *Bokkeveld Series*.—This series, where it outcrops in the area covered by the map, is predominantly shaly. The full succession is not seen in any one section. In the west the beds are largely covered by Cretaceous rocks, and in the eastern half by Tertiary deposits and sands. The lower limit of the beds is well-defined in the western part of the area; but in Albany, Alexandria, and Bathurst, the line of junction between the Bokkeveld and Witteberg is often difficult to determine, and the true position of the isolated inliers of shales near Alexandria is rather doubtful.

In the west, the lower beds of the Series crop out in the foot-hills of the Winterhoek range and to the south of Uitenhage. North of Glen Somers and Wilge Rivier a sub-division corresponding to the First Shales, First Fossiliferous Sandstone, and Second Shales of the type areas can be drawn up. The First Shales are mainly grey and purple shales and phyllites with rather thin bands of soft sandstone, dipping at steep angles. The phyllites are ferruginous, sometimes with thin secondary veins of hematite; reddish nodules are frequent in them, as are peculiar ferruginous nodules associated with fibrous silica.

The First Sandstone is quartzitic and massive. On Eland's Hoorn Outspan it is overturned, dipping at 30° to the E.S.E. On Wilge Rivier a specimen of *Spirifer antarcticus* was seen in it. The

Bricks, tiles, and rough pottery are manufactured at Grahamstown. The material used is weathered shale from the lower Dwyka Shales, which have here become converted into a variegated clay of considerable thickness. In this area the Dwyka Tillite has, at certain places, been weathered to depths up to 40 feet, and has formed a whitish clay with contained pebbles and boulders of more unweathered material, chiefly vein quartz. Research on the value of these clays is now being carried out under the auspices of the Research Grant Board.

VIII.—THE UNDERGROUND WATER RESOURCES OF THE UITENHAGE REGION

BY
ALEX. L. DU TOIT, D.Sc.

1. *Introduction.*—Uitenhage is, so far as is known, the sole district of the Union in which conditions for artesian water are present, although the detailed study of the region has only served to reveal the complicated nature of the problem and its dependence upon important geological peculiarities. Closely linked therewith is the question of the source and permanence of the Uitenhage Springs.

Settlement has naturally been most advanced within the shallow valleys cut in the soft Cretaceous strata, and much difficulty has unfortunately been experienced in obtaining supplies of fresh water, this being particularly the case in the lower reaches, where the rivers have become tidal.

The development of irrigation within the Sundays River Valley, furthermore raises the question as to the possibility of striking large volumes of flowing water, such as could be used for supplementing the quantities available from the existing storage and diversion works, important when it is stated that on the large farm Balmoral (Imanzi) citrus culture is wholly dependent on artesian supplies. The area that could be irrigated with a continuous flow of say half a million gallons per diem is, however, much less than is popularly imagined, and the cost per acre would in most cases be much greater than under any practical scheme of storage. Limitations are accordingly set to such exploitation by economic conditions, nevertheless it is considered that there are distinct possibilities in several localities and that attempts should be made to prove the potentialities of such areas, either by private enterprise or with the assistance of the State.

2. *The Uitenhage Springs.*

The town of Uitenhage has, from its commencement, depended upon the presence of these valuable fountains. Arising in a little basin-shaped valley at the south-eastern end of the Great Winterhoek Mountains, four miles to the north-east of the town, and adjoining Sandfontein, the two "eyes" formerly issued in a reedy swamp and had a much greater discharge, but for various reasons their output to-day is very much less.

Concealed beneath the sand and pebbles with which the valley is filled, are tenacious red clays that rest upon the Table Mountain quartzites, and the springs issue at R.L. 585 feet* at the contact of these two formations. A very narrow ridge of quartzites rising to over R.L. 800 feet, separates the hollow from Sandfontein, while to the north the bare ridges rise to R.L. 1,100 feet and to greater heights further to the north-west.

This rocky ground constitutes the "intake" of the springs, and judging from their constancy in yield throughout the year, their gathering ground must be of considerable size. The quartzites are dipping northwards at about 50°, but are much jointed and in places brecciated and the rainfall evidently soaks in over the region to the west to make its way eastwards and to lower levels by means of these fine crevices; the rock itself being absolutely non-porous. No marked lines of crushing can be made out in the exposures to the west along which the water could be expected to travel with relative ease. The base of the quartzites plunges beneath the Cretaceous beds and the covering made by these clays and clayey conglomerates prevents the water that is slowly moving in the foundation quartzites from escaping excepting at certain points along the edges of this mantle, or at a few favoured spots within the area of the latter where, under the great hydrostatic pressure, it has been enabled to force its way through some thinner portions of this covering and so give rise to springs.

Examples of the former kind occur at a number of points along the base of ridge hemming in the Springs and also on the Sandfontein side, while instances of the latter are to be found on the centre of Sandfontein and at the lime kilns on the main road, midway between Sandfontein and Uitenhage. Nearly all these old well-known springs are to-day dry.

Half a century ago, according to an old account, there was a wide stream flowing from the Springs that delivered at the town from two to nearly three times the present yield, but in 1912 the output was gauged at 1,235,000 gallons per diem, which had fallen to 800,000 in 1916 despite several attempts to increase the yield by means of boreholes (up to 550 feet in depth) sunk into the quartzites right alongside one of the "eyes."

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* R.L. implies "Reduced height above sea-level in feet."

From these gaugings it would appear that the reduction first became apparent at the close of 1913, a year after the drilling of the successful borehole in the northern angle of Balmoral at R.L. 400, three and a half miles away, while the second period of diminution followed closely the boring at Sandfontein Station, one and a half miles distant at R.L. 488 feet. There can be no doubt that the sinking of these and the many other boreholes on Balmoral, with the consequent escape of relatively great volumes of water at much lower levels, has been responsible for a fall in potential at the Springs and to a reduction in their output, while it is not improbable that with further drilling in the Coega Valley, the town supply may be seriously endangered. For this reason boring to the east and immediately to the south of the Municipal area, is to be deprecated, though such might be done without risk within the town itself, or even at "Pannell's Mill" half-way to the Springs.

As is usual with waters taking their source from the Table Mountain Series, the quality is excellent, analyses showing under eight parts of solids per 100,000 in contrast to that issuing at Sandfontein with nearly forty, and at Balmoral with about fifty parts; the explanation of this difference will appear later.

3. *The Artesian Areas.*

(a) *The Zwartkops Valley.*—Resting upon a most uneven floor of quartzites or slates is the important group of sandstones and conglomerates representing the base of the Cretaceous and passing eastwards beneath the groups of the variegated marls. These basal beds form rugged country in the upper part of the Zwartkops Valley and also extend for a short distance up to Elands River and thence across the Cape road to Naroes, to be seen again to the south-east as a patch on Chatty. There are good reasons for believing that they extend beneath the Valley to the coast, occupying the floor of the great hollow which is bounded by the plateau of Cape rocks on the south between Elands River and Port Elizabeth—and by a partially buried ridge of Table Mountain quartzites on the north. This concealed depression stretches from Sandfontein in a south-easterly direction, Coega Kop and St. Croix Island representing uncovered peaks rising from its floor.

The basal arenaceous beds, which in places exceed 500 feet in thickness, are porous, and so form the "aquifer" or water-bearing formation, the chief intake being situated far up in the Zwartkops Valley, where the strata attain a height of many hundreds of feet above sea-level. The water is being transmitted eastwards beneath the thick covering of Marls, Estuarine and Marine Beds, and is not improbably in part escaping beneath the ocean.

Flowing water has been struck in six boreholes put down between fifteen and seventeen years ago on the farm Kruis River, on the sloping left side of the Elands River, just above its junction with the Zwartkops at heights of between 90 and 120 feet above the valley floor, or between R.L. 230 and R.L. 250 in a row, two miles in length. All

except the southernmost have been drilled directly in the Cretaceous sandstones with occasional layers of shale, lenses of lignite and concretions of marcasite. Full particulars are not obtainable but taken in order from north to south the boreholes are as follows :—

(1) Between 200 and 300 feet deep, about 40,000 gallons per diem ; (2) over 300 feet, yielding originally 250,000 since reduced to 60,000 ; (3) between 250 and 300 feet (in solid sandstones), 70,000 ; (4) collapsed ; (5) 100 yards distant from (4), between 250 and 300 feet, 40,000 (water slightly ferruginous and sulphuretted) ; (6) 444 feet, through 80 feet of red clays into the sandstones, 56,000 since reduced to 18,000. Just within the adjoining farm Mimosa Dale, right in the valley itself, pressure water was also struck. The surprising depths of cretaceous strata in view of the quartzite hills rising to east and west, is proof of the remarkably uneven character of the pre-Cretaceous floor, a matter of extreme importance in the locating of borehole sites in this area.

To the east on Stone Quarry, the marls rest directly on Bokkeveld slates, but on Chatty the conglomeratic sandstones dipping north-eastwards reappear, from which issues a spring, and boring about half a mile to the north ought to yield a flowing supply. The sandstone group cannot be traced to the south-east, but it is not improbable that boreholes just below the Bethelsdorp Village would be successful.

The steady eastward dip of the marls near Uitenhage town and their consequently great thickness, has led to failure in striking the sandstones in the 560 feet borehole on Naroes (put down as a matter of fact for petroleum), in that 624 feet deep in the railway yard at the town—in which the supply was inexhaustible, but too salt—in the borehole 750 feet deep on Mr. W. Smith's property, on the high ground of the town, and in the boring 800 feet deep at Red House, almost entirely in the estuarine beds.

Outstanding is the boring, 3,620 feet deep, a mile to the south-east of Zwartkops Junction on the flats close to the shore at about R.L. 15, put down in search of oil, but which passed through Marine and Estuarine Beds and variegated Marls into the basal sandstones at 3,150 feet. Fresh water springs were passed through at 960, 1,250, and 1,530 feet, and a brine spring at 2480, while hot water was struck at 3,400, which at the cessation of boring flowed at the rate of 250,000 gallons per diem with a static pressure of 100 lb. per square inch and temperature of 130° F. It carries 48 parts of solids per 100,000, is strongly chalybeate and is being used for medicinal purposes at the Zwartkops Baths.*

The mineralization of the waters in this Basin is due principally to the abundance of marcasite or pyrite in the sandstones which militates against the chances of obtaining satisfactory qualities far away from the margins of the basin, for even the waters on Kruis River carry appreciable amounts of ferrous sulphate, though they are quite satisfactory for irrigation.

* For details see G. W. Smith, S.A. Journal Science, Vol. IX, 1913, p. 119.

It is anticipated that flowing water would be struck within the town of Uitenhage at the depth of between 900 and 1,000 feet, which could be used for secondary purposes or for irrigation; at Despatch the depth would probably become prohibitive.

(b) *The Coega Valley and the Farm Balmoral.*—The problem here is more complex because the quartzite floor is so highly irregular, boring operations not infrequently showing that the red Marls rest directly, and perhaps at a shallow depth, upon the bed-rock; for example at the "Limekilns" on the Uitenhage Commonage—the water-bearing sandstones being apparently only developed within pre-cretaceous hollows cut in the quartzite. Such irregularity is indicated by the 558 feet railway borehole at Sandfontein Station R.L. 488, on the flat beneath the quartzite ridge, which only struck that rock at 542 feet and giving a flowing supply got upon the contact of 260,000 gallons per diem, which has since fallen off somewhat. The water is appreciably saline and is not used for locomotive purposes any more than is necessary.

Artesian conditions seemingly obtain in the little valley between Hillwagt and Centlivres Station the sandstones being developed along the base of the range immediately to the west. Between Centlivres and Bluecliff Stations the floor of Bokkeveld slates projects in the form of ridges, the depth of the Marls is often shallow and large supplies are not very probable; the conditions over Grass Ridge to the east are probably no better.

The circumstances on Balmoral (Imanzi) are most peculiar. The pre-cretaceous quartzite ridge projects through the Marls in several conspicuous knobs on that farm and on Sandfontein, the highest of which rises to R.L. 640, is also exposed along the Coega channel on Balmoral and forms the concealed core of the isolated central hill on that estate which rises to R.L. 610. On Sandfontein several springs formerly issued from the clays and limonitic breccias generally along the base of the quartzite bodies, also on Long Wood (the eastern portion of Balmoral) only one of which is still flowing, while the Balmoral hill is smothered by a thick coating of hard brown or black slaggy-looking "ironstone," a deposit formed from the evaporation of the water, which carries in solution some sulphate of iron. There are many little "craters" from which water used to issue, for, as the ferruginous matter accumulated, the orifices became choked and the water consequently tended to burst out at some other spot close by, an action manifestly repeated again and again. The circumstances indeed recall those connected with the "mound springs" of the great Artesian Basin of Australia, which in similar fashion to the above commonly make their appearance where inliers of the floor jut through the covering of younger strata or where the latter is relatively thin.

The hydrostatic pressure can be judged from the fact that the water on Balmoral will rise to well over R.L. 520, whereas the valley which the hill commands drops to just under R.L. 240.

In the northern corner of Balmoral, a hole was sunk in 1912 at R.L. 400, redrilled later to 232 feet which struck the quartzites below the red Marls at about 200 feet. The flow was estimated at 800,000 gallons per diem, but is now discharging at between 200,000 and 300,000, the water being tepid, pyritic and conspicuously sulphuretted. Another hole half a mile to the south-south-west is in clays to 455 feet with practically no water. Many other unsuccessful attempts have been made to tap the water-bearing channels at a lower level; for example the borehole 400 feet deep just behind (south-south-west of) Balmoral Hill with another one closeby to 300 feet, that on Klein Balmoral on the south-eastern slope of the hill at R.L. 335, 500 feet deep, that failed to reach the quartzites, and the two holes nearer the river at R.L. 245 both over 500 feet deep just giving a trickle of water.

In contrast the hill itself is literally studded with boreholes, for as the flow diminished due to natural causes, to choking of the holes or the corrosion of the casing, new passages were drilled; the number to date probably exceeds 35. These show beneath the slaggy ferruginous covering a mass of clays from 100 ft. in thickness upwards resting on the quartzites; the latter rising at highest to about R.L. 450, but the material right on the contact consisted in some cases of a fine gravel and sometimes of conglomerate. Two of the boreholes threw up great volumes of red clay and one of them rounded quartzite pebbles six inches in diameter. Situated so closely together mutual interference has not been uncommon.

That known as "Edwards" at R.L. 520 discharged 400,000 gallons per diem, others gave smaller flows, but altogether the output, which is used for irrigation, is very considerable.

There can be no doubt that the water is being derived primarily from the Uitenhage Beds and inferentially from the basal sandstones preserved in the original hollows in the quartzite floor, and that it is able to make its way to higher levels through joints in the quartzites, along the contact of the latter with the Marls or through more gravelly bands locally developed in such a position. All the waters are tepid, having a temperature of from 89 to 91° F. and arising therefore from a considerable depth, while they carry appreciable quantities of salts, mainly sulphate of iron and alumina (alum) and are distinctly sulphuretted. While these flows are regarded as originating in a different way from the Uitenhage Springs, there can be no doubt as to a certain amount of underground connection between the two systems through the medium of the joints and fissures in the underlying rock, etc., so that the reduction in pressure at Balmoral has resulted in a lowering of the hydrostatic level at the Springs in the same way that it has been responsible for the drying up of the majority of the springs in the neighbourhood, most of which, it is important to note, yielded (and still yield) water of a much better quality than that issuing from the boreholes.

It follows that within this limited area it is imperative that drilling should not be abandoned before striking the quartzites, though success would depend upon the intersection of either a gravelly band along the contact or an adequate system of jointing in the hard foundation neither of which could be predicted from surface observations. A number of the holes sunk away from the Hill have not been carried down to the requisite depth ; and this applies also to the lower part of the Coega Valley. On Welbedachts Fontein a spring issues in the bed of Coega and a borehole in the line therewith 138 feet in depth gave a great yield of slightly sulphuretted water before caving of the walls occurred, but the several other holes on this farm, two of them over 500 feet deep, tap what can be termed "surface supplies."

The only place where boreholes have passed through the "Marls" is on the northern base of the quartzite ridge of the Coega Kop where water has been obtained at quite shallow depths. It is clear that the section of the valley between Balmoral and the railway displays artesian possibilities, more particularly the righthand side between the river and the great fault-line passing a few miles to the south—as shown on the map. While borings would generally have to be deep, say between 500 and 1,000 feet, it is quite likely that in spots the buried quartzite chain would be struck at a much shallower depth. On the left side of the valley the north-easterly dip is carrying the beds down rapidly and the depths would soon become too great.

(c) *The Sundays River Valley.*—The synclinal structure of this area is certainly conducive to artesian conditions, but the great thickness attained by the "cover" will usually involve deep boring while the quality of the supply is also in some doubt.

The circumstances are different from those existing in the Zwartkops Valley in that the seal would be formed by the blue and grey clays and sandy shales of the Marine Beds, while the water-bearing division would be constituted by the underlying series of yellow, soft sandstones interbedded with mudstones and red and green clays belonging to the Wood Beds and Variegated Marls. Owing to the high dip away from the Zuurberg, the Enon Series, which is the water-bearer in the region to the south-west, plunges too deeply to be reached anywhere at points more than a few miles to the south of its outcrop along the foothills of this range, but boring could be done in the narrow belt running from Kirkwood through Enon to Kremlin. The water-bearing character of the Wood Beds is indicated by the spring at the Dunbrody Mission which emerges at the outcrop of one of these soft sandstones where the latter passes beneath clays in the bed of the Witte River. The main intake of the basin would accordingly be situated within the Coerney Valley chiefly where the altitudes of the ground are as a matter of fact by no means great —in certain places not much over R.L. 300 feet—and consequently the pressures to be expected could not be so high as in the Zwartkops Valley. Owing further to the continuous southerly dip of these strata, at angles of between 8 and 15 degrees commonly, and to the

width of the covering of Marine Beds, it is certain that the horizon to be sought would be at a considerable depth in the area between Coltman's Drift and Addo, even making a liberal allowance for the progressive thinning of the sedimentary divisions in a southerly direction.

The water could not be expected to rise above the surface anywhere save over the lower parts of the valley itself—up to the height of perhaps 100 feet above river level—at the most. Several boreholes have been sunk in such situations, the most important being the one 860 feet deep wholly in Marine Beds at the former office of the Sundays River Settlements a little over a mile north of Addo Station, starting at R.L. 125. Basing our estimates solely on the plotted dips, the thickness of the Marine Beds should be several thousands of feet at Addo, but the observations by Dr. Haughton of an horizon indicative of the top of the Wood Beds at the great bend in the canal on Penshurst near Barkly Bridge on a gentle arch in the formation would point to a considerable thinning out of the strata and therefore of the effective covering in a southerly direction.

It is accordingly suggested that one of the most suitable localities for testing the potentialities of the basin would be on the southern side of this gentle anticline on Lot X of Penshurst, since the Wood Beds and Marls reach nearest to the surface here whereas on the northern side they appear to have been deeply dropped by faulting. It would be necessary to go down not less than 500 feet, while between Addo and Coltman's Drift, which ground is situated close to the axis of the trough, the corresponding figure would probably be over 2,000 feet. To the north on the contrary the depth would become less; trials could accordingly be made in the narrow strip running due eastwards from the Dunbrody Mission across Tregaron, Scheepers Vlakte, Disco and Swanepoels Kraal and upon the outcome of such work would depend any drilling on Eblana or the deeper parts of the basin.

Far to the east the S.A. Railways put down in the marls and sandstones seven boreholes at and to the east and north of Sandflats Station, which were either dry or gave brack water. The deepest of them is 1,525 feet, at the railway station, with some fresh water above 800 feet, but below that point salt water was struck, and owing to the immense difficulties experienced in drilling this soft formation, to corrosion of the casing, etc., the hole had unfortunately to be abandoned without having tested the deeper horizons.

4. *Shallow Supplies.*

The region presents difficulties in water-boring generally, because of (1) the usually soft or clayey nature of the cretaceous beds, thus necessitating casing; (2) their relatively impervious character, involving small supplies; and (3) the frequently saline quality of the water; the only redeeming feature is the ease of drilling, as compared with the rocks of the Cape or Karroo Systems.

Good fresh supplies have been struck in the Alexandria limestones of the plateau country east of Barkly Bridge, the rain being readily absorbed by the porous formation, to be held up by the cretaceous clays beneath.

The Uitenhage Marine Beds furnish limited quantities, generally of a brackish character, as for example on the Elephant Reserve—east of Addo, or on the flats just south of Coega Kop.

The Wood Beds and Marls, containing intercalated soft sandstones, frequently furnish good supplies, though not always of high quality, as for instance on Welbedachts Fontein and Coega in the Coega Valley and on Blaauwbaatjes Vley, north-east of Centlivres. Up to the Kariega Valley there are many boreholes as at Stembok Vlakte 240 feet deep and Glen Connor 463 feet deep, though the water there is too saline for engine purposes, and a supply has had to be obtained by drilling in the Witteberg Beds on the rising ground.

Outside the areas occupied by the Cretaceous System, difficulties are naturally met with as in other parts of the Union, but speaking generally, boring is more consistently successful. The jointed character of the Table Mountain Series is responsible for numerous small springs along the base of the mountains, the cleaved condition of the Bokkeveld slates is favourable for supplies, while the tilted position of the Dwyka and Ecca Series is of advantage for obtaining water. The tilted and folded Witteberg Series is certainly troublesome, but there are usually zones of slaty rocks in which drilling can be done instead of in the intensely hard quartzites of that formation.

5. *Coastal Supplies.*

A considerable stretch of coast is waterless, for example the shore of Algoa Bay, with its barrier of white sand dunes rising behind the sandy beach. The conditions are nevertheless not as discouraging as might appear, for there is no doubt that in many places bordering the ocean water could be obtained, although perhaps brackish.

Instructive are the beach sections at Schoenmakers Kop, eight miles to the south-west of Port Elizabeth, where the superficial limestones and consolidated brown sand make a belt a couple of miles in width and rest upon and conceal a terrace cut across the Table Mountain quartzites, the edge of which stands not many feet above sea-level, with surface rising steadily inland. The rainfall over this belt is in great part absorbed by the porous material and travels underground along the sloping surface of quartzite to appear as strong springs along the shore a little above highwater mark; the quality is slightly brackish.

About a mile and a half north of the Coega River mouth, springs of fresh water issue right on the beach from a coarse shelly limestone of recent geological age, though only accessible at spring tides. Here again the infiltration over the higher country at the back through the sand and limestone, reaches the surface of the underlying Uitenhage Marine Beds and travelling along the sub-surface slope made by the latter, emerges at or below sea-level. Not improbably

much water is actually escaping in this fashion without any visible sign thereof. Such underground seepages would naturally follow any depressions in the impervious "floor," and success would consequently be dependent on the striking of one of these concealed water-ways; supplies have actually been obtained by boring on Spring Mount, a part of Groen Kop, and on the adjoining farms at points behind the coastal dunes, the water occurring in a bed of gravel resting on blue shales.

Doubtless these geological conditions extend eastwards along the coast for many miles and it should be possible to obtain potable supplies either right on the shore, where the limestones, if not exposed, lie at a shallow depth, or at some distance behind, where the covering of brown sand is thin.