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“Boring for Water in the Cape Colony.”

By BERNARD WILLIAM RITSO, M. Inst. C.E.

THE land of the Cape Colony rises from the sea towards the interior in a series of terraces formed by ranges of mountains which, having comparatively little descent on the landward side, constitute a succession of gigantic steps from the coast to the Great Karroo, a plateau which may be described as forming a portion of the central table-land of South Africa.

The lowest of these steps is the coast plateau, between the sea and the coast ranges. It averages 600 feet in height, and, from a breadth of 30 miles throughout the extent of the west coast-line, widens to 50 miles near the Cape and along the south coast, gradually narrowing to only a few miles near Port Elizabeth, and varying between 10 miles and 20 miles in width on the east coast. The Little Karroo, which forms the next step, consists of a long narrow plateau, 1,200 feet in height, 200 miles in length and 50 miles in breadth, and lies between the coast ranges and the Zwart and Zuurberg mountains. The third plateau, which is of much larger dimensions, and is bounded on the north by the Great Inland Chain (which traverses the whole of the Colony from east to west), has an elevation of 3,000 feet, and is known as the Central Karroo. The last step leads to the Great Karroo, which is the highest and most extensive of these plateaux, and stretches northwards to beyond the Orange River, eastwards to the Stormberg Mountains, and westwards to near the coast, but varies in altitude between 4,000 feet and 6,000 feet above sea-level. On the eastern slope of the Colony these terraces are naturally ill-defined, the ground sloping irregularly and presenting an undulating surface up to a plateau known as the Eastern Uplands, the height of which varies between 4,000 feet and 6,000 feet above sea-level. Further east along the coast are the Transkeian Territories, rudely terraced from the sea to the foot of the Drakensberg Mountains and varying similarly in height. Griqualand West

and Bechuanaland, which also form a portion of the Colony, are situated on the great central table-land of South Africa, lying to the north of the Orange River and to the east of the Orange River Colony, the altitude of which corresponds to that of the Great Karroo.

Geological Formation.—The geology of the Colony has been, so far, only partially examined on systematic lines, but the results of investigations which have been made from time to time by qualified observers supply material for arriving at more or less definite conclusions regarding those portions which have not yet undergone analysis. A geological survey is, however, in progress, and an instalment of a map dealing with the south-western districts has already been published. It is needless to observe that even this instalment is of immense value, representing, as it does, a portion of a country in which not only diamonds, but gold and coal have been found. The information it affords regarding subterranean water-areas and the probable resources of the remaining large area of land is obviously of the highest importance, looked at from the point of view of the future development of the country; and the publication of the remaining instalments of the work is anticipated with considerable interest. The progress of the undertaking, however, is dependent upon the provision made by Parliament from time to time, as circumstances permit. In the division of the great rock-masses of the sub-continent into systems of strata, the absence of fossils in the earliest formations of the Palaeozoic and Eozoic eras has made the accurate correspondence of these rocks with those of the Silurian and Laurentian periods difficult to determine, and has led to the adoption of a nomenclature derived from the localities of their principal occurrence for all the strata exhibited in South Africa. The Malmesbury beds are the oldest sedimentary deposits in the Colony, and consist of non-fossiliferous slates, phyllites, mica-schists, and quartzites, into which granite intrudes, outcrops of it being found in the Cape Peninsula and neighbouring districts in areas of considerable extent. This group is chiefly exposed on the western and southern parts of the coast plateau, and covers the whole of the Malmesbury division, from which it takes its name. Resting unconformably on this ancient slate series and above the granite is a formation of quite a different petrographical character, composed of coarse sandstone and conglomerate, which constitutes the upper portion of Table Mountain for a height of 2,000 feet, and is therefore designated Table Mountain sandstone. This series also forms the greater part of the coast ranges. Next in succession,

and lying unconformably on it, are a series of strata called the Bokkeveld Beds, which occupy the whole of the Little Karroo. These are fossiliferous shales, sandstones, and graywacké, and can be identified with the rocks of the Devonian age. Forming the mountains between the Little and Central Karroos is a group of blue micaceous quartzites known as Witteberg Beds. Fossils are rare in these, but the alga-like marking of most of the rocks distinguishes the series. Conformable to and above these quartzites lies a formation of conglomerate and interbedded shales called (from its characteristic occurrence near the Dwyka River) the Dwyka Series. The outcrop of this conglomerate has been traced in the form of a huge ellipse, extending into Natal and the Orange River Colony. This outcrop, which appears to be the rim of a great basin, varies in width between a few yards and many miles. The constituents, too, of this conglomerate have peculiarities that have caused much division of opinion as to its origin. Succeeding this remarkable formation, and also lying conformably, are a series of shales, mudstones, and sandstones containing plant remains, which correlate it with the carboniferous epoch. These have been named Ecca Beds, from a mountain pass in which the whole thickness of the series is exposed. The beds cover the Central Karroo, and extend through the middle of the Colony in an easterly direction to Pondoland. Lying unconformably on the Ecca Beds are a series of sandstones and shales containing fossil reptilian remains, which spread over most of the Great Karroo except in the north-east corner, where it is overlaid conformably by another series of sandstones and shales which are classed as Triassic. The former are known as Karroo Beds, and appear to be a transition group between the Palaeozoic and the Mesozoic era, there being no break in time as shown by unconformity in the European system. The latter series of strata are known as Stormberg Beds. They occupy the highest parts of the Colony on the slopes of the Stormberg and Drakensberg Mountains. Between them and the Ecca Beds nearer the coast there is an extension of the Karroo Beds through the Colony proper to the Transkeian territories. The more recent formations are wanting in this Colony, except a development, on the shores of Algoa Bay and in some of the southern divisions, of a formation representing the whole of the Jurassic series, and some beds of small extent of Pleistocene and of Recent age near Cape Town and on the east coast.

Rainfall and Rivers.—Over about three-sevenths of the Colony, which includes the Great and Central Karroos, the north-west part of the coast, and a portion of Bechuanaland, the rainfall is less than

10 inches annually; over another three-sevenths, which takes in the Southern Karroo and the eastern uplands, it is between 10 inches and 25 inches; and only over the remaining one-seventh, consisting of part of the coast, the Cape Peninsula, and the Transkeian territories, does the rainfall exceed 25 inches. That vast tract of country called the Karroo, which comprises half the area of the Colony, and the soil of which is formed from strata of the Ecce and Karroo Beds, would, with sufficient rainfall, be one of the richest districts in the country, instead of being a stony desert covered with a scanty vegetation of scrubby plants needing but little moisture for sustenance. Further inland the country becomes drier, the mountains extracting the moisture brought up from the ocean by the winds before it reaches the interior. Only in the eastern part of the Colony are some of the rivers found to flow constantly; and these run in channels cut through the soil, 20 feet to 30 feet in depth below the surface of the surrounding country, and increasing in depth to hundreds of feet near the coast, so that they are of little use for watering cultivated lands. Owing to the steep angles of their beds, the other rivers of the Colony for a few hours after a rainfall resemble raging torrents, but soon become practically dry channels and remain so until the next storm. A few of them are utilized for purposes of irrigation, but, owing to various causes, operations in this direction have not yet assumed any considerable magnitude.

State-aided Boring.—The general spirit of progress which has in recent years shown itself in a marked degree in this country has undoubtedly led to the question of the development of its resources, particularly with regard to the utilization of underground water. This has received the earnest consideration of the Government and of many members of the farming community, with the object of overcoming the prevailing natural disadvantages; and the attitude of the Government is evidenced by the introduction, about 8 years ago, of a scheme for boring for water by the aid of the State, the main object of which was to assist the farming community by undertaking the boring for water upon their lands, in various parts of the Colony, upon terms which admitted of practically all classes of that community availing themselves of the services of the Government boring-plants and of the skilled operators in its employ. The very great and increasing extent to which land-owners and occupiers have availed themselves of the facilities afforded by the Government for obtaining a good water-supply from underground sources amply testifies to the value and beneficial character of the results achieved in the past.

Subterranean Water.—Owing to the geological conditions and to the fact that the whole of the artesian areas in the world are found in the cretaceous and newer formations, it was not expected that deep-seated supplies of underground water which would rise to the surface would be found. Experiment and the experience gained in the last few years have confirmed these anticipations, but at the same time the important and gratifying facts have been established beyond question that an excellent supply of underground water does exist almost all over the colony at a reasonable depth below the surface, and that this supply can be tapped and utilized by means of boring at a cost within the means of almost any stock farmer or agriculturist; and, although the bore-holes are not large enough to permit of extensive irrigation, agriculturists are only too glad to make use of them for the high cultivation of small areas, such as gardens, orchards, or lucerne fields. The depth below the surface at which these supplies of water are met with varies between 50 feet and 500 feet, and in about one-third of the bore-holes the water flows at the surface of the ground, while in the others it rises to within easy pumping distance. The principal sources of flowing water are the Karroo Beds, which have been subjected to more recent volcanic movement, and dolerite has been intruded into fissures formed in the sedimentary crust with very little disturbance of the strata. These ridges of igneous rock form what are practically underground dams, seldom, however, of any great extent. In the Karroo Beds the strata are porous—the sandstone more so than the shales—to a depth of about 100 feet, and then become compact and impervious. In other parts of the Colony also water flowing at the surface is met with, but the occurrence of the necessary conditions is less frequent. The Ecca Beds of the Central Karroo yield good supplies at depths of 50 feet to 200 feet, and the Bokkeveld Beds of the Little Karroo at still greater depths, but the supplies tapped towards the coast-line in the older rocks are generally further below the surface and not so plentiful. In Bechuanaland also the underground water is scarce and more difficult to reach, while in the Transkeian territories sufficient boring has not yet been done to afford an idea of the volume and depth of the supplies available. Since, however, the Karroo and Ecca series occur there and the rainfall is much greater, there is every reason to suppose that water will be found in larger quantities than in the drier regions of the Karroo. These subterranean waters are usually of excellent quality, though occasionally they are found impregnated with salts, or with sulphuretted hydrogen from the decomposition of iron pyrites. When, however, the

gas has been evaporated by exposure to the atmosphere, the water is often drinkable. Indeed, cattle have sometimes been found to prefer it to pure water.

Selection of Sites.—In the great Karroo and Eastern Uplands, where the beds of sandstone and shale are almost horizontal, and are traversed in all directions by dykes of igneous rock, the selection of sites is not difficult, as the impervious dolerite obstructs the flow of the subterranean water and encloses spaces of various areas, forming underground tanks, which, if the strata have any inclination and the denuded ends of the porous sandstone beds be exposed, act as true artesian areas; a careful examination of the dip and strike of the strata, and of the position of the walls of impervious rock, points to a situation for a bore-hole which will drain the whole of the enclosed area, while, under favourable conditions, water will flow at the surface. In districts where no disturbance has taken place, the ordinary problem in connection with the denudation and erosion of the land surface, the deposition of alluvium and the effect of dip, strike, and structural jointing of the strata on the lines of underground drainage, presents itself; but in areas of volcanic or axial disturbance the question is complicated by faults and by folding of the strata, and requires considerable experience, allied to keen observation, for its successful solution. Practical acquaintance with the formation, obtained by boring a number of holes, is of great assistance, and the local knowledge of the occupier of the land is sometimes of value. The degree of success so far achieved in the selection of sites has been gratifying, a high percentage of the total number of bore-holes put down having yielded a satisfactory supply of water.

Bore-holes.—Approximately 2,500 holes have been bored by the Colonial Government since the first plant was purchased in 1890, and of these about 75 per cent. have been successful. They vary in depth between 50 feet and 500 feet, and between 2½ inches and 6 inches in diameter. Many of these have originally been put down of a smaller diameter and have been reamed out, when the supply of water struck was large enough to warrant it, in order to insert a deep-well pump-barrel of sufficient capacity. Only bore-holes in the softer formations are lined, or where the rock is interstratified with layers of looser material which will not stand alone; most of the bore-holes in the Ecce and Karroo Beds only require short lengths of lining-tube through the soil. Both collar-jointed and flush-jointed tubes are used, the collar-jointed being preferable for driving, as they are stronger both in the tube

and in the joints. The yield of the bore-holes varies, both in relation to the size of the hole and the strength of the supply, between 1,000 gallons and 50,000 gallons, and sometimes as much as 100,000 gallons, in 24 hours. The water generally stands in the bore-hole much higher than where it was struck; but when it does not flow at the surface it is raised by an ordinary deep-well pump; the larger holes have usually a windmill of the American steel aermotor type erected over them. Bore-holes are generally sunk 50 feet below the point where the water is struck, in order to strengthen the supply, and the pump cylinders are placed well below the water surface-level to allow for lowering of this level by pumping. Exhaustive tests of these water-supplies are made, and the effect on the surface-level of a lengthened period of continuous pumping is carefully recorded. Sections of all bore-holes, with core samples of each of the strata passed through, are preserved for future reference.

Methods of Boring.—Over the larger area of operations, where the rock is generally only a few feet below the surface and often at the surface, the diamond rock-drilling system is essential for penetrating such solid formations with economy, rapidity, and precision; but in the loose and friable material, where the diamond-drill is useless, the wet percussion method is adopted. In the majority of cases a combined jumper- and diamond-drill has been found most economical and efficient. As the pumps and boring-rods in both plants are the same, the rotary plant only requires the addition of chisels, lining-tubes, and driving-apparatus to equip it to deal with any formation; but where only layers of clay or any cohesive material not containing rock fragments are met with, the transport of the jumper-plant can be done away with by replacing the diamond-crown with a steel cutting-tool boring a smooth hole in the clay, which will stand alone for a short time until flush-jointed lining-tubes are inserted. Difficulties are met with in the coast divisions, or in boring in drift or alluvial deposits in river valleys, through layers of running sand and nests of hard boulders, the former having to be promptly lined off and the latter gradually broken up and extracted. Accidents occur chiefly through the diamond-crown or steel tool becoming jammed in the bore-hole, necessitating special tools or the enlargement of the bore-hole for their recovery.

Boring Machinery.—The classes of machine employed are: (1) steam-power diamond-drill; (2) hand-power diamond-drill; (3) hand-power jumper-drill; (4) combined hand-power diamond- and jumper-drill.

(1) *The Steam-Power Diamond Drilling-Plant.*—This plant consists of a boring-machine and force-pump, an engine and boiler, and a winch and derrick. The machine is of the chain-feed type. The main frame is supported by four tubular legs braced transversely and longitudinally, splayed in the downward direction, and terminating in points fitting into shoes which slide in grooves on longitudinal timbers resting on the ground, so that the machine can be moved back when withdrawing the boring-rods or testing the supplies of water tapped. The upper ends of the legs carry headstocks, from which the drill-frame is suspended by hollow trunnions, being adjustable about the trunnions as an axis, and capable of being clamped for boring at any angle. The drill-frame is a casting comprising a central collar, bored vertically to receive the boss of the crown-wheel, which rotates the boring-rods, and forming a bridge connecting an upper and lower pair of vertical arms. The trunnions of the drill-frame are carried by the upper pair of arms, which form bearings for the driving-spindles, on the inner ends of which are bevel-pinions which gear with the crown-wheel, the spindle being driven by a pulley and belt from the engine. Projecting from the lower part of the arms are spindles, upon which are mounted the feeding-down lever and chain-wheels. The chain of each wheel is led up and connected to the end of a feeding-down crosshead, having eyes clamped upon the upper ends of a pair of vertical guide-rods, fitted to slide in vertical guide-tubes, clamped by pinching-screws in sockets carried by the boss of the drill-frame, the chains passing on opposite sides and the feeding-down levers projecting in opposite directions on either side of the drill-frame. To each lever is fixed a stud, on which is pivoted a counter-balanced pawl, engaging with the indented flange of the chain-wheel, and the outer end of the lever is adapted to receive a lengthening-tube to be slipped on and designed to carry the weights used in feeding down. The lower ends of the guide-tubes are clamped in the eyes of the ends of a lower crosshead, similar to the feeding-down crosshead, which serves to secure the lower end of the guide-tube, and to steady the boring-rods. Both the upper or feeding-down crosshead and the lower crosshead have bored central eyes adapted to receive removable bushes of various internal diameters to suit the different sizes of core-barrels and boring-rods, these bushes being held in place in the crosshead by pinching-screws. The crown-wheel by which the boring-rods are rotated is adapted to receive half bushes or liners of various sizes, to suit the different diameters of core-barrels and boring-rods. The boss of the crown-wheel is formed

with a raised lug or tooth which abuts against and makes driving connection with the flange of the half bush or bushes, these in turn making driving connection with a feather of segmental section fitting on and clamped to the core-barrel or boring-rod, with a driving cramp embracing the barrel or rod and having a set-screw bearing against the back of the feather. This cramp, as well as the feather, is easily adjustable upon the barrel or rod, and different sizes of cramps and half bushes are provided, since the core-barrels, being 6 feet to 10 feet in length, must, if the rock to be bored be near the surface, pass through and be driven directly by the crown-wheel. The water connection to the upper end of the tubular boring-rods is made by a bent pipe or goose-neck, connected at one end by flexible hose to the force-pump, the other leg passing downwards through a gland into a stuffing-box, a prolongation of which is connected by a union to the upper end of the boring-rods. The boring-rods are $1\frac{1}{8}$ inch in diameter and weigh 4 lbs. to the foot. A $3\frac{1}{2}$ -inch force-pump with an air-chamber is generally used, but if the depth of the hole, or the nature of the formation met with, require it, a more powerful pump is substituted. The engine is of the Tangey pattern and is attached to a 2-HP. vertical boiler, mounted on wheels and fitted with a dissel-boom for draught by horses or oxen. The winch, of the ordinary crab type, can be driven either by a belt from the engine or by hand-power, and the derrick, made of $2\frac{1}{2}$ -inch tubes with specially strengthened joints, has four legs of 28 feet in length, connected by a pin and shackle, from which are suspended the 4-inch iron pulley-blocks and 3-inch rope-tackle for lifting and lowering the boring-rods.

(2) *The Hand-Power Diamond Drilling-Plant.*—This comprises a boring-machine and pump of the same construction as the steam-power plant, but of a lighter make, and is driven by means of crank-handles. The boring-rods are also lighter, being $1\frac{1}{2}$ inch in diameter and weighing $3\frac{1}{8}$ lbs. per lineal foot. The winch is also similar, but a tripod of lighter tubing is substituted.

(3) *The Hand-Power Jumper-Drill.*—This includes monkey-weight lifting-jacks and all appliances for driving and drawing lining-tubes, a sinker-bar, a tripod and lever, steel chisels and a force-pump; but 1-inch gas-pipe is used instead of the boring-rods when the depth renders the latter heavy to lift. The amount of work executed by this class of plant is so small that no effort has been made to design a more perfect drill, such as those used on the continent of Europe.

(4) *The Combined Hand-Power Diamond and Jumper Drilling-Plant.*

—This plant is made up by adding to the hand-power diamond-drill all the parts of the hand-power jumper-plant which it does not already possess. The two hand-power plants can also be operated by animal power by the use of a horse-gear and belt, and all four plants are provided with a deep-well pump to test the quantity and constancy of the supplies of water tapped. The steam-power plant will go down to a depth of 500 feet or 600 feet, but after that depth is attained the weight of the 'boring-rods becomes too great for a gravity feed, which has no appliance for counter-balancing or relieving the weight and for manual labour to draw the long line of rods. Moreover, at greater depths a steam-pump is necessary, which, with the winch, would require more steam than so small a boiler can supply; in fact, a larger and more powerful plant is indispensable.

Diamond-Crowns.—Four qualities of Kimberley stones are employed in boring, as well as Brazilian carbonado. The latter is an amorphous and porous variety of diamond, having the appearance of carbon imperfectly crystallised, and is the hardest substance known. It is almost exclusively found in the Chapada Diamantina, or diamond field of the province of Bahia, where it occurs, in pieces sometimes as large as a walnut, in the ancient sedimentary deposits of the Eozoic era. Owing to the increasing difficulties of mining in that region, it is becoming exceedingly scarce, and, as the demand for boring is rapidly increasing, the price has risen so enormously that it can only be used for hard volcanic or metamorphic rocks which no other kind of diamond will cut. The Author visited these mines while they were still being worked by slaves, and no doubt since the abolition of slavery in Brazil in 1885 labour difficulties have been a prime factor in limiting the output to such small dimensions. There is a class of diamond found at Kimberley, of no value for ornamental purposes, which is nearly as hard, but worn by attrition into spherical globules and lacking the facets necessary for good cutting, and to which has been given, on account of its shape, the name of "shot bort." This class of stone is similar in appearance to the Brazilian variety known as "ballas," and unfortunately, like the Brazilian carbonado, has become more rare at the mines, while the demand has so increased that the Colonial Government have now to pay £7 per carat for the same quality as they bought for 3s. 6d. per carat when boring for water was commenced a few years ago. The other qualities of Kimberley stones employed in the bulk of the work are brilliants and bort of ordinary and inferior grades. The latter are granular and partially crystallised

stones, often much worn by friction and quite unfit for cutting into jewels. In order to unite the various qualities and economise the more expensive stones, combinations of different kinds of diamonds are made, which experience has proved to be successful. Six classes of crowns and reamers are prepared to suit the various strata met with in different parts of the country, viz., "special" A, B and C, composed respectively of equal caratage of Brazilian carbonado and Kimberley shot bort, Brazilian carbonado and Kimberley bort; then "good" A, B and C, consisting respectively of Kimberley brilliants, Kimberley ordinary bort, and Kimberley inferior bort. Other combinations of Kimberley stones are made, especially for reamers, which require more caratage of diamonds than a crown of the same size, as the cutting-surface must cover the whole annular space of rock reamed, but, as the cutting is easier, the quality of diamonds may be inferior. These, however, can be classified under the three qualities mentioned. The steel crowns in which the diamonds are mounted are $2\frac{1}{8}$ inches, $3\frac{1}{8}$ inches, and $4\frac{1}{8}$ inches in outside diameter, and 3 inches, $4\frac{1}{4}$ inches, and $4\frac{1}{2}$ inches in length, have a female thread for attachment to the core-barrel, and are set alternately on the outside and inside of the cutting-face, which is $\frac{3}{8}$ inch, $\frac{7}{16}$ inch, or $\frac{1}{2}$ inch in width, with six, eight, or ten stones, according to the size. The insides of the crowns are tapered so that an annular hardened steel spring, grooved and bevelled, placed in the larger space, more remote from the cutting face, between the tapered inside of the crown and the core of rock cut by the diamonds, will, if the crown and core-barrel be lifted out by the boring-rods, grip the core, break it off, and bring it up. The crowns and reamers are alike in construction, except that the reamer has a slightly wider face than the crown, and has a guide projecting to ensure it following exactly the bore-hole being reamed. No core-spring is necessary for a reamer, as that tool makes no core, the parings being brought to the surface by the water-flush. Reamers are of $3\frac{1}{2}$ inches, $4\frac{1}{2}$ inches, and 6 inches diameter, with a width of face of $\frac{1}{2}$ inch, $\frac{11}{16}$ inch, and $\frac{3}{4}$ inch respectively, corresponding to half the annular space of the enlargement. The steel of the crowns and reamers is found to wear most in sandstone, and diamonds boring in that rock require frequent resetting, for, should a stone become loose and drop from its mounting, the crown will rotate upon it and quickly break the rest of the diamonds. The actual wear of the diamonds is considerable, and the harder the rock the more wear they sustain. The loss by breakage, however, is generally due to unequal density of rock, such as is met

with in the clay-slate of the Malmesbury beds, which contains quartz infiltrated in fine veins, and has been found very damaging even to the best quality of diamonds. No substitute for diamonds in cutting hard rock has yet been discovered, and although many attempts have been made, no substance has been invented which approaches in hardness even the inferior classes of bort. Crowns and reamers are set at the head office, and are despatched by registered post to the boring operations in progress all over the Colony, but every boring-plant (of which there are forty now at work) is provided with a spare crown, so that one is in use while the other is being reset, and arrangements are being made to keep a stock of all sizes and classes of both crowns and reamers at the head office, so that in cases of emergency a damaged tool may be replaced without delay.

Deep Boring.—As has been already mentioned, the geological formation of the Colony does not indicate the existence of any deep-seated source of water-supply, such as has been found in Australia and other countries, nearly all these true artesian areas being in strata of the Cretaceous period, which does not exist in this country. With the object, however, of more fully testing the potentialities of the country in that direction, a large steam-power drill was purchased in England, and a deep bore-hole was commenced upon a site selected by the Geological Commission on the Central Karroo. The type of deep-boring plant employed, however, was not a success, and the cost of working became very heavy as the bore-hole descended; nevertheless a depth of 1,500 feet was bored, but no water was tapped below the levels at which it is usually found in that district. Operations were eventually discontinued, owing to the exhaustion of the funds voted for that specific purpose, and the plant has since been used for boring holes of large diameter to the usual depths, for providing water for locomotives along the route of the main lines of railway.

General Results.—Although the actual volumes of water tapped cannot bear comparison with the larger supplies found in some other countries, the cost involved is correspondingly small, and the system adopted by the Colonial Government of hiring out a boring-plant, with a skilled foreman to work it, on moderate terms, has met so well the needs of the stock and agricultural industries that an enormous number of applications for the use of the boring-machinery has been received from farmers and others. About 8 years ago operations were commenced with two or three hand-power drills, and, although there are now forty plants in the field, it is found that, even with that number, it is not possible to

deal with the growing volume of applications as rapidly as might be desired. In order to enable the demand for the services of the Government drills to be more readily disposed of than the present somewhat limited plant permits of, it is in contemplation to purchase a number of additional drills, and to that end the merits of various new types of boring-machinery are now receiving the consideration of the Government. The question of the possibility of procuring larger supplies of water for the purposes of irrigation, by boring holes of greater diameter, is an interesting one. The chief factor would, however, appear to be that of expense, which would naturally follow the employment of the more powerful machinery which it would become necessary to provide, and of the larger and more costly crowns with which such machinery would have to be equipped. The cost of the stones for these larger crowns, apart from the enormously increased caratage required, would indeed be more than proportionately higher than that of the diamonds for the smaller crowns, for the reason that the price per carat for large stones is considerably in excess of that for those of smaller size and of similar quality. Thus with more expensive machinery and diamonds the cost of bore-holes increases rapidly with the size, and beyond a diameter of 6 inches would become, under the present conditions of high-priced diamonds and expensive transport, too costly to fall within the means of the majority of farmers, and thus the aim of the Government to assist that community would be frustrated. There is, however, the alternative as to whether, if the formation can be worked at a reasonable cost, it would not be better, when a proved supply of water is found at a moderate depth, to excavate a well round the bore-hole and to erect a bucket-pump that would raise a large quantity of water economically if operated by horse-power. Over some cultivated areas bore-holes have been put down at convenient distances apart, with windmill-pumps, an arrangement which effects economy in the distribution of water. A convenient size for such holes is $3\frac{1}{2}$ inches in diameter, reamed out well below the water-level to allow of the insertion of a 4-inch pump-cylinder, which would yield a sufficient supply to irrigate 3 acres or 4 acres of land from any depth less than 200 feet. The result of the experience so far gained has also suggested the advantages of boring as a mode of obtaining supplies of pure water for domestic purposes, and, in illustration of what has been accomplished in that direction, it may be mentioned that the Colonial Government has supplied gaols, asylums, court-houses, and other public buildings, with considerable success and with notable economy. Latterly some steps

have also been taken with the object of utilizing and adapting this means of supply for small towns and villages, although operations in that respect have not been carried to any great extent.

Boring for the Imperial Military Authorities.—Having, prior to the outbreak of hostilities, executed some boring for the Imperial Government at one of the base-camps near Cape Town, the Colonial Government was approached, soon after the war broke out, with a request that it would undertake the sinking of bore-holes to provide water for General Gatacre's division, which was at the time in the Stormberg; and in response the Colonial Government immediately caused three boring-plants, equipped with two foremen each, for continuous working, and a field superintending inspector, to be placed at the disposal of the military authorities for service with that division. Excellent supplies of water were obtained for the column while in the Stormberg district, while subsequently during its march into the Orange River Colony two out of the three boring-plants, fully equipped, accompanied the division, with the result that plentiful supplies of water were obtained at various points *en route*, for the purposes of camps, military posts and hospitals. Similar assistance, and with like excellent results, was rendered to the troops while encamped at Rensburg and at various points in the surrounding country, a steam-power plant being successful in tapping a large supply of water for General French's cavalry division while stationed in the neighbourhood. When, subsequent to Lord Methuen's reverse at Magersfontein, the Modder River became contaminated, and enteric fever made its appearance, resulting in considerable mortality among the troops, two more fully-equipped steam-plants were sent to that officer's camps, and, working without intermission, obtained an excellent supply of pure water within 30 hours of their arrival. Bore-holes to the number of ten were also sunk, in the course of a few days, at Enslin, Graspan and Belmont, not only with the object of providing those camps with water, but in order to meet the anticipated requirements of the main army under Lord Roberts on its forward movement. Subsequently, immeasurable assistance was rendered to the army under the Field Marshal during the operations and advances which resulted in the relief of Kimberley and the capture of Bloemfontein. Particularly was this the case with regard to the immense convoys following the army, without the provision of water for the transport animals employed, by which the execution of the gigantic military operations involved (an essential feature of which was rapidity

of movement) would undoubtedly have been most seriously hampered. Additional boring-plants were subsequently despatched to Bloemfontein to meet the enormous demands of the army while resting there prior to the resumption of the advance northwards, and, in illustration of the immense value of the work accomplished, it may be mentioned that during the possession, by the enemy, of the waterworks at Sanna's Post, supplying the city of Bloemfontein, water was obtained by means of bore-holes and pumped into the street-mains there. Boring-plants subsequently accompanied the army during its march to Pretoria and during various operations to the north, a boring-plant even accompanying the column which cleared the country to the Portuguese frontier. General Tucker's Division depended for water entirely on the bore-holes at Karee Siding, the only other source of supply being unfit for use, owing to surface pollutions. Bore-holes were also put down between Kimberley and Mafeking for the use of the force which achieved the relief of the latter place. Drilling operations are still in progress at Komatie Poort, Kaapmuiden, Pienaar's River, Kroonstad, and other important points at the front and on the lines of communication, and, since the Boer commandoes have again invaded the Colony, drilling-plants have been employed in boring for water for military purposes within the defences of Middelburg, Steynsburg, Richmond, and other fortified stations. Up to the present date, it may be mentioned, some seventy bore-holes have been successfully executed for the military authorities at various camps, forts, military posts, and hospitals in Cape Colony, the Orange River Colony, and the Transvaal. The value of the supplies of pure water thus provided for the use of the army in the field, and of the troops guarding the lines of communication, cannot be over-estimated in a country like South Africa, with its sub-tropical climate and comparatively waterless character. The benefits derivable from the availability of plentiful supplies of pure water are experienced not so much, perhaps, during the actual march of an army (the expeditious movements of which naturally militate against the employment of boring-gear) as when troops are grouped in camps of a more or less stationary character and at base-hospitals and the like. Its advantages in connection with the establishment and maintenance of posts on lines of communication are also of great importance, since the determination of the position of such posts becomes a comparatively easy matter when the essential question of water-supply is effectively solved by the employment of boring-plants. The source of supply has a most

important influence on the health of the troops, especially in a semi-tropical climate, much of the sickness which the army has had to contend with being due to the consumption of contaminated water from streams and surface sources; and the immense advantage of being able to procure naturally-filtered water is so apparent that it will be readily admitted that the assistance rendered in this direction by the Colonial Government has undoubtedly saved many valuable lives to the Empire and contributed not a little to the success of the campaign. This is the first time in history that boring for water has been a feature in military operations, and the inestimable value of the results which have followed its adoption in the present campaign will undoubtedly lead to the water-boring machine, in qualified hands, becoming a factor of prime importance in any future wars in which the theatre of operations presents difficulties in that direction such as faced the British army in South Africa.

The Paper is accompanied by two photographs of the boring-plant referred to.