The position and general configuration of "The Rock" are well known. Gibraltar is described in the local directory as a "bold headland promontory insularly jutting out into the sea." It runs in a north-south direction and is composed mainly of limestone. The Rock rises almost abruptly from the sea to a height of about 1,400 feet, it is about three miles in length and has a maximum width of about three-quarters of a mile. The area of the actual city is some 104 acres in which live the majority of the total civil population, estimated at the present time at approximately 16,000 persons. At its northern end (usually referred to locally as North Front) Gibraltar is connected to the Spanish mainland by a flat sandy isthmus some 950 to 1,800 yards wide and 1,500 yards in length. At no place is this plain more than ten feet above sea-level. Of this isthmus, some 800 yards lie within British territory, while the remainder forms a neutral zone which is mutually respected as far as buildings or permanent occupations are concerned.
Gibraltar is peculiar in having a dual system of water supply. For such purposes as street washing, fire fighting, general sanitary purposes and (except in a few instances) personal ablutions so-called “sanitary water" is supplied by the municipal authorities. For these purposes water is drawn from wells sunk in the sandy soil at the North Front, whence it is pumped to reservoirs at various levels and distributed by a system of pipes to all parts of the Rock. This water has a high salinity, varying somewhat with the seasons of the year and the amount of water pumped. The average chlorine figure is 700 to 800 parts per 100,000. It is, of course, undrinkable and, even for sanitary purposes, possesses several disadvantages which will be discussed later. The water available for drinking purposes, washing clothes and other purposes for which sanitary water is quite unsuitable is derived almost entirely from the rainfall. The rain is collected and stored in reservoirs excavated in the heart of the rock, which have been built and are maintained by the City Council for the supply of the civil population. This supply is supplemented by water collected in underground tanks of private houses, the roofs of the houses serving as catchment areas. The Naval and Military authorities have each their own separate systems of supply which it is not intended to discuss in this article.

Prior to the British occupation, most of the drinking water was derived from wells sunk in the red sands which skirt the westernmost side of the Rock and the northern strip of plain; but recourse was always had to tanks for the collection of rain water from roofs or other catchment areas in case of siege or emergency. A Moorish aqueduct, the line of which can still be traced, conducted water from the Alameda Gardens area to a fountain near the site of the present City Council offices in the centre of the city. Although the population appeared to suffer no discomfort or inconvenience from drinking the aqueduct and well waters, they were subsequently found to be seriously contaminated due, doubtless, to the gradual concentration of inhabitants and to the disposal of the waste water and sewage by soakage in pits.

The danger of this state of affairs was quickly realized by the then sanitary authorities and, as soon as alternative supplies became available, orders were given to fill up the wells and stop the use of water from that source. This threw heavy responsibility on the municipal authorities and, in the absence of any obvious sub-surface supply, more and more use was made of rain water drawn from prepared catchments on the hill sides and collected in tanks during the wet season.

A report by the Barrack and Hospital Improvement Commission in 1870 states that there were 520 rain water tanks and 252 private wells in use, many of which ceased to yield in the dry season. The latter were estimated to give about 2,280,000 gallons a year. In 1877, a detailed study of the geology of Gibraltar was made by Messrs. Ramsey and Geikie, who submitted a report to the Colonial Office on the water supply problem. In this report they dismissed the idea that any useful supply of water could be
G. D. Jameson

obtained from the limestone, a theory with which subsequent observers have not invariably agreed. Little more appears to have been done until 1890, when Major Tulloch, R.E., carried out further investigations and submitted a report on "The Water and Sewerage of Gibraltar."

In his report Major Tulloch draws a vivid, if somewhat gloomy, picture of the water situation as it then existed. "The public scheme for the supply of the civil population with this first necessity of life is of the very humblest description. There are two small reservoirs situated near the Moorish Castle, one with a capacity of 481,285 gallons, and the other of 1,257,444 gallons. The latter is fed with the rain falling on a few acres of ground just above, and the water is conveyed in iron mains to different parts of the town and sold from taps at the rate of one centimo per gallon or 8s. 4d. per 1,000 gallons. Nothing can better bring home to the mind the scarcity of this first essential of health than the willingness of the inhabitants to pay this extraordinary price for it. The Sanitary Commissioners in 1889 realized an income of about £630 by the sales. The quantity sold every year depends on the rainfall, but if we take it at about 1,200,000 gallons, such a supply as this distributed over the whole year for the civil population—say 20,000 people, does not even amount to a quart a day. Besides the public source, the only other which the Sanitary Commissioners utilize for the purpose of the civil population is that obtained from some condensers erected in the Southport Ditch, which were once capable of producing about 10,000 gallons in twenty-four hours or say half a gallon per head of the civil population. The actual quantity condensed in 1889 was 903,500 gallons or about a pint per head per day. There are two other sources, but not used by the inhabitants. One is an aqueduct running along the bottom of the Alameda Gardens which catches the water percolating through the red sands in this locality. The yield is but 500,000 gallons per annum, too insignificant for public wants and it cannot, moreover, be relied on. For these reasons the supply has been abandoned. The last source is a well on the neutral ground at the extremity of the British Lines, and about 200 yards from the sea. The Sanitary Commissioners, however, reserve this supply for the shipping, so that it is not available for the inhabitants. It will thus be seen that, after every possible source has been drawn on, the total public supply of good water available for the civil population amounts to the large quantity of not two quarts per head per diem. Fortunately, private enterprise has stepped in and to some extent supplied the deficiency, for the majority of the residents have tanks or reservoirs under their premises in which they catch the rain that falls on the roofs of their houses. No precautions are taken, however, to filter the water before it enters the tanks, nor are the inhabitants alive to the necessity for keeping the roofs of their houses clean, for these places are used for all sorts of improper purposes, such as, for instance, the washing and hanging of clothes, the keeping of poultry, etc. It requires no stretch of imagination to conceive what abominations must often, under
such circumstances, be washed into these tanks, which are not only liable to be polluted with sewage leaking through into them from the defective house drains, but in which the deleterious matters from the roofs steadily accumulate, as these tanks are often not cleaned out for years."

Major Tulloch's first recommendation for improving the public water supply was that a tunnel should be driven into the mountain to the east from the Trafalgar Cemetery in accordance with the details furnished in his report. This procedure would appear to have been proposed to a certain extent on the "hit or miss" principle, as a further recommendation advises that, should water not be found, the tunnel should be continued to the eastern coast and used as a sewer. There now exists, in approximately

![Fig. 1.—Gibraltar, eastern side showing catchment areas.](image)

the site recommended by Major Tulloch, a tunnel connected with an extensive system of fissures and caves, in one of which there is a plentiful supply of water. The water level rises and falls with the tide and, when recently tested, the water contained about 60 parts of chlorine per 100,000. There are also three other tunnels which pierce the rock from side to side; one at 30 feet and two at 370 feet above sea-level. In the former there is a constant stream of water but the quantity is too small to have any economic importance. Failing the discovery of water by boring into the rock, Major Tulloch recommended that the supply of subsoil water available at North Front be exploited.

In 1895-96, the municipal authorities took the initiative of improving the water supplies by the preparation on the western face of the Rock of some 3½ acres of catchment and the provision of reservoirs to contain the run-off. This was increased in 1897-99 by another 11½ acres of prepared
surface and the construction of 5,000,000 gallons of storage in the heart of the Rock.

In 1903, ten acres more of catchment were constructed on the steep sandy slopes of the eastern face of the Rock, eventually increased to thirty-three acres when another tank of 2,000,000 gallons capacity was built inside the Rock. In 1934, another reservoir of 1,000,000 gallons capacity was completed, the total storage capacity at the present time being, therefore, approximately 9,700,000 gallons. The construction of an eighth storage reservoir is at present under consideration.

The present system for the public drinking water supply for the civil population consists, therefore, of the collection of rain water on specially prepared catchment areas and its storage in large reservoirs in the heart of the Rock. The catchment areas on the western side consist of the natural surface of the rock, cleared of trees and undergrowth, and roughly cemented over to form a comparatively smooth surface. Those on the eastern face consist of corrugated iron sheets supported on a wooden framework. The eastern catchment areas are liable to damage by frequent falls of stone from the overhanging rock and special arrangements are necessary to ensure that all such damage is repaired as quickly as possible. The supporting wooden structures are also subject to the ravages of the white ant, the necessary renewals being an expensive and by no means easy matter. Rain falling on the catchment areas collects in an open channel at the foot of the areas, passes through a “grit chamber” in which grosser particles of contamination are removed and then flows directly into the storage reservoirs. The storage reservoirs are constructed in the heart of the Rock, the limestone

Fig. 2.—Catchment areas (near view).
being removed by blasting and the use of pneumatic drills. The loose stone is then removed through one of the tunnels bored through the Rock and is subsequently used for road making, etc. When the excavations are completed the reservoir is lined with a smooth, impervious material. A second tunnel has been bored through the Rock from west to east in connection with the storage reservoirs, carrying the continuation of the channel which collects the water from the catchment areas and also providing a roadway for the staff of the waterworks. By a simple arrangement the flow of water can be directed into any particular reservoir as desired. The distribution of water from the storage reservoirs is controlled by valves situated in a building at the western entrance of the waterworks. In this

house are also a number of mercury manometers which show, at a glance, the amount of water remaining in each reservoir on any particular day. The flow from the storage reservoirs, which are situated about 370 feet above sea-level, is by gravity through a series of distributing pipes. In a few instances, a piped supply is laid direct to houses. In other cases, water is distributed from public "fountains" situated in various parts of the town. The pipe system is also so arranged that private tanks can easily be refilled as required from the public supply.

The supply of water is measured by meter and is sold at the following prices:—

<table>
<thead>
<tr>
<th>Type of Supply</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>To factories, hotels and private houses</td>
<td>1s. 3d. per 100 gallons</td>
</tr>
<tr>
<td>From fountains (delivered)</td>
<td>3s. 0d.</td>
</tr>
<tr>
<td>From fountains (undelivered)</td>
<td>10d.</td>
</tr>
</tbody>
</table>

Fig. 3.—Reservoir under construction.
In addition to the public supply, a large number of houses in Gibraltar have their own underground tank for the storage of rain water collected from the roofs during the rainy season. In 1929, the number of private tanks was between 600 and 700, with an estimated total storage capacity of about 8,000,000 gallons. House owners can be required by law to provide collecting areas and tanks for the storage of rain water in connexion with any dwelling-house, and the provision of a suitable underground tank is generally insisted upon by the municipal authorities when proposals for new buildings are submitted for approval.

The municipal catchment areas are situated in comparatively inaccessible places, far from any inhabited area and, except for chance contamination by birds, apes, or the few other small animals living on the Rock, the likelihood of the main drinking water supply being polluted at its source is remote; a fact which makes the outbreak of any water-borne epidemic highly improbable. No system of filtration or sterilization by chemical methods is employed, nor does it appear to be necessary. The first rains falling on the catchment areas are run to waste by diverting the flow into a natural fissure in the rock (communicating probably eventually with the sea) until the water comes down clear. Coarse screening in the grit chambers and storage in the reservoirs are sufficient to produce a reliable drinking water. The water from the storage tanks is tested monthly for bacteriological purity, and the standard of *Bacillus coli* absent in twenty-five cubic centimetres is almost invariably maintained throughout the year. The entrances to the reservoirs are guarded by mosquito-proof doors which,
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up to the present, have proved effective in preventing the breeding of mosquitoes in the large quantities of water stored in the reservoirs throughout the summer. Chemical analysis of the water shows little of interest except that, unlike most rain water, that collected from the Gibraltar catchments has an average chlorine figure of 2 to 3 parts per 100,000. This is most probably accounted for by the sea-spray and sand blown onto the catchments during violent storms.

Gibraltar has an annual average rainfall of some thirty-three inches. In theory, about 99 per cent of the rain falling on prepared catchments can be collected and preserved. In actual practice, however, only some 50 per cent to 60 per cent of the annual rainfall eventually becomes available for the public drinking supply. The remainder is lost in washing the catchment areas, run to waste when the tanks are full and accounted for by leaks, burst mains, etc. The quantity unavoidably run to waste when the tanks are full is not entirely wasted, as it is run into the sanitary water storage tanks with the object of diluting the brackish water and diminishing its salinity.

With an average annual rainfall of thirty-three inches, giving approximately 22,000,000 gallons available for collection on the catchment areas, it would appear, on the face of it, that the supply of a reasonable amount of drinking water per head per day would be assured. Especially when it is remembered that numerous privately owned tanks are available to supplement the public supply. During 1934, the amount of water available for the resident civil population from the public supply has averaged approximately three gallons a head a day. There are, however, certain factors to be considered in this connexion. The rainfall in Gibraltar is not distributed evenly throughout the year. Practically all the rain falls during the months October to April. The months of May, June, July, August and often September are "dry" months during which little, if any, rain usually falls. Also, should an exceptionally large proportion of the rain fall in mid-winter a large quantity of valuable water may be unavoidably lost owing to lack of storage capacity. Although the year 1933 was a year of more than average rainfall, the water situation in the late autumn gave rise to some anxiety, owing to the fact that a large percentage of the total fall occurred in January (14·96 inches), that the rains in April were comparatively scanty, and that between the end of April and the end of October only the negligible quantity of 0·11 inches of rain fell. There is, moreover, an increasing demand for fresh water and the sales from the City Council reservoirs are rising steadily year by year. Although additional storage accommodation is continually being added, it is no easy matter to keep pace with the ever-increasing demands of the consumer.

There is also an increasing demand for more water for sanitary purposes. To quote from a report recently issued by Dr. Beeby Thompson:

"Increasing demands for water have led to the addition of more and
more salty waters until it has reached a salinity of about half that of sea
water. This brackish water causes corrosion of pipes, meters and fittings,
and is a sore point with the inhabitants who are compelled to use this
water for general household and other purposes, such as car washing, with
its attendant disadvantages. About 20,000,000 gallons a month of brackish
water are used averaging 700 to 800 parts of chlorine per 100,000 and the
maintenance of this quality is not without difficulty owing to overdrawning
from the wells with consequent admission of sand and damage to pumps.1
Although hot salt-water baths may be pleasantly invigorating, if taken in
moderation, they are apt to pall after some years, especially, as the soap
necessary to produce a lather in Gibraltar bath water is very, highly
alkaline and its continued use is a source of actual discomfort to persons
with tender skins. Also, the corrosive effects on the metal and paintwork
of motor cars of the sanitary water used in liberal quantities for street
washing has to be experienced to be appreciated. It would obviously,
therefore, be a great advantage if water of a single quality could be made
available for all purposes which, if not bacteriologically pure, could be used
without discomfort for all domestic purposes except drinking and which
could, if necessary, be rendered safe and innocuous by filtration or
chlorination."

In the summer of 1933, a visit was paid to Gibraltar by Dr. Beeby
Thompson with a view to advising on potential sources of a pure and
adequate water supply. In his report he discusses the available sources of
supply and draws certain conclusions. As he points out, his investigations
tend to show that there are two probable sources of supply available, the
sub-soil water in the upper sands at the North Front and collections of water
which, in all probability, exist in the Rock itself. To quote from Dr.
Thompson's report, the total area of land surface exposed at Gibraltar has
been calculated at 1,160 acres. If all the rain which fell on the Peninsula
could be collected, the yield in an average year would be about 3,828,000
tons—say 850,000,000 gallons. Probably not less than 25 per cent of the
Peninsula is occupied by buildings, roads, paved or drained areas, or
prepared catchments which prevent access of water to the ground, but
against this has to be placed the amount of water collected in tanks; All
authorities who have studied local meteorological conditions and interested
observers agree that the Rock absorbs practically all rainfall and that
surface run-off is negligible, except in the case of the most violent storms.
As most of the land surface is fissured limestone with little soil one might
fairly safely assume that something in the neighbourhood of half the rainfall
or, say, 1,435,000 tons of water gain access to the sub-soil of the Peninsula
in an average year. Obviously, however, only a portion of that water which
reaches the level of saturation would be recoverable under the most
favourable conditions.

The question arises, where does the water go which enters the Rock ?
At North Front alone, the area of exposed sands between the Rock escarp-
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ment and the neutral zone frontier is about 320 acres, but obviously a fair width of the plain beyond the boundary fence could be regarded as a potential source of supply for our wells. A thirty-three-inch rainfall would represent some 1,000,000 tons of water in this area alone, of which 80 per cent or 800,000 tons may sink to the saturation zone and escape loss. The top sands in the North Front district are separated from the deep sands by a band of clay. The top sands were originally tapped to provide the so-called sanitary water, but to meet the increasing demands for this commodity the wells were deepened by holes bored at the base of the shafts to admit water from the deep-seated, free yielding sands found at a depth of about thirty feet. It has been found that the average chlorine content of the water from the top sands down to twenty feet, as proved by the tube wells, is about 15 parts per 100,000 in that part of the plain near the British lines, while that of the deep waters does not fall lower than about 550—650 parts per 100,000. Dr. Thompson infers that the local rainfall on the plain has little influence on the supply and quality of the water from the present wells, although it eases the pumping duty by raising the local and regional water table. The lower water below the clay is isolated from the top water on the sandy North Front plain and the distance from the Spanish mainland virtually precludes travel of water from that source in the upper sands. If this theory is accepted, one is compelled to consider replenishment from a deeper source, and the two possible alternative sources are the tertiary strata probably underlying in places the basement clay bed or a northern subterranean connexion with the water which sinks into the Rock. Of the two, the latter is, in Dr. Thompson's opinion, by far the most probable, as the tertiary rocks of the Spanish mainland are very disturbed, distorted and not very permeable. On the other hand, the huge quantity of water which gains access to the Rock must find a free outlet somewhere or the water table would rise in the caverns near the sea level. In the absence of any recorded springs of any importance, the view is accepted that it escapes below sea-level and, as the major fissure system flows in a north-south direction, water would naturally tend to flow in that direction and emerge at the north and south ends. Numerous galleries and tunnels have been driven into the Rock from time to time and in these a wonderful view of the rock conditions can be obtained. The drainage of the Rock is evidently a complicated process, for water does not, as might be expected, cascade down the major fissures exposed in the galleries but, apparently, follows more or less obscure channels which, at the moment, provide the easiest path for its descent. Large caves and caverns occur in the body of the limestone at elevations ranging from sea-level to about 1,000 feet. Some of these are located too far distant in the heart of the mountain for one to attribute their formation to sea-water action at various stages of elevation of the Rock, nor is it possible for them to be attributed to human agencies. As examples may be quoted St. Michael's cave in the upper Rock and Ragged Staff cave near
sea-level, which are both very extensive and are associated with a complicated system of fissures, the extent of which has never been determined. None of the caves much above sea level contain water, nor has any large pocket of trapped water been discovered as far as can be ascertained. All water which enters the Rock appears to sink rapidly to near sea-level, which represents the zone of saturation. In the case of the Ragged Staff caves, a gallery extends nearly to the caves at a level of about thirty feet above O.D., so that the water contained therein would only have to be raised some thirty-five to forty-five feet to give a free discharge to the Mediterranean and enable the capacity of the cave system to be measured. The water obtained from Ragged Staff caverns in 1933 showed 60 parts of chlorine per 100,000 and there was evidence that this had been so for some considerable time.

There are, therefore, possible grounds for believing that considerable volumes of rain water are conserved in cavern and fissure systems of economic size near sea-level, but until further experiments are completed, it is unsafe to venture any predictions. The amount of water which gains access to the Rock after due allowance for occupied areas, artificially prepared catchments and areas of questionable value, is thought to be about 315,000,000 gallons in a year of average rainfall.

As regards the North Front isthmus as a potential source of fresh water, the conclusion is arrived at that by suitable methods it might be possible in years of average rainfall to draw about 110,000,000 gallons of water with a salinity which is not objectionable from the alluvial sands at North Front. It is considered unlikely that the North Front wells alone would furnish enough water of acceptable salinity to satisfy the present and increasing demands for domestic and city purposes. Supplemented by other sources of supply, it might certainly be possible to replace the present sanitary water by a quality which would cause little discontent and diminish the corrosion troubles which are now a constant source of expense and annoyance.

On his own initiative, the City and Water Engineer to the City Council has for some time past been exploring the water-bearing possibilities of the North Front district. A trial one-inch tube was driven to a depth of about fourteen feet in a selected spot and water containing only five parts of chlorine per 100,000 was found. The one-inch tube was then replaced by a three-inch tube and the yield increased from 600 to 1,000 gallons per hour. Four two-inch tube wells were driven in within a radius of twenty-five feet of the original tube and a series of pumping tests were carried out. The wells yielded approximately 2,000 gallons per hour, but the chlorine figure gradually rose to 14.4 parts per 100,000. Another site was selected (called No. 8 Well) and a two-inch bore tube driven in to a depth of twelve feet. At this depth further progress was found impossible. A six-feet-diameter hole was then excavated and the obstruction was found to be a solid bed of indurated sand. This was broken through and water
rose to such an extent that the pumps, working to full capacity (10,000 gallons an hour), were unable to lower its level or keep the water down for further sinking purposes. The water was analysed and found to contain 10.6 parts of chlorine per 100,000; a figure which appears to be constant even after prolonged pumping. The supply thus found was exploited by the erection of a pumping station to deliver water through suction, rising and delivery mains to a 40,000 gallon storage tank from which, after previous treatment with chloramine, it is available for delivery to refrigerating plants, shipping, &c. Although this supply is, more or less, as yet in the experimental stage, there are reasons for believing that a minimum yield of 6,000 gallons per hour of potable water is available from this source even at the end of the dryest summer and the yield is believed to be permanent. Contrary to the opinion of some other investigators, the City Engineer believes that there is continuity of the strata between Spain and Gibraltar and the water tapped by No. 8 well is part of a large stream of fresh water from the mountains of Spain. Whether this is correct or not, there appears to be little possibility of surface contamination as the water is separated from the surface sands by a bed of impermeable rock some two feet thick and the water levels of this well are independent of those in the nearby wells (some of them brackish) or in the surface sands.

Schemes for increasing this supply and extending it to feed other parts of the town and certain factories in the North Front district have been prepared, and it is perhaps not too much to hope that at some future date a piped supply of fresh water may be available for general use, a boon which will be appreciated by anyone who has done a tour of service on the Rock.

Not only would such a supply add greatly to the amenities of life in Gibraltar, but it would go a long way to solving the problems of mosquito control. The prevalent mosquito in Gibraltar, and the only one of medical interest, is the Aedes (stegomyia) aegypti which, as is well known, is a "domestic" mosquito and breeds by preference in the many tanks, tubs and barrels in which the thrifty householder stores what is, at present, a precious and rather expensive commodity in Gibraltar.

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