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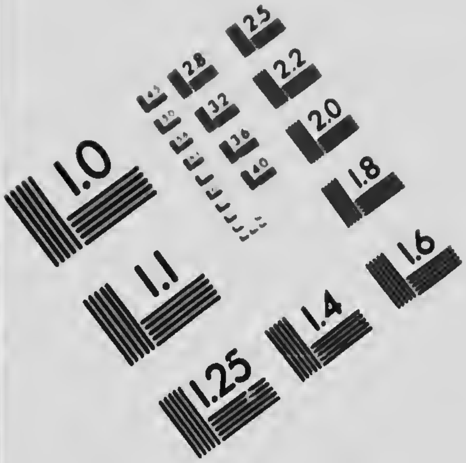

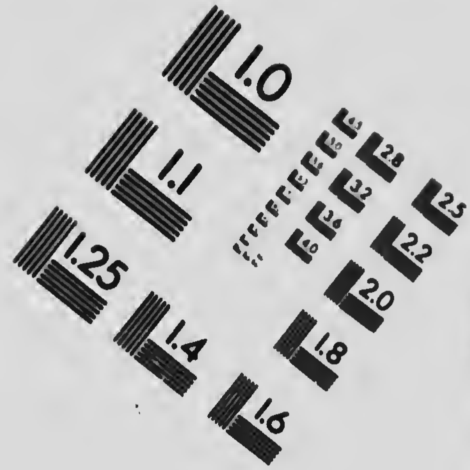

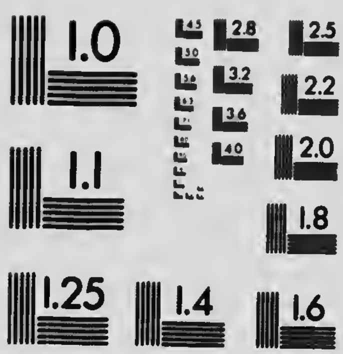

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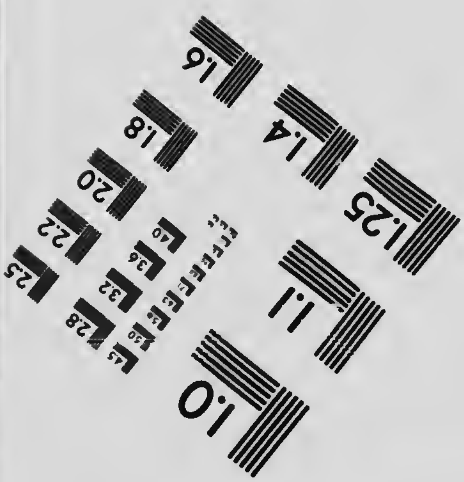

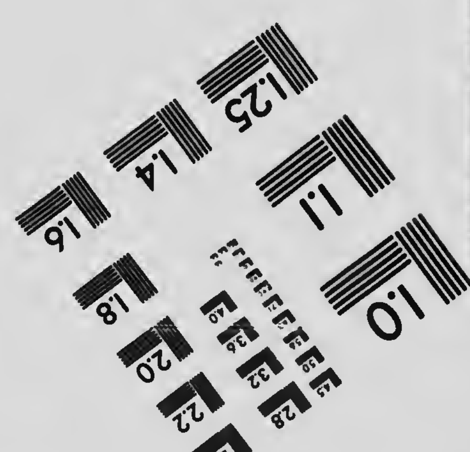

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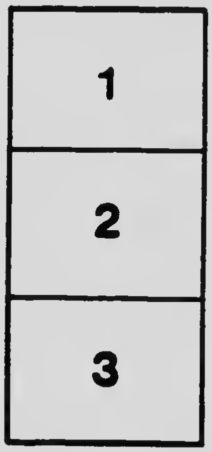
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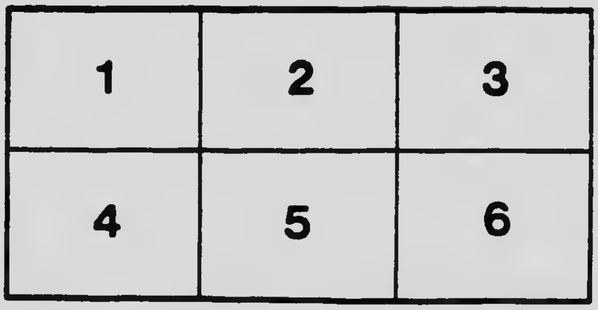
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PLATE I.

Explanation of Plate I.

Illustrating the vertical jointing and fissuring of limestone strata at Montreal. Note also the inclined dyke traversing the beds.

CANADA
DEPARTMENT OF MINES
HON. LOUIS CODERRE, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

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The Artesian Wells of Montreal

BY

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CONTENTS.

ILLUSTRATIONS.

PREFACE.

In 1904 the Geological Survey issued a report by F. D. Adams and O. E. LeRoy on "The artesian and other deep wells on the Island of Montreal," and in this report the records of borings made up to the end of 1903 were collected and discussed. Since the publication of this report the number of borings put down in search of water has been doubled. There are now (April, 1913) 179 wells which together are capable of supplying about 7,000,000 gallons of serviceable water each day. In view of the importance of the subject and because of the amount of new information now available as a result of the large number of wells drilled since 1903, it has been deemed advisable to prepare the following report. The importance of collecting information about these wells, in a reasonably short time after their completion, may be emphasized, as many of the borings mentioned in the earlier report have changed hands and except for what is recorded in the earlier report, nothing is now known about them.

Only deep borings are considered in this report. In the district around Montreal, the farmers and others are in many instances supplied with water from wells drilled by hand. These only penetrate boulder clay or at most, extend only a few feet into the rock. The water is derived from the clay or often from the plane of contact of the clay and rock, and the supply is sufficient only for very moderate demands. Most of these wells flow naturally. On the other hand, only twelve of the deep wells, here considered, flow naturally; but as the water is under pressure and as it invariably rises to a high point in the well and usually to within 20 to 30 feet of the surface, the wells thus come under the heading of artesian wells as that term is now generally understood.

The most general use made of the artesian water in Montreal is for cooling purposes—such as condensing steam—in the summer time. It is largely employed, too, in boilers, but owing to its much higher concentration in salts than river water it is generally not so satisfactory as the latter, but it is, of course, cheaper. Some of the artesian water is very satisfactory for drinking purposes, especially that containing much sodium chloride and sulphate. As much of the water contains free sodium carbonate it is useful to tanneries and laundries, and that which contains free calcium sulphate is useful in breweries.

It has been found possible to show the areal distribution of the different kinds of waters on a map of Montreal, and the nature of the water likely to be obtained on sinking a well in some parts of the city can be predicted with considerable certainty.

In the main, the deductions drawn in the first report have been fairly well substantiated. The chances of striking water are, however, considerably more favourable than appeared from the data then available. Only one well in 10 yields less than 5,000 gallons per diem. Also with regard to the depth to which it is advisable to bore, the conclusions there deduced have been well verified. The greatest supplies of water are obtained between 300 and 1,000 feet in depth and the chances of striking water below 1,000 feet, as will be set forth in detail later, rapidly diminish.

The water generally rises to within 20 feet of the surface and consequently an ordinary suction pump can be used for pumping. In many cases, however, an air lift is employed and then a cistern must be used for separating the water and air.

The results obtained during this investigation almost certainly establish the fact of the absence of any water-bearing horizon and this fact makes the prediction of finding water in any place more hazardous than it otherwise would be. It appears, however, that there are some districts which are unfavourable and others favourable. The few generalizations which can be made in this regard will be set forth in detail later.

Nearly all borings have been made with the ordinary percussion drill. Detailed logs of borings have been preserved in the case of wells recently made and these have given some additional information concerning the depth of geological horizons, though the information is rather meagre, as is to be expected from the fragmentary nature of the records. The wells have in nearly all cases been put down by the Wallace Bell Company, and to Mr. William Bell is due the credit of preserving these records which, besides being of practical value, must always have a permanent scientific interest as being the only direct records of rocks far beneath our feet, that we shall have for a long time to come.

For the purposes of this report all information available concerning the wells has been collected, but a special point has been made of obtaining chemical analyses of the waters. Bacteriological tests and determinations of the hardness and of the total salt content are only of minor importance for the purposes of this memoir, but analyses, in which the most important constituents of the salts present in the water are determined, are of the utmost value and have furnished most interesting conclusions.

New methods of comparing analyses have been devised and an attempt made with a certain amount of success, to trace each water to its several origins. F. W. Clarke says in his Data of Geochemistry, "No law can be framed to cover even the regularities for the exceptional waters are too numerous and too confusing." An attempt is here made to unravel some of these complications.

The author wishes to express his thanks to Mr. William Bell for the information concerning the wells he so willingly placed at his disposal. He is further indebted to the owners of the various wells who in all cases, have furnished him with the information at their disposal.

He is especially indebted to Dr. Donald and Mr. Milton Hersey who have supplied many analyses of waters; to Mr. James Ewing for supplying large scale maps of Montreal; to Dr. Adams and Dr. Bancroft of McGill University, and to numerous others, all of whom have shown an interest in this investigation that has been most encouraging.

The Artesian Wells of Montreal.

CHAPTER I.

SUMMARY AND CONCLUSIONS.

NATURE OF UNDERGROUND CIRCULATION AT MONTREAL.

Montreal is situated upon an area of limestone strata which extend in depth to about 1,400 feet below the surface. The underground water circulation occurs along fissures in the limestone and is mainly confined to the first thousand feet, and below this depth the circulation seems to rapidly diminish. Presumably below 1,000 feet the fractures in the limestone are largely closed whereas above this depth the open fractures or crevices in the limestone increase in number and size continuously up to the surface. The crevices are very numerous and in general are approximately vertical. The fact that the crevices approximate the vertical explains why two borings close together often strike water at different depths and are unconnected.

Mount Royal is a plug of igneous rock which has cut through the limestone; radiating out from it in all directions, are countless dykes usually from 2 feet to 30 feet wide. These dykes often act as a retaining wall impervious to the further circulation of the water. In several instances water has been struck after penetrating a dyke. Sometimes layers of shale and sandy layers in the limestone act in the same way as the dykes, but they are sporadic in their distribution and no water-bearing horizon can be correlated with any particular layer of shale.

There is no known law governing the distribution of the crevices in the limestone in which the water circulates, so that it is impossible to predict in any given area where and at what depth water will be found.

Nevertheless from the records of the numerous wells already bored it is possible to determine the probabilities of striking water in Montreal as a whole.

CHANCES OF STRIKING WATER AND THE DEPTH TO WHICH IT IS ADVISABLE TO BORE.

There are now 179 deep wells in Montreal and only 1 well in 9 yields less than 5,000 gallons per diem. The capacity of a well, however, is not the only thing to be considered as the water when found may be of an undesirable quality rendering it unfit for use. A calculation has, therefore, been made in which an allowance is made for those wells which for one reason or another, are unsuitable for the purpose for which they were put down. The resulting estimate is a bit haphazard as some proprietors possess wells which are useless to them but which other companies would be happy to possess. Reckoned in this way 2 wells in 9 are put down to no purpose.

Of the 179 wells sunk to depths of 60 feet or more only 11 struck water between the surface and 150 feet, the average capacity being 42,836 gallons per day.

Of the 169 wells sunk to depths below 150 feet, 24 struck water between 150 and 300 feet, the average capacity being 33,894 gallons per day.

Of the 147 wells sunk to depths below 300 feet, 51 struck water between 300 and 500 feet, the average capacity being 63,600 gallons per day.

Of the 95 wells sunk to depths below 500 feet, 47 struck water between 500 and 750 feet, the average capacity being 61,437 gallons per day.

Of the 53 wells sunk to depths below 750 feet, 22 struck water between 750 and 1,000 feet, the average capacity being 51,800 gallons per day.

Of the 33 wells sunk to depths below 1,000 feet only 8 yield flows of over 5,000 gallons per day and only 9 over 10,000 gallons per day, the average capacity being 10,000 gallons per day.

Based on the above data the chances of striking water between various depths may be approximately expressed as follows:

Depth in feet	Chances	Max. daily capacity in gallons	Average daily capacity in gallons
0 to 150	1 in 16	120,000	42,836
150 " 300	1 " 7	72,000	33,894
300 " 500	1 " 3	432,000	63,600
500 " 750	1 " 2	240,000	61,437
750 " 1000	1 " 2½	120,000	51,800
Over 1000	1 " 3	120,000	10,000

The above figures show that below 1,000 feet the chances of striking substantial supplies of water become very small.

With regard to the chances of striking a supply with a capacity of 100,000 gallons or more per day, the following data are available.

Of the 179 wells, 24 have a capacity of 100,000 gallons (i.e. 1 in 7½) or more and their average depth is 540 feet. Of these 24 wells 16 fall between the depths 400 to 700 feet, and of the rest, 4 wells are shallower than 400 feet and 4 wells are deeper than 700 feet.

Based on the above data the chances of striking a flow of 100,000 gallons or more at various depths may be approximately expressed as follows:

Depth in feet	Chances
0 to 400	1 in 6
400 " 700	2 " 3
Over 700	1 " 6

From the above results it is apparent that the most favourable depths for obtaining good supplies of water are between 300 and 1,000 feet. Above and below these depths, the chances of obtaining good supplies are much smaller.

Unfavourable Areas for Obtaining Underground Water.

There are two areas in which there seem to have been an exceptional number of failures. One is south of the Grand

Trunk station and between Notre Dame street and William street. The other area is around the Hochelaga yards of the Canadian Pacific railway. Though at present the number of borings is hardly sufficient for a generalization yet it would certainly appear that the whole area is unfavourable which includes the Hochelaga yards and which is bounded by Frontenac street on the southwest, the St. Lawrence river on the east, Pie IX avenue on the northeast, and Forsyth street on the northwest.

Favourable Areas.

On the other hand an extremely favourable area appears to be that occupied by the Angus shops of the Canadian Pacific railway and the Montreal abattoirs, and as far as the few wells at present bored can indicate, this area might be extended to Lafontaine Park and Mount Royal avenue, to the mountain.

PRESSURE OF THE WATER.

Only twelve of the wells in Montreal flow naturally and in these cases the natural flow is small. In most the water rises to within 30 feet of the surface and can be pumped with an ordinary suction pump. In a few cases the water is raised with an air lift and this method, in a number of instances, has increased the capacity.

TEMPERATURE OF THE WATER.

The temperature of the water varies from 48 degrees to 52 degrees F., and remains fairly constant throughout the year. The mean temperature of Montreal is 41½ degrees and as the temperature in the earth's crust rises 1 degree F. for about every 50 feet in depth, the temperature of the water is such as is to be expected from waters rising from depths of from 300 to 500 feet.

Many of the artesian waters are used for cooling purposes in summer.

CHARACTER OF THE WATER.

None of the artesian waters in Montreal contain free acid; that from well No. 18 is the only chalybeate one and is so strongly charged with iron that it deposits it in drinking vessels. The water of well No. 88 is the only one to which the name mineral water could be applied as its salt concentration is 530 grains per gallon.

Most of the artesian waters are alkaline and contain free sodium carbonate. Many are saline and contain chlorides and sulphates of calcium as sodium. Many of the waters contain sulphuretted hydrogen.

All of the artesian waters are more saline than the city water taken from the St. Lawrence river as in circulating through the rocks the undergro /aters decompose the rocks and dissolve some of their solub constituents. St. Lawrence River water contains about 3 grains of salt to the gallon and the artesian waters on an average contain about 40 grains to the gallon. In consequence artesian water generally forms more scale in boilers than city water and its suitability for this purpose depends largely upon the composition of its saline content. Calcium carbonate is the chief scale-forming material in boilers and if the waters are high in this they are bad for such purposes. In general the shallower well waters are high in calcium carbonate. On the other hand, sodium carbonate in water causes the calcium carbonate to be precipitated not as a scale in the boiler but as a fine, suspended precipitate. Therefore, if the water is blown off from the boiler frequently, many of the artesian waters which contain sodium and calcium can be used to good effect. As city water chiefly contains calcium carbonate, though, of course, in small amounts, it is sometimes advantageous to mix some artesian water with the city supply for use in boilers. Calcium sulphate in waters to be used in boilers, and some of the artesian waters contain this salt, is bad as it is deposited as a scale in the boiler.

A few waters in Montreal contain sodium chloride, sodium sulphate, and some sodium carbonate with very little else. Such waters can be used satisfactorily for steam purposes if the boiler is blown off frequently enough. Certain salts, however, especially magnesium and sodium sulphates, cause priming in the boiler and artesian water containing such salts generally must be discarded for steam purposes.

Some of the waters are used in tanneries and laundries and are very satisfactory on account of their content of sodium carbonate and consequent "soft" nature. Much is used in breweries where the artesian waters which contain free calcium sulphate are most suitable.

Some waters are used for drinking purposes and on account of their fairly low saline content often prove very satisfactory. Those which contain much calcium are hard and those with much free sodium carbonate have a laxative effect. On the other hand waters which contain free sodium chloride and sulphate are very satisfactory for drinking. Artesian water is good for drinking as it is generally uncontaminated. In a few cases contamination was found to be caused by careless pumping. If an air lift is employed to raise the water, the air must be pure and it is essential to have clean conditions at the pumping station. In some cases artesian water is contaminated naturally. This is especially likely to be the case in a limestone area where fissures occur and surface water can get down into the well, especially into the upper part. In sandstone a process of filtration occurs, but in fissures in limestone the purification of the water is not nearly so satisfactory. In the case of one well the source of contamination was discovered and it was blocked out with concrete in the upper part of the boring.

DISTRIBUTION OF WATERS.

The most important constituents of waters and those which are always determined in a commercial analysis, are sodium, magnesium, calcium, chloride, sulphate, and carbonate. A map accompanying this report shows the relative proportions of these constituents in the artesian waters of a large number of wells in the city, and from this map the following facts of chief practical importance are gathered.

The majority of the waters are high in sodium, but there are two areas characterized by wells whose waters are relatively high in calcium or in calcium and magnesium combined and this latter water is, therefore, not satisfactory for use in boilers as there is almost always considerable carbonate present.

One of these areas, situated to the east of Mount Royal, contains wells whose waters are generally marked by the dominance of chlorine over sulphate, and the other, situated to the northwest of Mount Royal, contains wells in which sulphate as a rule predominates over chlorine. The precise boundaries of these areas are difficult to define partly because of the want of a sufficient number of analyses and partly because the waters of wells neighbouring these areas of calcium-rich waters are to a greater or less extent of a transitional nature.

Calcium Chloride Area.

The area with waters high in calcium or calcium and magnesium and, as a rule, with chlorine preponderating over sulphate is situated to the east of the mountain and is roughly defined by the following streets: Wellington, Shearer, Seigneur, Guy, St. Catherine, Ste. Monique, Inspector, and Dalhousie. Included in this area are the following wells: Nos. 54; 167; 10; 3; 89; 135; and 178. It must be emphasized that the above boundaries are not rigidly accurate but only approximate. Well No. 122 for example falls just outside the area demarcated above but belongs to this group.

It is to be noted that between Mount Royal and this area sodium wells occur and that these as well as the calcium wells in their proximity have more sulphate than chloride.

Calcium Sulphate Area.

The existence of the area with waters high in calcium to the northwest of the city should be of interest to brewers for the reason that the waters here often contain free calcium sulphate. This area includes Outremont and extends from Maplewood avenue to the Canadian Pacific Railway yards at Outremont, and thence probably out to Cote de la Visitation road, back to Mile End station and thence to Maplewood avenue. It appears to be a lenticular shaped area.

Wells Nos. 160, 120, and 13 are especially characteristic. Wells Nos. 159 and 95 are clearly related in composition but are not so high in calcium, while wells Nos. 143, 144, 145 are high in calcium but are high in carbonate instead of sulphate.

Sodium Area.

In composition the majority of the waters of the rest of the wells in Montreal are high in sodium and regarding these the following remarks may be made.

Wells with waters high in sodium carbonate encircle Montreal. Reference is made to well No. 134 on the south, No. 140 on the southwest, No. 154 on the northwest, and No. 64 on the northeast. Well No. 95 on the west belongs to the same group but shows characters allying it with the neighbouring calcium sulphate area.

There is a large sodium area, extending from Mount Royal on the southwest to Maisonneuve on the northeast—bounded on the west by the calcium sulphate area, on the south by the calcium chloride area and Mount Royal, and on the east by the St. Lawrence river.

Just south of the Hochelaga yards—one of the unfavourable areas referred to above—there is an area with waters high in calcium. Wells Nos. 37, 47, and 57, show this and a discussion regarding them is presented in chapter IV.

Over this sodium area in the northern part of the city, the relative proportions in the waters, of carbonate, sulphate, and chloride vary somewhat sporadically. In Maisonneuve borings have struck two different kinds of water at different levels. The upper water is dilute and probably high in sodium carbonate whereas the lower water is a highly saline solution of sodium chloride and sulphate. Well No. 88 is an example of this saline class, but the nearby wells Nos. 175 and 176 are of normal concentration though containing sodium sulphate and chloride to the exclusion of calcium salts.

Over the rest of the area sodium carbonate generally predominates, but the relative proportion between the sulphate and the chloride varies considerably. In the southern part of the area, near McGill university, the sulphate predominates, as in wells Nos. 157 and 30. In the southwest the chlorine content is high, as in wells Nos. 96 and 127. Around the Angus shops and Montreal abattoirs, the sulphate constituent predominates over the chloride but the chloride predominates in well No. 121. In the Place Viger well, No. 101, and the Laurentian Baths well, No. 48, the sulphate constituents are the more important. Again to the south of the calcium chloride area in St. Henry, saline sodium water is present as well No. 92 shows, and the nearby well No. 129 is another example of a well devoid of calcium and containing mostly sodium chloride and sulphate.

RELATION BETWEEN COMPOSITION OF WATER AND DEPTH.

One of the most interesting conclusions arrived at is that the waters can be classified areally but not according to depth. Two wells sunk close together may strike water at different depths but the water is of the same general character. As examples, the two wells at the Laurentian Baths may be cited, Nos. 48 and 132. Again in the case of wells Nos. 96 and 127 the same kind of water was struck at 250 feet, 500 feet, and 805 feet.

There are, however, some very notable exceptions. At Maisonneuve it is noticeable that two kinds of water were struck at different levels, the lower being a highly saline one. At the central Y.M.C.A. well, No. 179, a sodium water was struck at 520 feet, and a calcium water at 825 feet. The import of this is that this well is near the boundary between a calcium and sodium area and the two areas overlap.

SULPHURETTED HYDROGEN IN WATERS.

Sulphuretted hydrogen occurs rather sporadically and not many rules of importance can be laid down with regard to it. Well No. 154 for example contains little and well No. 26 close by is full of it. The three wells, Nos. 88, 92, and 54, which are very saline, are all sulphurous—the first two high in sodium chloride and sulphate and the latter in calcium chloride. Well

No. 13, high in calcium sulphate, though not so concentrated as the others, is very sulphurous. The sodium carbonate waters are not so sulphurous as the saline waters and the large sodium area to the northeast of Mount Royal is on the whole fairly free from sulphuretted hydrogen.

In several cases when a very sulphurous water has been obtained on boring, the sulphurous content to a large extent disappeared after several weeks pumping. That the sulphuretted hydrogen seems to slowly accumulate in the water, if left stationary, is a common observation in the case of only slightly sulphurous water used for drinking purposes.

OTHER INFORMATION OF PRACTICAL IMPORTANCE.

(1). It is a bad practice to locate a well at the bottom of a steep slope as the artesian water under these conditions is very liable to be contaminated by surface drainage.

(2). Increase in the supply can sometimes be obtained by springing the well.

(3). In chapter V, in the remarks concerning well No. 103, will be found information regarding the cost of a well and the time it took to drill it.

(4). There is a possible but not very probable water horizon beneath Montreal city containing an abundant and pure water supply. It probably occurs at a depth of about 2,700 feet and in the case of one well already drilled if it were increased in depth by 200 feet it would very likely strike this horizon.

SUMMARY OF TENTATIVE CONCLUSIONS OF MORE SCIENTIFIC IMPORTANCE.

(1). The underground circulation occurs in fissures in limestone which gradually decrease in numbers from the surface downwards and below 1,000 feet are few and far between.

(2). The circulation is governed by laws different from those obtaining in porous rocks like sandstones and it still demands mathematical analysis.

(3). The underground water originates partly in the Laurentian highlands and partly in the St. Lawrence lowlands.

(4). At Montreal the water obtains a high content in sodium carbonate probably from the dyke rocks intersecting the sediments.

(5). In different parts of Montreal, different saline waters arise whose salts possibly originated at the time of the volcanic eruption of Mount Royal. The dominant salts of these waters are: (a) calcium sulphate; (b) calcium chloride; (c) sodium sulphate and chloride.

(6). The calcium carbonates waters are partly derived by mingling of the above types and are partly of original and local origin.

(7). The above types of water intermingle and give rise to the actual waters of Montreal.

(8). A water in the process of underground circulation can alter its concentration without any great alteration of its relative composition.

(9). In the process of intermingling of these different waters in the limestone, certain soluble constituents are in some way removed.

(10). The proportion of magnesium to calcium increases as the proportion of sodium in the water increases.

(11). Several new graphical methods of representing analyses are described and illustrated.

(12.) A new and natural method of classification is adopted for Montreal waters.

(13). A vesicular dyke rock was found at a depth of 1,000 feet.

CHAPTER II.

UNDERGROUND WATER CIRCULATION.

GENERAL OBSERVATIONS.

Most water is originally derived from the ocean by evaporation and deposited upon the land in the form of rain. The annual rainfall of the world is 26,000 cubic miles according to Prof. Sollas. This is disposed of in three ways and the relative importance of these varies enormously in different countries and under different conditions. In Britain where the mean annual rainfall is 39½ inches, the distribution has been estimated[1] as follows:

Evaporation and absorption by vegetation	57%
Surface run-off	18%
Percolation	25%

These numbers serve to show the great importance of underground circulation, more water being absorbed in this way than directly finds its way to streams and rivers.

The more evenly distributed the rainfall is throughout the year the greater will be the percolation and the less the run off. On the east post of Bengal where as much as 67 feet of rain has been recorded in one year, the surface run off will be by far the most important factor; whereas again in Texas, several large streams are entirely evaporated away before they reach the sea.

The effect of vegetation upon these three factors is generally to diminish surface run off by increasing evaporation. On the other hand percolation is diminished by vegetation and for this reason it is on the autumn rain and winter snows that the underground supplies of water are chiefly dependent.

That portion of the water which sinks into the earth's crust here alone claims our attention. This water passes down through porous strata or through cracks and fissures thus giving rise to a system of subterranean water circulation, and finally

[1]Woodward, "Geology of Water Supply."

comes to the surface again at some lower level in the form of springs, or passing out into the sea along the continental margins, is lost in the waters of the ocean.

A few of the conditions governing underground water circulation as outlined by Sir Archibald Geikie[1], will here be given.

"The water which sinks below ground is not permanently removed from the surface, though there must be a slight loss due to absorption and chemical alteration of rocks. Finding its way through joints, fissures, or other divisional planes, it issues once more at the surface in springs. This may happen either by continuous descent to the point of outflow, or by hydrostatic pressure. In the former case, rain-water, sinking underneath, flows along a subterranean channel until, when that channel is cut by a valley or other depression of the ground, the water emerges again to daylight. Thus in a district having a simple geological structure, a sandy porous stratum, through which water readily finds its way, may rest on a less easily permeable clay, followed underneath by a second sandy pervious bed, resting as before upon comparatively impervious strata. Rain falling upon the upper sandy stratum will sink through it to the surface of the clay, along which it will flow until it issues either as springs, or in a general line of wetness along the side of a valley. The second sandy bed will serve as a reservoir of subterranean water so long as it remains below the surface, but any valley cutting down below its base will drain it."

"Except, however, in districts of gently inclined and unbroken strata, springs are more usually of the second class, where the water has descended to a greater or less distance, and has risen again to the surface in fissures, as in so many syphons. Lines of joint and fault afford ready channels for subterranean drainage. Powerful faults which bring different kinds of rock against each other are frequently marked at the surface by copious springs. So complex is the network of divisional planes by which rocks are traversed, that water may often follow a most labyrinthine course before it completes its underground circulation. In countries with a sufficient rainfall, rocks are

[1] Text-book of Geology, Fourth Edition, Vol. 1, pp. 465–8.

saturated with water below a certain limit termed the *water-level*. Owing to varying structure, and relative capacity for water among rocks, this line is not strictly horizontal, like that of the surface of a lake. Moreover, it is liable to rise and fall according as the seasons are wet or dry. In some places it lies quite near, in others far below, the surface. A well is an artifical hole dug down below the water-level so that the water may percolate into it. Hence, when the water-level happens to be at a small depth, wells are shallow; when at a greater depth, they require to be deeper.

"Since rocks vary greatly in porosity, some contain far more water than others. It often happens that, percolating along some porous bed, subterranean water finds its way downward until it passes under some more impervious rock. Hindered in its progress, it accumulates in the porous bed, from which it may be able to find its way up to the surface again only by a tedious circuitous passage. If, however, a bore-hole be sunk through the upper impervious bed down to the water-charged stratum below, the water will avail itself of this artificial channel of escape, and will rise in the hole, or even gush out as a *jet d'eau* above ground..................

"That the water really circulates underground, and passes not merely through the pores of the rocks, but in crevices and tunnels, which it has no doubt to a large extent opened for itself along natural joints and fissures, is proved by the occasional rise of leaves, twigs, and even live fish, in the shaft of an artesian well. Such testimony is particularly striking when found in districts without surface-waters, and even perhaps with little or no rain. It has been met with, for instance, in sinking wells in some of the sandy deserts of the southern borders of Algeria. In these and similar cases, it is clear that the water may, and sometimes does, travel for many leagues underground, away from the district where it fell as rain or snow, or where it leaked from the beds of a river or lake."

The height to which water rises in a well depends on : (1) the height of the surface through which the water originally passed underground; (2) the resistance met with while flowing underground; and (3) whether the water at the point where the well is sunk, is or is not confined; (4) other factors not always understood. If the water is confined, it may exist under considerable pressure, and on the water-bearing horizon being penetrated by a well, the water will rise in the well and may even overflow at the surface. If the water is not confined under pressure, the water in a well will rise only to the general underground water-level.

The conditions governing the Montreal underground water supply are complex and before describing them in detail, a brief description of the geology of Montreal and vicinity will be given. This description is mainly a reprint of the section dealing with this subject in the former report, pages 17 to 25, with certain additions.

SKETCH OF THE GEOLOGY OF MONTREAL AND VICINITY.

The Laurentian plateau extends from Labrador southwest to Lake Superior, and thence northward to the Arctic ocean, and has an area of over 2,000,000 square miles. The St. Lawrence plain bounded on the north by this plateau, stretches from the Notre Dame mountains, in Quebec, to Lake Huron and southward into the United States. The Laurentian plateau is a rolling, comparatively hilly and rugged country. That portion of it in the immediate neighbourhood of Montreal, rises abruptly from the plain, the elevation becoming gradually greater on going to the north. Just within the plateau, northwest of Montreal, it has an average elevation of about 600 feet above sea-level, while 15 miles farther north the average elevation reaches 1,000 feet, and 25 miles still farther north the country frequently attains an elevation of 1900 feet, while some hills rise still higher; the most notable of these is Trembling mountain, the summit of which is 2,380 feet above the sea. The valleys are more or less filled with drift and in the hollows are numerous lakes, the abundance of the latter being one of the most characteristic features of the Laurentian highlands.

The St. Lawrence plain is flat and thus offers a strong contrast to the topography of the plateau. The average elevation in the vicinity of Montreal is about 100 feet above sea-level, but there is a gentle rise towards the northwest, which gives the plain at its junction with the plateau an elevation of about 300 feet. The whole area is drift-covered and forms farming lands of exceptional fertility.

The continuity of the plain, within the general area here described, is broken only by Mont Calvaire at Oka, and by Mount Royal, rising behind the city of Montreal. The former is an outlier of the Laurentian plateau—an ancient island in the Palæozoic era—and has an area of about 30 square miles, while the latter is the most westerly of a line of old volcanoes and laccolites, known as the Monteregian hills, which cut the Palæozoic rocks of the plain. In the following brief description of the geology of the Montreal district only the salient points concerning the different formations will be noted, the reader being referred for more extended descriptions to the reports mentioned in the foot-note.[1]

The Laurentian Plateau.

This plateau is composed of a great complex of rocks, mainly of igneous (plutonic) origin, such as granites, syenites, gabbros, etc., but also comprises some of the most ancient sediments of the earth's crust. Since their formation these rocks have suffered great alteration, being now folded, contorted, crushed, and recrystallized. The thermo-dynamic forces have destroyed their original structure, and subsituted for it a banded or schistose character. These metamorphic rocks are termed gneisses and schists, the designations being modified to indicate the composition of the particular rock under consideration; for example, granite gneiss, mica schist, amphibolite, etc.

The highly altered sediments folded in with these igneous rocks belong to what is termed the Grenville series. They con-

[1] Geology of Canada, 1863. Chaps. 3, 4, 5, 6, 7, 8, 9, 10, and 13.

Ells, R. W., Report on a portion of the Province of Quebec comprised in the southwest sheet of the Eastern Townships. Geol. Surv., Can., Vol. VII, 1896; pp. 44–50, 74–75, 85–86.

Adams, F. D., Geology of a portion of the Laurentian Area lying to the north of the Island of Montreal. Geol. Surv., Can., 1897, part J.

sist of beds of rusty-weathering gneisses, impure crystalline limestones, garnet rock, amphibolites, and quartzites, corresponding respectively to the shales, limestones, calcareous shales, and sandstones of unaltered sedimentary strata. This series is very important, not only as representing some of the very earliest sediments on the surface of the earth, but because of the many minerals of economic value which it contains.

Subsequent to the Grenville period, but still in Pre-Cambrian time, there was a great development of igneous activity along the southern edge of the plateau, and great masses of anorthosite were intruded in the above-mentioned series. Anorthosite is a gabbro made up almost wholly of labradorite feldspar. A later series of intrusions is represented by the numerous dykes which cut all these older rocks. These dykes are chiefly diabases and are pre-Potsdam in age and are thus quite distinct in character and age from those connected with the intrusion of Mount Royal.

The St. Lawrence Plain.

Towards the close of the Cambrian and at the beginning of the Ordovician period of Palæozoic time, the Laurentian plateau, standing at a certain elevation above the sea which then covered the plain, was acted upon by the various agents of erosion and decay, both subaërial and marine. The accumulation of debris derived from the waste of the Laurentian continent was assorted by the waves and deposited in the sea along the flanks of the primitive continent. Thus a series of stratified rocks was laid down on the sea floor and these rocks now underlie the St. Lawrence plain.

The formations of the Upper Cambrian and the Ordovician developed in the vicinity of Montreal, are the following, enumerated in ascending order:—

Potsdam sandstone.
Beekmantown or Calciferous sand-rock.
Chazy limestone.
The Trenton group—consisting of limestones.
Utica shale.
Lorraine (Hudson River)—consisting of shales and sandstones.

Potsdam Sandstone.—The Potsdam sandstone of Upper Cambrian age was the first formation laid down, in this region, on the Pre-Cambrian floor. It is represented in type by the modern sand and gravel deposits which flank our coasts. Its lowest members are beds of conglomerate, holding pebbles of Pre-Cambrian gneisses and quartzites. These beds pass upwards into evenly stratified, fine-grained, and very quartzose sandstones. It is distinctly a shallow water formation and many layers show false bedding, ripple marks, with tracks and burrows of animals which crawled upon the shallow sea bottom or burrowed in the sand. The formation in this district flanks the Laurentian plateau, first as a narrow band which, broadening out in its southern extension, embraces the old island of Mont Calvaire and extends southward into the counties of Vaudreuil, Soulanges, and Beauharnois. Ile Perrot is wholly underlain by the Potsdam and there are small exposures on the Island of Montreal at Ste. Anne de Bellevue, where fine worm burrows and ripple marks are to be seen in the nearly horizontal beds.

Beekmantown or Calciferous Sand-rock.—A slow sinking of the Laurentian plateau was in progress from the beginning of the Potsdam period, and as a consequence, the succeeding formation, the Beekmantown (Calciferous), representing deeper water conditions, immediately overlies the Potsdam, the two being united by transitional beds, so that the lower formation insensibly graduates into the upper. Marine life was more abundant during this period, as evidenced by the number of fossils enclosed in the Beekmantown. Gastropods (sea snails), cephalopods (ancient types of devil or cuttle-fish), and many forms of brachiopoda found a suitable environment in the calm waters of the Beekmantown sea.

The rock itself varies somewhat in character, but usually is a greyish, semi-crystalline dolomite or magnesian limestone, which is generally arenaceous or siliceous and occasionally argillaceous. In many instances it holds geodes of quartz and calcite, and irregular streaks and patches of black chert.

In horizontal distribution it succeeds the Potsdam, forming a second belt along the margin of the old continent, and is well developed in the counties of Terrebonne, Two Mountains, and on the northwest side of Ile Jesus, the west ends of Ile Bizard and the Island of Montreal, and south of Lake St. Louis and in the county of Beauharnois. From surface measurements the thickness of the formation seems to vary from 300 to 450 feet, but the borings obtained from the Gas Company's wells in the City of Montreal, indicate a thickness of over 1,000 feet.

Chazy Limestone.—In Chazy time, with a further deepening of the sea, the conditions became more truly oceanic, and there was consequently a great development of marine life, particularly of the brachiopoda. These, through the accumulation of their shells, built up extensive beds of limestone, many of the latter consisting almost wholly of the shells of a single species, *Rhynchonella plena.*

The formation is represented by granular, semi-crystalline light and dark grey limestones, made up in great part of shells and their comminuted fragments. Interstratified with the limestone beds are occasional shaly layers which indicate the influx of muddy waters into the prevailingly clear waters. In geographical distribution the formation appears as a narrow sinuous band following the Beekmantown (Calciferous) and which broadens out as it crosses the middle of Ile Jesus and the Island of Montreal. From the southwest end of Ile Jesus, another body passes across Ile Bizard and the west end of the Island of Montreal, and thence passing beneath the waters of Lake St. Louis occupies an area extending from Chateauguay and Caughnawaga on southward. The field relations give the Chazy a thickness of about 300 feet; but the information gained from the boring at the Turkish Bath hotel indicates a thickness of 785 feet.

Trenton Group.—The Trenton group, into which the Chazy insensibly merges, consists of three divisions which, in ascending order, are known as the Lowville (Bird's Eye), Black River, and Trenton formations.

The Trenton is one of the most persistent and conspicuously marked series of strata of the Ordovician in North America, and judging from the abundance of the remains of marine invertebrate life, this period evidently represents long continued and truly oceanic conditions, the waters being clear and probably warm. In addition to numerous representatives of previously mentioned marine families, trilobites and corals flourished, the latter especially giving rise to great beds of limestone.

The rock is usually a granular, semi-crystalline, dark grey limestone, more or less bituminous, and contains a variable amount of argillaceous (clayey) material. In many instances the limestone beds are separated by thin partings of shale, these being thicker and more pronounced at the top of the series where the Trenton passes into the Utica formation.

The Trenton group runs in a rather broad band from l'Assomption to south of the St. Lawrence. It is extensively developed in the vicinity of Montreal, and immediately underlies the city. In the district about Montreal it appears to have a thickness of about 700 feet.

Utica Shale.—The marine conditions prevailing in the Trenton were succeeded in Utica time by a gradual elevation of the sea bottom, and the clear deep water of the former period became shallow and muddy. This change of conditions was not favourable to the existence of those forms of life which flourished in the Trenton, consequently they for the most part disappeared, their place being taken by forms of life adapted to cold and muddy waters. The Utica formation consists of thinly laminated black and brownish black shales often bituminous and which are vey brittle, usually breaking up where exposed to the weather into small thin fragments. The formation on the Island of Montreal extends from Verdun to Point St. Charles. There is also a small area at the north end of the island. It underlies the harbour of Montreal and forms the south end of St. Helens island.

Lorraine (Hudson River) Shale.—The Utica formation passes upwards into the less bituminous and sandy shales and the thinly bedded sandstones of the Lorraine. The conditions of deposition must have been somewhat similar to those of the Potsdam period, except that the sands were mixed with clay instead of being purely arenaceous.

These formations, from the Potsdam to the Lorraine in this area, have been very little disturbed. Over the greater part of the area they either retain their original horizontal position, or dip to the southeast at a low angle, seldom exceeding 5 degrees. The Chazy and Trenton on Ile Jesus and Montreal island, however, display a low anticlinal arch, the axis of which runs northwest from Mount Royal. This is traversed by two others, one on each of the islands, with axes almost at right angles to the main anticline.

Another anticline with an axis running north 23 degrees west is seen in the western portion of the district, the central part or dome of which is occupied by the Pre-Cambrian outlier of Mont Calvaire. Between Mont Calvaire and the border of the Laurentian plateau, the outcrop of the Potsdam and Beekmantown (Calciferous) gives to the former the outline of an hour-glass.

The Igneous Intrusions of Mount Royal.—During Devonian or post-Devonian time the part of the St. Lawrence plain in the vicinity of Montreal was the scene of great volcanic activity, the present evidences being the line of igneous hills which extend from Shefford to Mount Royal. These hills, greatly reduced in size and representing merely roots of the original volcanoes or in some cases uncovered laccolites, by reason of the flatness of the plain, form striking topographic features, and are locally known as mountains.

The igneous mass of Mount Royal occupies an area of about 1½ square miles, and is surrounded by the Trenton limestone, through which it has broken, and which has been in many places thereby altered to marble. The main part of the mountain is composed of essexite, a plutonic rock composed essentially of plagioclase feldspar, augite and hornblende, with a little nepheline. Olivine is in some places present as an accessory constituent. This essexite was subsequently cut through by a later intrusion consisting of nepheline syenite, a rock which is genetically related to the former and which consists essentially of orthoclase feldspar, nepheline, and hornblende. It represents a more acid phase of the original magma. The nepheline syenite appears as a comparatively broad band along part of the northwest flank of the mountain and also elsewhere over smaller areas. This intrustion is quarried at Outremont for road metal and is of particular interest in that it has furnished a number of rare minerals.

Associated with these intrusions is a great swarm of dykes, that is to say, more or less steeply inclined or vertical walls of igneous rock, which cut the essexite, nepheline syenite, and the surrounding stratified rocks in all directions. There are also numerous sills or sheets of the same, intercalated between the beds of the stratified rocks. These dykes and sills consist of a complete series of those rarer varieties of dyke rocks which belong to the nepheline syenite-essexite magma, and which are known as bostonite, camptonite, alnoite, tinguaite, etc. They are related genetically to the former intrusives and represent the closing stage of the volcanic action. The dykes may be seen in almost all large exposures of rock in the vicinity of Montreal, as for instance in Mount Royal park, the Corporation quarry at Outremont, the Mile End quarry, or on St. Helens island.

These dykes in their underground extensions, forming impervious walls crossing the fissures through which the water runs, certainly have a very important influence locally in determining the courses taken by the subterranean waters.

Pleistocene.—Between the Devonian and the Pleistocene a great gap exists here in the geological record, the upper part of the Palæozoic and the whole of the Mesozoic and Tertiary being unrepresented.

During Pleistocene time, however, it is known that an Arctic climate prevailed and that the area was covered by the great ice sheet known as the Laurentian glacier, which gave rise to certain deposits characteristic of glacial action. These drift deposits consist of clays, sands, and gravels, the lowest member being the boulder clay ("hard pan") composed of glaciated boulders embedded in a fine clay or rock flour. This is very compact and resists erosion as readily as many of the old stratified rocks. The upper members of the drift, which are stratified clays, sands, and gravels, were formed during a post-Glacial submergence, which followed the retreat of the ice sheet. In the vicinity of Montreal they are known as the Leda clay and Saxicava sands and gravels From the abundant fossil remains (shells) in these marine deposits, it is inferred that the climate was sub-arctic, as closely related species (in many cases identical) are now found living off the coast of Labrador.

This marine submergence was very widespread, the sea-level reaching a height of about 625 feet on Mount Royal and covering the entire plain.

As the land slowly rose again, the sea retreated, and marked by a terrace each level at which it remained stationary for a time. In this way the series of terraces encircling Mount Royal mark the successive stages of emergence from the Pleistocene sea. These terraces are well developed at Montreal between the mountain and harbour, the most prominent ones being those on which Sherbrooke street and St. Catherine street are located, and which form striking features in the landscape along the banks of the St. Lawrence both to the north and south of the city.

Thickness of the Sedimentary Formation at Montreal.

Information from well borings gives the following information concerning thickness of the strata on Montreal island.

Utica..............	210 feet (summit not present.)
Trenton............	+695 "
Chazy.............	785 "
Beekmantown......	+1065 "

The Utica only covers a very small portion of Montreal island, at Point St. Charles and a few other places. Well No. 153 passed through 210 feet of Utica shale before striking limestone. On the opposite side of the river at Longueil, the Militia Department's well No. 141 passed through 380 feet of alternating beds of shale and limestone before striking a purer limestone. At Laprairie the thickness of the Utica appears to be much greater, as Dr. Haanel mentions in the report on the mining and metallurgical industries of Canada, that a boring there passed through 1,500 feet of shale before striking limestone of which it passed through 800 feet.

The maximum thickness of the Chazy was determined at 785 feet from the log of the Turkish Bath well No. 87.

The summarized log of the well is as follows:

Pleistocene (drift)	50 feet.
Trenton group	590 "
Chazy	785 "
Beekmantown	125 "
	1550 "

The boring did not start at the top of the Trenton and 590 feet is only its minimum thickness. Moreover, at a depth of 637 feet in well No. 92 a tail of the trilobite Dalmanites, a fossil characteristic of the Trenton, was found. This would make the Trenton at least 637 feet thick and other evidence shows that it is even thicker than this. For at well No. 108 which starts near the top of the Trenton the Beekmantown was not struck at 1,500 feet and this makes the Chazy and Trenton together 1,480 feet thick. Subtracting 785 feet for the thickness of the Chazy leaves 695 feet as a minimum thickness of the Trenton.

At the Windsor Hotel well No. 178, at a depth of 1,500 feet specimens were brought up which showed a content of magnesium equal to 29 per cent of the calcium. This indicates that the Beekmantown dolomite was probably struck at this depth. The surface covering here is 25 feet and, therefore, the Chazy and Trenton are 1,475 feet thick. This makes a minimum thickness for the Trenton at the Windsor Hotel well No. 178 of 690 feet. This is interesting as at the Turkish Bath Hotel well situated only 1,000 feet from the Windsor Hotel well and at approximately the same elevation the Beekmantown was struck 100 feet higher up. It must, therefore, be assumed that either the thickness of the Chazy or Trenton changes rapidly or else that the contact between the Beekmantown and the Chazy bends down between well No. 87 and well No. 178.

With regard to the thickness of the Beekmantown it is only possible to be certain about a minimum value as no boring has ever completely penetrated it. The Gas Company's well, No. 61, was still in it at a depth of 2,550 feet and if 700 feet plus 785 feet are subtracted from this for the thickness of the Trenton and Chazy respectively it makes the Beekmantown at least 1,065 feet thick.

There is a large discrepancy between the thicknesses obtained in these borings and the thicknesses obtained from the width of outcrops. One reason is probably that there are faults in the region which have not been observed and another is that the sediments may increase in thickness away from the old shore-line of the Palæozoic sea towards the deeper sea where Montreal is situated; the thicknesses as deduced from measurements made across the outcrops of formations nearer the old shore-line would be less than those determined by borings at Montreal away from the old shore-line.

In wells Nos. 108 and 137 two pieces of Laurentian granite were found. Without any further information on the subject it is assumed they got there by accident.

No wells have been obtained by boring into the igneous rock of the mountain. The boring No. 66 is just on the edge of the igneous rock and for 80 feet it went through it, but at that depth limestone was struck. It is interesting as showing the funnel-shaped contact which must occur between the igneous rock and the limestone.

CONDITIONS GOVERNING UNDERGROUND WATER CIRCULATION AT MONTREAL.

Underground water, in a general way, follows the direction of the general slope of the surface. Like the surface drainage it is endeavouring all the time to find a lower level. The general direction of underground water circulation in the Montreal district is from the northwest, from the Laurentian highlands southwest across the St. Lawrence lowlands. All the water which falls upon the drainage slope to the west of the city will contribute its share to the underground circulation, but much will find its way into river channels before reaching Montreal.

There are perhaps four distinct possible sources for the Montreal underground water. Firstly, the Laurentian highlands; secondly, the St. Lawrence lowlands; thirdly, the Ottawa river which bathes the western and southeastern sides of Montreal island; and fourthly, waters imprisoned in the sediments at the time of their formation or waters which originated with the intrusions of the igneous rocks of Mount Royal.

Considering that the underground water at Montreal is under pressure and rises generally above the level of the Ottawa river, its derivation from this river might be almost ruled out of account. But it is unwise to be too dogmatic, for as shown later the height to which water rises depends upon factors not well understood, and probably is as much dependent upon local conditions as on the height of the source. Nevertheless the Ottawa river seems an unlikely source as there is no reason for thinking artesian wells are confined to a region south of the Ottawa river.

Not much weight either can be put upon waters imprisoned in the sediments as an important source for underground waters. They very likely contribute, but it is more a case of their being replaced molecule for molecule by other water which forms the main bulk of the underground flow.

Probably most of the underground water at Montreal enters the sediments in the St. Lawrence lowlands, but some, and it is impossible to say how much, comes from the St. Lawrence highlands. Under this supposition it is thought that the water from the Laurentian areas enters the Palæozoic sediments of the lowlands either at the outcrops near the junction of the sediments with the crystalline rocks of the Laurentian highlands or else reaches the Palæozoic sediments after entering fissures in the crystallines and subsequently welling up into the overlying sediments. Fissures would not be as common in the crystalline rocks as in the sediments yet there is every probability that they exist. Water is struck quite frequently on boring in the old crystalline rocks of Connecticut and Georgia,[1] for example, though supplies are mostly limited to the first 300 feet.[2]

As mentioned previously the underground circulation at Montreal is not confined to any water-bearing porous rock at any definite horizon but occurs in fissures and cracks in the limestone and at no particular horizon. The flow of water is more of the nature of a seepage through fairly small openings than a flow in large underground channels. In most of the wells

[1] Ellis, Water Supply, U.S.G.S. 160., pp. 19-28.

[2] Fuller, "Underground water papers," water supply, pp. U.S.G.S. 160, p. 68.

the water level falls in a very marked fashion when pumping occurs and sometimes considerable time elapses before it rises again to its normal level.

The following discussion of data will give an idea of the nature of the underground circulation at Montreal.

The Canadian Northern Railway tunnel through the mountain passed close to well No. 166 and near it a large flow of water was encountered and the limestone was found to be much fissured. Water-bearing fissured zones in the limestone, however, must be localized and not generally diffused, for in boring wells it is noticeable that there is no general seepage through the strata as a whole as would be inferred if the water gradually increased in quantity as a well got deeper, but instead, in each case the water is struck at one or more definite levels.

Generally, wells bored near one another do not strike the same water-bearing fissure. In a few cases, however, the existence of a connexion between the water of two adjacent wells, has been proved. The two wells belonging to the Canadian Brewing Company, Nos. 6 and 99 for instance, are about 50 feet apart and by pumping one well both wells could be made to run dry; however, the boring of the second well increased the combined capacity by half as much again. These two wells offer further light on the nature of the underground passages in which the water circulates. Well No. 6 is 580 feet deep and the water rose to 28 feet from the surface. Well No. 99 is 830 feet deep and the water rose to only 112 feet from the surface. As the two wells are connected, this shows that the water-channel connecting the two wells offered a resistance to the passage of water equal to a head of water of 84 feet.

The Angus shop wells, Nos. 11 and 12, are 86 feet apart, and are also connected. Information concerning them will be found in Chapter V and will repay reading by those contemplating an endeavour to increase the capacity of their wells and by those interested in the process of underground circulation. It is there shown that pumping either well decreased the capacity of the other and that the flow from both together was only 6 per cent greater than that from No. 11 alone. When, however, the diameter of the bore of the second well was increased from

4 to 5 inches for a length of 100 feet, the combined flow was increased 12 per cent. It was further shown that when an air lift was increased in length from 100 feet to 150 feet in one of the wells, mud and grit were blown into the other well; this was due to the air lift reaching below the casing. The connexion between these two wells must have been small enough to offer considerable resistance to the flow of water through it, otherwise the effect on the one well of pumping the other would have been greater.

A unique case of connexion has been established with great probability in the case of the Y.M.C.A. well, No. 179, and the Windsor Hotel well, No. 178. In Chapter IV, it is stated that one of the analyses of the Y.M.C.A. water and that of the Windsor Hotel well were identical and, further, that on the day pumping was started from the Windsor Hotel well, No. 178, the level of the water in the Y.M.C.A. well suddenly fell. These two wells are approximately, 1,300 feet apart. It is interesting to observe, as it may have a bearing on the question, that these two wells are almost on the line prolonging a fault of 25 feet displacement inferred to exist on the other side of Mount Royal.[1] Further, the fact that when the Canadian Northern Railway tunnel, which is 1,500 feet north of the Y.M.C.A. well, was being bored, the water got extremely muddy and for three or four weeks retained a muddy taste after which it got better, suggests that this well is in an area of extensive fracturing or faulting.

The facts stated in Chapter I regarding the chances of striking water in boring show that the largest flows are got between 400 and 800 feet; below this the average flow decreases rapidly and below 1,000 feet is extremely small. The inference is that the fissures in the limestone are more common at higher levels than below 1,000 feet or else there must be other unknown factors governing the underground circulation. Most of the fissures in the limestone are the planes along which the limestone breaks in quarrying and they are of the nature of joint planes. They can be seen in almost any exposures of limestone in Montreal and Plate I shows an example. This photograph brings out a point of importance, namely, that in attitude the joint planes

[1] Map of Montreal: Inter. Geol. Congress, Guide Book, No. 3.

approximate the vertical. The latter point explains why wells bored close together often are unconnected and strike water at entirely different depths. Nevertheless as pointed out in Chapter IV, the water obtained in any such pair of wells has approximately the same composition.

In Chapter IV it is pointed out that the underground waters in Montreal are mostly high in sodium carbonate and consequently have small dissolving power upon the limestone through which they pass; perhaps this explains why the fissures even near the surface are of very moderate dimensions only and have not been enlarged into large underground passages and caverns which are such a marked feature in many limestone countries. Occasionally, however, large crevices are met with in the course of boring as indicated in the case of wells Nos. 48 and 57.

If underground water is under pressure and not held in above by some impermeable rock, it will rise to the surface and perhaps overflow as a spring. On the other hand, it is shown in Chapter IV that most spring waters in the vicinity of Montreal have an entirely different origin from the artesian waters and it appears, therefore, that the true underground water is generally held below in some way and only rises when a means of escape is given it by boring. There are, in the Montreal area, two important factors which prevent the underground water from rising to the surface. One is the presence of dykes and the other is the occurrence of shaly and other impermeable layers in the limestone. At the Frontenac Breweries well, No. 120, for example, water was struck after boring through a hard siliceous limestone. At Peck's well, No. 150, and the Y.M.C.A. well, No. 179, water was struck after passing through shale. At the Independent Breweries well, No. 127, water was struck after passing through an altered bostonite dyke. It was a common observation in boring the Canadian Northern Railway tunnel through Mount Royal, that water was found at the contact between bostonite dykes and the limestone.

On account of the conditions above indicated, it is impossible to predict where water will be found as there is no regularity in the distribution of the dykes nor of the impermeable layers in the limestone. Only occasionally, indications of regularity can be observed.

It has already been stated that two wells in proximity generally strike water at different levels. At the Laurentian Baths one well struck water at 280 feet and the other, close by, at 250 feet as well as at 450 feet. The Canadian Bread Company well, No. 96, struck water at 250 feet and 500 feet, while at the Independent Breweries well, No. 127, close by, water was struck at 500 and 795 feet. But as in the latter case the water was held in by a dyke, the fact that water was struck in both wells at 500 feet, must have been a coincidence.

It is impossible to explain the supposed absence of the fissures below 1,000 feet by any change in the nature of the rock, for the Chazy which, it is true, comes in rather below this depth, is very like the Trenton and is lithologically indistinguishable from it.

It must be pointed out that the process of circulation under the conditions which prevail at Montreal is little understood. In considering these conditions, the strata may be looked upon as an immense sponge in which the spaces occur in abundance above and gradually decrease below. To make the analogy complete the sponge must be full of plate-like barriers. A circulation through fissures of the kind described—some probably of capillary dimensions—is quite different from a circulation in a porous sandstone, for example. The workers who have taken up a study of underground circulation from the theoretical[1] point of view have only considered the case of circulation through a porous material. The process here is of a different nature and this is indicated more particularly by a consideration of the height to which water rises in the different wells. For a porous water-bearing bed this depends on the height of the source and the resistance offered by this bed to water moving through it. In Montreal, however, the facts show that there is some other factor or factors which influence it, and which do not depend merely upon the difference in resistance offered to the water in traversing different courses. In the first place a study of the tables in Chapter V, in which the height to which the water rises

[1] Grundwässer und Queller—Hans Höfer von Heimhalt.
King, Franklin, Hiram, Principles and conditions of the movements of ground water: U.S.G.S., 19th Ann. Rept. Pt. II, pp. 61–384.

in the well is tabulated, shows that in the majority of the wells, it rises to within 20 or 30 feet of the surface; in a few cases it overflows; in most instances it does not reach the surface. To this general rule there are only 9 marked exceptions in the cases of the 117 wells concerning which the data are sufficient to permit the drawing of conclusions.

It appears that the height of the lip of the well above sea-level makes little difference. Thus in the only well on the mountain, whose lip is at a height of 450 feet, the water rises to within 5 feet of the surface. At the Angus shops which are at an elevation of 150 feet, the water rises to within 10 feet of the surface, and the waters of the wells in the lower part of the town which are not much above the level of the St. Lawrence (28 feet), almost all rise near to but not to the surface.

There is just a slight indication that the water level is lowest in the deeper wells. For example, the four most marked exceptions to the rule that the water rises close to the surface, are wells Nos. 99, 2, 148, and 161. Of these Nos. 99, 148, and 161 are all about 800 feet in depth—decidedly in the deep class. Well No. 99 is a curious case as it is connected with well No. 6. The former is 830 feet deep and the water rises to 112 feet from the surface, while well No. 6 is 580 feet deep and the water rises to 28 feet from the surface. This again indicates a tendency for the lower water level to occur in the deeper well. The Laurentian Spring Water Company's wells indicate the same thing. In well No. 48 which struck water at 280 feet, the water rose 20 feet above the surface, but in the case of well No. 132 which struck water at 250 feet, and 450 feet, the water rose only to within 52 feet of the surface. In the latter case it might be thought that the saline water which, as explained in chapter IV, is thought to influence the deeper well more than the shallower, might be at lower pressure, but in well No. 88 which struck the typical saline water at 1,190 feet, the water rose 10 feet above the surface and is under higher pressure than usual. With regard to the slight tendency of deeper wells to have a lower water level, it is worth noticing that all of the shallow wells dug by the farmers in the drift, flow naturally.

It may be emphasized now that the waters struck in two adjacent wells and rising to different heights, nevertheless, have in general the same chemical composition. They are the same waters, have the same origin and circulate under the same general conditions, and the height to which they rise is governed not only by the height of the source from which the water came, but, also, mainly by local conditions.

F. D. Adams[1] has shown that cavities may exist in granite to a depth of at least 11 miles where they will be closed by a flowing of the granite; and in Solenhofen limestone, a very homogeneous and compact stone, cavities may still occur at 10 miles beneath the surface. Nevertheless, at Montreal it appears that fissures are much less frequent at a depth of only 1,000 feet[2] beneath the surface than at the surface; so that although the fractures may not have been closed by a flow of the limestone they are tighter. The evidence from mines points to the same general conclusion as frequently the upper levels contain most water and the lower levels less and less and finally none. This is not only the case with plutonic rocks, for at Elkhorn, Mont., in a mine in limestone, most of the water occurred about 1,400 feet.[2] Nevertheless, although it appears as if the fractures are less frequent or tighter below 1,000 feet, yet it is quite possible water may be contained in the porous Potsdam sandstone which lies below the limestone and dolomite. The deepest well is 2,550 feet deep and did not penetrate the Potsdam sandstone. It is impossible to say definitely how much deeper it would be necessary to bore this well in order to strike the Potsdam, as the thickness of the Beekmantown dolomite beneath Montreal is not known. One thousand and sixty-five feet of the Beekmantown was penetrated in the well mentioned and a hypothetical calculation suggests that within another 111 feet the Potsdam might be struck. Borings in Montreal have shown that the Chazy is 2·6 times the thickness estimated by Sir W. Logan from surface indications. If we increase his determination of the Beekmantown from surface outcrops in the same ratio, the Beekmantown would have a thickness of 1,176 feet beneath

[1] Jour. Geol., Vol. 20, 1912, pp. 97–118.
[2] M. L. Fuller, Loc. cit., p. 65.

Montreal. Well No. 61 has already been bored through 1,065 feet and it seems very probable that in a few hundred feet the Potsdam would be struck. Water is found elsewhere at depths as great as 3,000 feet; and although if present in the Potsdam, it would be only under a moderate pressure at Montreal as the collecting basin is not at a high level, yet there is a possibility that good water might be found and in abundance.

CHAPTER III.

COMPOSITION AND CLASSIFICATION OF WATERS.

COMPOSITION OF WATERS.

Most surface and underground water is derived from rainfall. Rain-water is quite pure, with the exception of a little ammonia, possibly nitrates and nitrites, and a small amount of carbonic acid, oxygen, and nitrogen gathered from the air. Directly this falls upon the ground it begins to decompose the rock and soil, and carries off some of their constituents in a soluble form. Its action is the more effective, the greater the amount of carbon dioxide which it contains.

River-waters which act upon the rocks for a comparatively short time, are only slightly concentrated, but their composition is a direct index of the geological nature of the country through which they pass. Underground waters, on the other hand, which in percolating through the rocks have had more chance to act upon them, are invariably more concentrated than river waters. These waters vary greatly in their composition and the uses to which they are put.

The healing powers of mineral springs depend upon the salts which they contain and which thay have dissolved from the rocks in the process of underground circulation. These waters are generally very concentrated and their specific healing power depends upon the presence of some special salt or combinations of salts. For further information on this subject reference may be made to "Mineral waters of the United States of America, and their therapeutic uses" by J. K. Croll. There is only one well in Montreal with salt concentration high enough for it to be considered as a mineral water. This is well No. 88 with a salt concentration of 530 grains per gallon.

As the salt concentration in Montreal waters is on the average only about 40 grains per gallon, many of these are very suitable as drinking waters. To determine whether a water is suitable for drinking and other commercial purposes a bacteriological examination is always made and also a determination of the total salt content. Usually together with these the so-called hardness is determined.

By testing the frothing power of water, a rough estimate can be made of its calcium content. Soap consists of the sodium salt of a fatty acid and its property of frothing depends on the fact that it is slightly hydrolyzed in solution and that there is a little of the free fatty acid present. If a calcium salt is present, however, it forms an insoluble compound with the fatty acid and prevents frothing. If there is free sodium carbonate present in the water, the above test is not reliable, however, and this applies to most Montreal waters. The above types of analyses are not of much use for the purposes of this report, beyond occasionally indicating a relationship.

In order to determine the best method of treating water if it is to be used for boiler feed water, it is necessary to determine the salt composition, and for this purpose especially and for other purposes as well, it is customary to determine the six most important constituents of the dissolved salts, namely sodium, magnesium, calcium, chloride (Cl), sulphate (SO_4) and carbonate (CO_3). Silica is often determined, but it usually occurs only in small amounts, and no use has been made of the silica determinations in this report.

In stating the results of an analysis, a chemist generally combines the above radicles in hypothetical combinations. There are some forty different ways of doing this and of expressing the results but the most common way is as follows: first the sodium is united with chloride (Cl). After this, any remaining sodium is united with sulphate (SO_4). The remaining acids are combined with magnesium and calcium in the order named.

The engineer has long held to these methods as it enables him to see the amount of various substances to be added to a water to fit it for various commercial uses. It is certainly without scientific meaning, however, for in an ordinary dilute solution, such as these underground waters are, a salt is believed to be entirely broken up into its constituent acidic and basic parts, that is, into *ions*, or as they are also termed, *radicles*.

In the cases of the various available analyses of Montreal well waters it has been necessary for purpose of comparison to reduce all the analyses to the same form; consequently a re-calculation has been made of all the analyses and in each case the amount of the six main constituents is stated.

A method of comparison has been devised based on the method of stating analyses adopted by Chase Palmer in a bulletin, titled "The geochemical interpretation of water analyses" and published by the United States Geological Survey. Instead of comparing the physical weights of the radicles, the *reacting* values are determined as proposed by Palmer and used as a basis for comparative purposes.

The relative proportion in which the six main constituents combine with one another, is well known and is the *equivalent combining weight*. Thus, two atoms of sodium will combine with two atoms of chloride (Cl), or one molecule of carbonate (CO_3), or one molecule of sulphate (SO_4). The relative weights of 2 atoms of sodium, 2 atoms of chloride, 1 molecule of carbonate, and 1 molecule of sulphate, are as, 23: 35·5: 30: 48. That is, 23 parts by weight of sodium will unite either with 35·5 parts by weight of chloride, or 30 of carbonate, or 48 of sulphate. These values, 23, 35·5, 30, and 48, are the *equivalent combining weights* of, respectively, sodium, chloride, carbonate, and sulphate. If, then, in the case of any analyses the physical weights of the constituents are divided by their respective *equivalent combining weights*, the resultant values will express the relative number of atoms or molecules of the various constituents present. These values for the relative numbers of atoms or molecules, are termed the *reacting values*. In other words, by this method instead of expressing the amount of each constituent by its physical weight, it is expressed as the number of "individuals" (atoms, molecules) of each constituent present. In any analyses so stated, the total number of "individuals" of the bases or positive radicles (sodium, magnesium calcium, etc.) is exactly the same as the total number of "individuals" of the acids or negative radicles (chloride, carbonate, sulphate, etc).

The following table gives the ***equivalent combining weights***, and the ***reaction coefficents***, of each of the six main constituents, the latter being merely the reciprocal of the former.

	Atomic or molecular weight	Equivalent combining weight	Reaction coefficient
Sodium (Na)........	23	23	0·0435
Magnesium (Mg)....	24·32	12·16	0·0822
Calcium (Ca).......	40·09	20·04	0·0499
Chloride (Cl)........	35·5	35·5	0·0282
Sulphate (SO_4)......	96	48	0·0208
Carbonate (CO_3)....	60	30	0·0333

In order that the procedure following may be understood, the calculations relating to the analyses of the water from well No. 154, are herewith reproduced.

Analysis of water from well No. 154.

	grains per gal.
Calcium carbonate ($CaCO_3$)........................	4·50
Magnesium carbonate ($MgCO_3$)....................	5·41
Sodium carbonate (Na_2CO_3)......................	13·34
Sodium sulphate (Na_2SO_4).......................	13·37
Sodium chloride (NaCl)...........................	3·99
	40·61

Atomic and molecular weights.

Atomic weights	
Ca...........................	40
Mg...........................	24
Na...........................	23
Cl...........................	35·5
C...........................	12
S...........................	32
O...........................	16

Molecular weights	
$CaCO_3$......................	100
$MgCO_3$......................	84
Na_2CO_3......................	106
Na_2SO_4......................	142
NaCl.........................	58·5

Calculation of ionic concentration.

4·50 grains of $CaCO_3$ contain $\frac{40}{100} \times 4\cdot50$ or 1·8 grains of Ca;

and, therefore, 4·50−1·8 or 2·7 grains of CO_3.

5·41 grains of $MgCO_3$ contain $\frac{24}{84} \times 5\cdot41$, or 1·57 grains of Mg;

and, therefore, 5·41−1·57 or 3·84 grains of CO_3.

13·34 grains of Na_2CO_3 contain $\frac{46}{106} \times 13·34$, or 5·89 grains of Na;
and, therefore 13·34 − 5·89, or 7·45 grains of CO_3.

13·37 grains of Na_2SO_4 contain $\frac{46}{142} \times 13·37$, or 4·27 grains of Na;
and, therefore, 13·37 − 4·27, or 9·10 grains of SO_4.

3·99 grains of NaCl contain $\frac{23}{58·5} \times 3·99$, or 1·55 grains of Na;
and, therefore, 3·99 − 1·55, or 2·44 grains of Cl.

This gives, in all:

Ca	1·80	grains per gallon.
Mg	1·57	"
Na	11·71	"
CO_3	13·99	"
SO_4	9·10	"
Cl	2·44	"
	40·61	

Each of the above values is multiplied by the proper *reaction* coefficient, as given in a preceding table, in order to convert the physical weights into *reacting values*. The results are as follows:

Ca	0·90	
Mg	1·29	
Na	5·07	
		7·26
CO_3	4·68	
SO_4	1·89	
Cl	0·69	
		7·26

In order that different analyses may be more readily compared as regards their chemical nature, the reacting values are expressed as parts in 100. The final statement of the analyses then, is as follows:

Ca	6·20	
Mg	8·88	
Na	34·92	
		50·00
CO_3	32·33	
SO_4	13·02	
Cl	4·75	
	100·00	50·00

An advantage of this method of stating the results of analyses lies in its suitability for a graphical representation

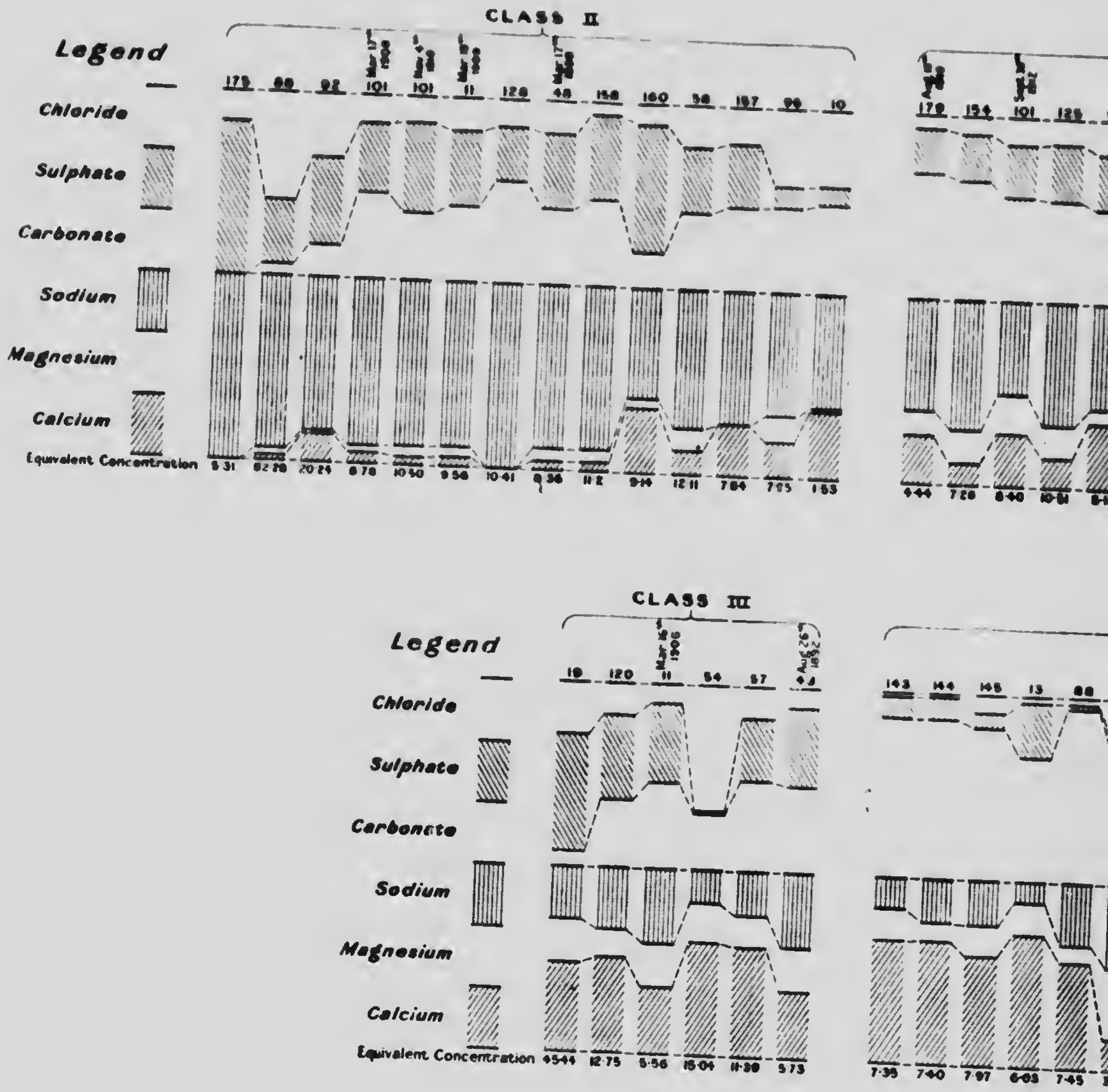

Figure 1. Illustrates chemical characters of un

eters of underground waters of Montreal.

of the analyses. Figures 1, 2, and 4 show the way this has been done and a discussion of the results, later, with the use of these figures will demonstrate its advantage.

In these figures every analysis is represented by a vertical line of constant length and the six main radicles are represented by divisions of this line whose lengths are proportional to the respective reacting values of the radicles. The three basic radicles are represented by the lower half of the line, the three acid radicles by the upper half, and, the two parts are necessarily equal, for as indicated above, a given reacting value of basic radicles must always have the same reacting value of acid radicles to combine with it.

By this method all the analyses are represented as though the concentrations were equal and the figures merely compare the relative proportions of the constituents in the salt content of the water. The equivalent concentration is, however, written below each column and so the concentrations are easily compared.

This graphical method has been modified in order to show on the accompanying map the areal distribution of the different chemical types of the waters. A circle is employed with an annulus around it which should theoretically have the same area as the circle. But it is found that the facts are brought out more clearly by making the area of the annulus larger than that of the circle. The bases are represented by sectors of the circle and the acids by sectors of the annulus in each case divided up according to the relative proportions of the different radicles present. The acids and bases are arrayed side by side in the order in which they are usually combined in a commercial analysis, which order has been stated above. It may be emphasized that there is no need to combine them in this way, but it is advantageous as it is possible to at once see from the table whether a water contains "free" sodium carbonate or calcium sulphate or anything else.

CLASSIFICATION OF WATERS.

Sterry Hunt[1] thought of two types of spring water as originating in the Palæozoic rocks of eastern Canada: on the one

[1] Vide Geology of Canada, 1863, p. 562.

hand, a water coming from the deeper, dominantly calcareous strata, and high in "strong" acids to the exclusion of carbonate; and on the other hand, an alkaline water high in sodium carbonate and coming from the argillaceous strata of the higher divisions of the Palæozoic. These two extreme types belong to his classes 1 and 4 and by mixing together in different proportions they were thought to produce waters of his classes 2 and 3. Four of Sterry Hunts typical water analyses, one from each class, A, B, C, D, respectively, have been worked out by the method described above and are shown graphically in Figure 2. It is at once evident, however, from Figure 2, that B and C come much too close together to warrant any subdivision into classes based on these. A great deal of importance was placed by Sterry Hunt upon the degree of concentration of the waters, but in this memoir for reasons discussed, more especially

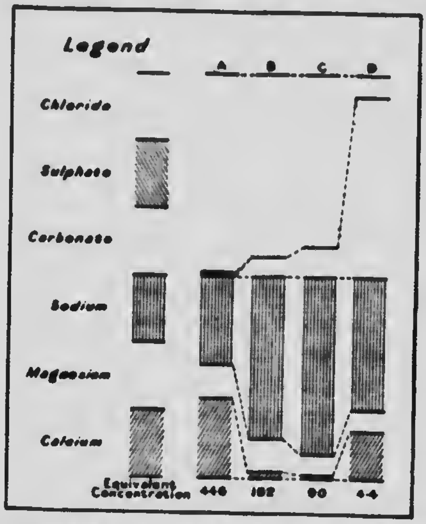

Figure 2. Illustrates compositions of four waters, typical of Sterry Hunt's four main classes of water.

in the following chapter, not so much significance is attached to it. Further, Sterry Hunt did not distinguish between calcium and sodium waters as such and these will be shown to have distinct and independent origins in Montreal.

Another method of classification has been used by Chase Palmer (Bull. 479, U.S.G.S.). His analyses are recalculated in much the same way as has been done above and his classes are divided as follows:

Class I. Strong acids less than alkalis and, therefore, free sodium carbonate present.

Class II. Strong acids equal to alkalis.

Class III. Strong acids greater than alkalis and less than bases.

Class IV. Strong acids equal to bases.

Class V. Strong acids greater than bases.

In this system more importance is placed on the relative amounts of acid and basic constituents present rather than on the actual amounts. The majority of the Montreal waters as they contain free sodium carbonate fall into class I, and the method brings, for example, into the same class wells like those of the Molson Park estate, Nos. 143 to 145, on the one hand, and on the other hand a well like the Laurentian Bath well No. 48, but these are manifestly quite different waters both commercially and scientifically. Again, Warden King's well No. 175 is the only one which falls into class 4, and the Viauville well No. 88 falls into class 2. As shown later there is no justification for such a separation. One point must be admitted, that this method brings the Outremont wells with free calcium sulphate and well No. 54 all into class 3, whereas these wells are separated in the scheme of classification advocated on following pages of this report. Nevertheless Palmer's method is an arbitrary system of classification and not a natural one. The system now proposed is one which naturally develops itself and as will be presently pointed out, any disadvantages it possesses, it has in common with all schemes for making hard and fast divisions in nature.

It will be shown in chapter IV that the following different classes of water characterize different areas in Montreal and that mixtures of them in various proportions would give rise to the various artesian waters of the city:

Sodium carbonate waters.

Sodium sulphate and sodium chloride waters.

Calcium sulphate waters.
Calcium chloride waters.
Calcium carbonate waters.

Figure 3 has been devised to show how Montreal waters may be considered as mixtures of these different types. In this figure the abscissae represent the percentages of carbonate ions

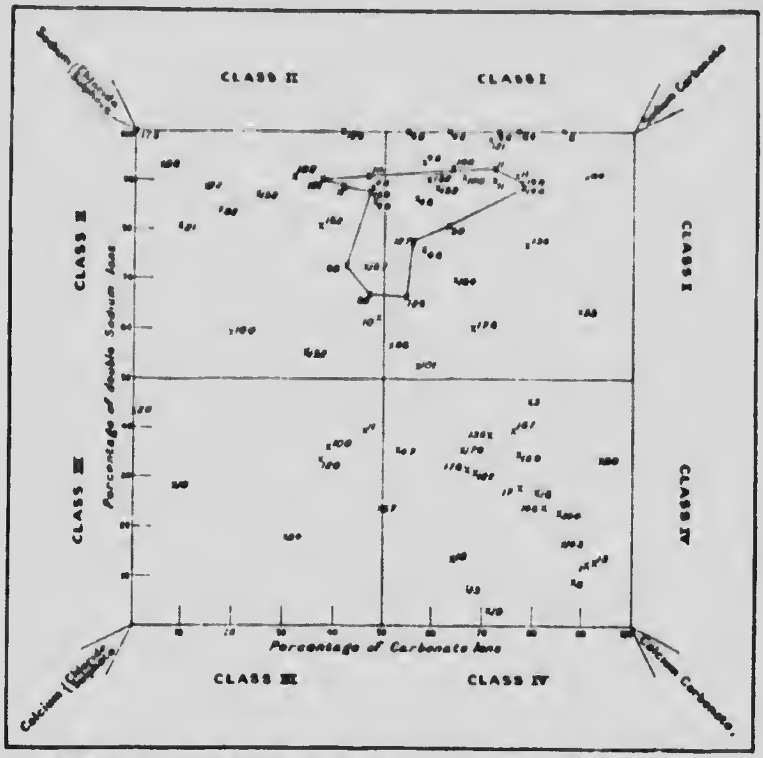

Figure 3. Classification of the underground waters of Montreal.

and the ordinates the percentages of double sodium ions. Consequently the four corners of the diagram represent respectively the following types of water:

Sodium carbonate.

Sodium {chloride. / sulphate.}

Calcium / Magnesium {chloride. / sulphate.}

Calcium / Magnesium } carbonate.

The relation between calcium and magnesium will be discussed in chapter IV; generally the calcium is far in excess of the magnesium and no serious error arises from considering them together as has been done. The same is true in the case of potassium as this is estimated in the analysis as sodium and in general the latter is far in excess of the former. The chloride and sulphate should be considered separately, especially in the case of the calcium salts; however, on a plane diagram this is impossible and in studying the diagram it is necessaary to bear this fact in mind.

The figure is divided into four parts by two lines and the waters classified according to the square they fall into. It is useful to make subclasses to indicate the proportion of chlorine to sulphate in a particular water. The classes and subclasses are as follows:

Class I. Sodium carbonate.

Class II.

- Subclass A. Sodium chloride.
- Subclass B. Sodium sulphate.

Class III.

- Subclass A. {Calcium / Magnesium} chloride.
- Subclass B. {Calcium / Magnesium} sulphate.

Class IV. Calcium carbonate.

This scheme of classification brings together into the same class all the waters high in calcium carbonate whether they contain "*free*" sodium carbonate or not. Most of these, moreover, in the diagram lie well within class IV and are not of an intermediate character like the sodium waters.

The waters of the sodium areas in Montreal lie within an area on the diagram delineated by a full line and this area is seen to be intermediate between classes I and II. In other words this means that most of the wells of the sodium area are mixtures of sodium carbonate and sodium sulphate and chloride waters in more or less equal amounts, but most of the wells high in calcium are high in calcium carbonate and not mixtures to the same extent of the carbonate with the strong acid salts.

The waters of wells Nos. 54 and 120, characteristic of the calcium chloride and calcium sulphate areas respectively, fall into class III. The waters of wells Nos. 13 and 160 of the calcium sulphate area, which should belong to the same class, fall into two different classes. This is due to the classifying of the wells by sharp divisions. Figure 3 shows, however, that the waters of these wells, Nos. 13 and 160, are decidedly nearer the calcium chloride and sulphate corner of the figure than the waters of the majority of the other wells.

CHAPTER IV.

DISTRIBUTION AND ORIGIN OF MONTREAL ARTESIAN WATERS.

DISTRIBUTION.

A cursory glance at the map of Montreal on which the chemical compositions of the waters of the various wells are represented, brings out the following points which in their practical aspects have already been treated of in chapter I.

The majority of the waters are high in sodium; but there are two areas in the city—one northwest of the mountain in Outremont and one southeast of the mountain—where the waters are high in calcium. But in the former area the waters are high in sulphate, while in the latter area they are high in chloride.

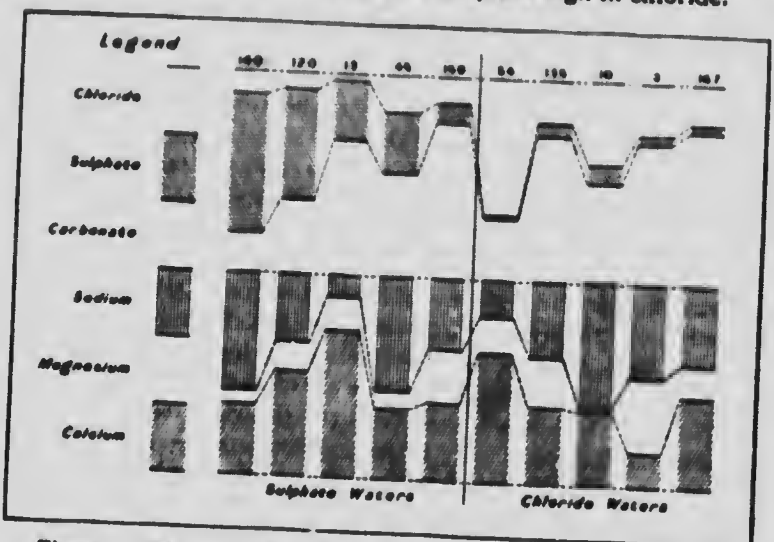

Figure 4. Illustrates character of waters from the two calcium areas of Montreal.

In Figure 4 the character of the waters in the two areas can be conveniently compared. In the case of wells Nos. 160, 120, and 13 which are characteristic of the calcium sulphate area, the high content in calcium is apparent and also the preponderance of sulphate over the chloride. The case of well No. 159 will be referred to later on. The waters of wells Nos. 54, 135, 10, 3, and 167 are typical of the calcium chloride area. Their high content in calcium is at once evident and also the preponderance of the chloride content over the sulphate.

It has already been pointed out that wells with sodium carbonate waters encircle Montreal, reference being made to wells Nos. 134, 150, 154, and 64. Well No. 95 belongs here too, but its water has been "influenced" by its proximity to the calcium sulphate area. What happens, however, when different waters mix will be discussed in detail later.

On examination, the sodium waters in the city are seen to be generally higher in strong acids than those just mentioned above as being on the outskirts and which are high in carbonate. There is one large area of sodium wells extending east of the mountain out to Maisonneuve and another area separated from the former by the calcium chloride area south of the mountain.

There are two places where waters arise which have a very high content in strong acids. One of these is in Maisonneuve and is typified by wells Nos. 88 and 175, and the other is in the area to the south of the calcium chloride area, and is typified by wells Nos. 92 and 129.

In Maisonneuve there are two different kinds of water: one struck near the surface and high in sodium carbonate, and the other struck lower down and high in sodium chloride and sulphate, and charged with sulphuretted hydrogen. In well No. 88, the lower saline water was struck at 1,190 feet, but in well No. 172 the normal water was struck at 95 feet while the saline water was found at 340 feet. The saline water appears, therefore, to come from lower down than the other. To these broad generalizations there are seen to be three rather marked exceptions in the cases of wells Nos. 57, 37, and 47 which are high in calcium. Figure 1 shows the similarity of the waters of wells Nos. 47 and 57 and wherein the water of well No. 57 differs from that of well No. 101, an ordinary sodium water which is situated quite close to well No. 57. The water of well No. 49 was described as being too hard for use in boilers and is, therefore, probably high in calcium and exceptionional too. Well No. 37 is remarkable as it is so close to well No. 6, the latter with a water very high in sodium, while the former is described as yielding water containing mostly calcium and magnesium sulphates. There seems to be a "*calcium influence*" in this neighbourhood causing the wells to be high in calcium. This area lies on the south side of an area which in Chapter I has been described as an unfavourable area for boring wells. Perhaps there is some connexion between these two facts.

The one analysis of the Laurentian Spring water shown in Figure 1 which varies most from the others, is very like that of these two wells. Perhaps on this one occasion the water came under the "*calcium influence*". For the same reason it is to be expected that more analyses of well No. 50 would show the effect, occasionally at any rate, of its proximity to this "*calcium influence*".

ORIGIN.

There are two distinct problems to be discussed here: first the origin of the water itself and second the origin of its salts.

The origin of the water has already been discussed on pages 12-14, Chapter II and the conclusion was there arrived at that most of the water originated from rain falling on the Laurentian highlands and the St. Lawrence lowlands, and it was impossible to say what is the proportionate part played by each of these sources.

With regard to the contained salts it has been shown that, in a general way, different areas in Montreal are characterized by chemically distinct types of water and this feature suggests that the various main types have originated in different places. The following are the six types to which reference is made: calcium sulphate, calcium chloride, sodium chloride, sodium sulphate, sodium carbonate, and calcium carbonate waters. Waters which contain approximately only one of the above six constituents are called in this report *pure types;* and it is believed that all other Montreal waters are *mixed types* formed by the mixing in varying proportions of two or more of these pure types.

Montreal well waters are almost unique for the reason that, although they arise from sedimentary rocks, they are so high in *sodium carbonate*. All over the eastern United States it is a common phenomenon for spring waters to contain all of the other constituents mentioned above, but a high content of sodium carbonate is very rare in waters rising from sedimentary rocks. There are a few instances as in Missouri where such waters arise from Carboniferous limestone.[1]

The Ottawa River water is remarkable among river waters for its high sodium content and according to R. A. Daly, it drains a greater area of Pre-Cambrian rocks than any other known river.

This analogy in respect to their high sodium content between the artesian waters of Montreal and the Ottawa, is certainly striking and suggests the possibility of a similar origin. According to this the part of the water which came from the Laurentian Highlands brought sodium carbonate with it and thus caused the high content of sodium carbonate in Montreal artesian waters. Of course, the Ottawa River water is much more dilute than the Montreal well waters; but nevertheless the waters, which, according to this theory, sink into the crystalline rocks of the Laurentian Highlands and ultimately find their way underground to Montreal, might have acted longer on the crystalline rocks than the water of the Ottawa river and would be expected to be more concentrated. This underground water on its way from the Laurentian Highlands, after leaving the crystalline rocks, would circulate for a long distance through limestone; but if it originally contained a high content in sodium carbonate it is not to be expected that the limestone would be dissolved, for limestone is not soluble in sodium carbonate water and a sodium carbonate water would even precipitate calcium carbonate if it came into contact with waters containing any.

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[1] Lindgren, Mineral Deposits, p. 59.

Another point which favours the common origin for part of the water and its dissolved sodium carbonate, is the fact already mentioned, that sodium carbonate waters surround Montreal. The sodium carbonate is different from the other salts in the Montreal waters in that unlike these it does not seem to arise from any definite areas, for sodium carbonate waters appear rather to "*bathe*" all the rocks.

The above theory as to the origin of the sodium carbonate in the waters can only be substantiated when analyses of waters from artesian wells in the St. Lawrence lowlands are obtained. It will also be necessary to make analyses of waters from districts so far away from Montreal that there can be no connexion between the salt content of the waters and the igneous rocks of the mountain and especially the multitude of dykes which cut the sediments around it.

Another theory as to the origin of the sodium carbonate, which suits the facts equally well and which in the present state of our knowledge appears to the author to be the more satisfactory of the two, attributes the content of sodium carbonate in the waters to the dyke rocks which intrude the sediments around Mount Royal. These dyke rocks are rather exceptional in the more than usual amount of sodium which they contain. In boring wells these dykes are continually encountered, sometimes fresh but more often in an altered state; and all the wells whose analyses are at present attainable, occur within an area whose rocks are intersected by these dyke rocks.

In summation, then, it is probable that water falling as rain, and derived partly from the Laurentian highlands and partly from the St. Lawrence lowlands, when it reaches Montreal acts upon and decomposes the dyke rocks and thereby gains its content of sodium carbonate. Even if this water originally contained calcium carbonate, as it must, the latter would be largely precipitated by the sodium carbonate derived from the dyke rocks.

With regard to the origin of the *sodium chloride* and *sodium sulphate*, and the *calcium chloride* and *calcium sulphate*, it has been already pointed out that waters containing them appear to arise locally in certain parts of Montreal and this makes impossible any origin consanguineous with the water in a far off source as might be the case with sodium carbonate.

These salts are certainly present in the rocks beneath Montreal and the artesian waters dissolve these salts from the rocks as they percolate through them and thus serve to show the salt content of the rocks from which these waters arise. The distribution of the artesian waters according to their chemical content indicates also a distribution of these salts in the crust of the earth. There are several possibilities with regard to their origin.

(1). They might, for instance, be derived in part from salt beds deposited at the same time as the sediments. In many parts of the United States and Canada, springs containing calcium and sodium chlorides and sulphates, arise from Silurian strata where there are known to be salt beds. At Montreal, however, the rocks are all lower than Silurian and the existence of salt beds in these is extremely unlikely so that this explanation might be disregarded.

(2). When sediments are deposited beneath the sea, some of the sea water or the salts it contains may be occluded within the pores of the sedimentary rocks; but the laws governing this are not well understood. A. C. Lane[1] showed that in the deep copper mines of Michigan, the normal potable types of water descend in diminishing quantities to depths of 1,500 feet beneath the surface. Below this, moisture is scant, but where it appears it consists of drippings of strong calcium chloride brine which is supposed to have been occluded in the rocks when they were deposited, and it is called *connate* water.

According to this theory an explanation as to the distribution of the different salts is still demanded. Though the sodium chloride and sodium sulphate occur more or less together, yet the calcium chloride and calcium sulphate occur in two areas sharply separated which indicates that these salts were occluded at different times or under different conditions.

This distribution could be explained according to the first theory as due to the evaporation of sea water, but, as shown above,

[1] Trans. Lake Sup. Min. Inst., vol. 12, 1908, pp. 154–163.

this theory is untenable. The laws governing the process of occlusion are not known, but it seems possible that there should be an order of this kind in the process of separation of the different salts. This theory cannot be disproved and is quite possible; but at Montreal, however, there is another possibility which from the facts to hand seems much more probable.

(3). The salts may have been injected into the sedimentary rocks at the time of the intrusion of the igneous rocks of Mount Royal. The relation of the different areas to the central core of Mount Royal is suggestive of some connexion between the two. The area of calcium sulphate waters is a lenticular area stretching from the mountain northward; the calcium chloride area is a more rounded one to the southeast; and between the two a sodium area stretches outward from the mountain. Mineral springs are very commonly associated with volcanic intrusions, especially in the dying down stages of volcanic activity; it is altogether probable that such existed at Montreal and that they have left behind in the sediments some of their salt contents. It may be emphasized that Mount Royal is a very ancient volcano; and that it has been quiescent for many geological epochs; and that no suggestion is made of there being mineral springs at the present day associated with the dying down phases of volcanic activity.

There are no ore deposits in connexion with the igneous rocks of Mount Royal, but there are several facts which make it likely that non-metallic salts originated with these rocks.

In boring the railway tunnel through the mountain a perfect network[1] of veins of gypsum was found in the igneous rock. Fluorspar, too, was very common and also pyrite. The calcium of the various minerals may have been derived from the limestone, but the sulphate, whether it was derived from sulphur, sulphuric acid or pyrite, and certainly the fluorine both owe their origin to the igneous rock. Since fluorine vapours appear to have been evolved, it is very probable that chlorine also was given off, especially as chlorine is of common occurrence in volcanic regions at the present day. The more than

[1] Oral communication from Dr. J. A. Bancroft.

usual abundance of sodalite minerals in the nepheline syenite of Mount Royal makes the occurrence of chlorine vapours still more probable. It is not to be expected that calcium chloride resulting from the action of chlorine vapours would be found like fluorspar near the surface at the present day because it is extremely soluble. Nevertheless, it is not unlikely that deep down in the earth, calcium chloride still exists, that it was formed there many geological epochs back either by the agency of mineral springs or perhaps by chlorine vapours emanating from the igneous rocks and acting directly on the limestone, and that waters circulating through the rock to-day are gradually dissolving it. The exceptionally high percentage of soda in the igneous rocks at Montreal makes it extremely probable also that sodium chloride and sulphate were present in the magmatic waters.

On the whole this third explanation seems the most probable and it is assumed, therefore, that the sodium and calcium chlorides and sulphates came up with the igneous rock and were distributed in the surrounding sediments in part possibly by water which itself was of magmatic origin.

To the sodium carbonate a different origin has been attributed. Some of it may have been formed like these sodium and calcium salts at the time of the volcanic activity of Mount Royal; but nevertheless since it differs from these salts in being more generally distributed and in never occurring in a condition of rather high concentration, and since unlike these it is exceptional to find it in artesian waters, it is more probable that the greater part of it has some rather exceptional origin distinct from that of these salts.

The whole problem of the origin of the salts at Montreal cannot be definitely settled until there are available analyses of well waters which are outside Montreal, and outside of the region of the intrusion of dykes and of the sphere of influence of the volcanic rocks of Mount Royal.

With regard to sodium chloride and sodium sulphate waters, a possibility exists that these were formed by a process of double decomposition when sodium carbonate waters came into contact with calcium chloride and calcium sulphate waters respectively, thus:

$Na_2CO_3 + CaCl_2 = 2\ NaCl + CaCO_3$

$Na_2CO_3 + CaSO_4 = Na_2SO_4 + CaCO_3$

The calcium carbonate is insoluble unless an excess of CO_2 is present and would be precipitated. To a certain extent this takes place and certain interesting facts will be brought out later in connexion with the mixing of different kinds of waters. But that this is not the main source of sodium chloride and sodium sulphate waters the following facts make plain.

In the northwest of the large sodium area to the east of the mountain where sodium carbonate waters come into contact with calcium sulphate waters, the characteristic sodium salt is not sodium sulphate as would be expected according to the above theory but sodium chloride; and similarly in the southwest of the same area where sodium carbonate waters and calcium chloride waters should intermingle, sodium sulphate waters appear and not sodium chloride. Later it will be pointed out how this sulphate content has even influenced the chloride content of some of the neighbouring calcium waters.

There must be then separate sources for sodium chloride and sodium sulphate. Moreover, this hypothesis is borne out by the waters of Maisonneuve where we have seen that at depths saline waters arise charged with the strong acid salts of sodium. On the west side of the calcium chloride area again is another area where highly saline waters arise charged with sodium sulphate and chloride as well No. 92 indicates.

It might be thought that the water of the calcium sulphate and calcium chloride areas were derived from this saline water high in sodium chloride and sulphate by the latter salts acting upon limestone and dissolving it thus:

$2\ NaCl + CaCO_3 = CaCl_2 + Na_2CO_3$

$Na_2SO_4 + CaCO_3 = CaSO_4 + Na_2CO_3$

This does not appear at all probable, firstly, because of the relation between sulphate and chloride in the northwest and southwest of the large sodium area, pointed out above, and secondly, because in the above double decomposition there is no known means of getting rid of the sodium carbonate and such a water as that of well No. 54 is, therefore, impossible. Furthermore the facts of the distribution of the waters and the high concentration especially of well No. 54 which is so high in calcium chloride, suggest very forcibly a definite area of origin for calcium chloride. By analogy the same thing appears probable for calcium sulphate.

Some waters are characterized by being high in *calcium carbonate*. These waters probably arise in two distinct ways: they partly arise by the mixing of other types of waters and are partly original. The calcium carbonate water of the Molson Park wells, Nos. 143 to 145, is shown later to be probably derived by the mixing of calcium sulphate waters with sodium carbonate waters re-acting according to the equation:

$$Na_2CO_3 + CaSO_4 = Na_2SO_4 + CaCO_3$$

sodium sulphate formed in the double decomposition being subsequently removed.

On the other hand several shallow springs have a high content in calcium carbonate e.g. Westmount springs, Outremont springs, and water struck while making the foundation to Mr. Sharpe's house on Lansdowne avenue. In these cases the calcium carbonate water is probably original and derived from a direct solution of the limestone by water which may have originated from a nearer source than that of the ordinary wells and has not percolated through the earth so far as the latter.

To sum up the conclusions under this head:

Montreal underground water is derived from the Laurentian highlands and St. Lawrence lowlands and to what extent each of these source contributes its share, is unknown.

Its salt content is largely sodium carbonate which is probably derived from dyke rocks cutting the limestone.

It also derives a content in sodium chloride and sodium sulphate and calcium sulphate and calcium chloride from the rocks, and these salts were probably injected into the sediments at the time of the intrusion of the igneous rock of Mount Royal. Its calcium carbonate content is derived partly from a direct solution of the limestone and partly from a double decomposition of some of the above salts, when waters containing them in solution mingle with one another.

Occurrence and Origin of Sulphuretted Hydrogen.

No very definite rules can be laid down with regard to the occurrence of sulphuretted hydrogen. The more saline waters generally contain it in greatest abundance as wells Nos. 88, 92, and 54 testify. Well No. 13, which is characteristic of the calcium sulphate area, is also sulphurous. Sodium carbonate water does not seem to be sulphurous, but its sulphurous content appears when it is mixed with the saline waters which arise from below.

It is a common observation that sulphuretted hydrogen often accumulates in a well water when it is left for any time without pumping; and again several waters which were highly charged with the gas when first struck, lost a large part of this on standing.

It may not be a coincidence that wells Nos. 54, 135, and 104 are highly charged with sulphuretted hydrogen and that these occur in two regions where many unsuccessful borings have been put down. It may be that near these dry areas a state of stagnation of the water exists and this causes the gas to accumulate.

The sulphuretted hydrogen probably arises from the reduction of sulphates by organic matter occurring quite commonly in the Trenton limestone which is sometimes black in consequence. It may be pointed out, however, that not only calcium sulphate but also sodium sulphate may be reduced in this way as is evidenced by the high content of sulphuretted hydrogen in waters charged with sodium chloride and sulphate.

"Spheres of Influence" and the Intermingling of the Pure Water Types.

The existence then of several types of waters has been well established and the following are illustrations of Montreal waters which approximate these pure types:

Sodium Carbonate.

No. 64. Montreal Locomotive Works.
No. 154. S. Nesbitt.
No. 134. Lower Canada College.

Sodium Sulphate.
No. 175. Warden King.

Sodium Chloride.
No. 88. Viauville Mineral spring.

Calcium Carbonate.
Nos. 143-145. Molson Park estate.
Outremont Springs.
Westmount Springs.

Calcium Sulphate.
No. 13. C.P.R. Outremont.
No. 120. Frontenac brewery.

Calcium Chloride.
No. 54. A. S. and W. H. Masterman.

In discussing previously the origin of these waters, the relation which they bear to one another was explained. It was there shown that there were certain areas characterized by the presence of the chlorides and sulphates of sodium and calcium and that calcium carbonate and sodium carbonate were more or less universally distributed. When the water which comes from the Laurentian highlands and St. Lawrence lowlands reaches Montreal it dissolves these salts in varying amounts and what happens when the different kinds of waters mix with one another will now be discussed. There are some specially interesting phenomena to be noted on the boundaries of the areas characterized by the presence of particular salts.

In the first place it happens in only a few cases that waters occur transitional with respect to their mineral constituents and their concentration. For example, the relation between wells 54, 135, and 89 is well brought out by Figure 1. Well No. 54 is the type well of the calcium chloride area. This area is bounded by a sodium area on both the east and the west. Well No. 135 is to the east of well No. 54, and well No. 89 to the west; well No. 135 is seen to be intermediate in character between No. 54 and No. 89, especially in regard to the carbonate and chloride content and ratio. This is to be expected since well No. 135 is nearer than well No. 89 to well No. 54.

Again well No. 95 is more or less transitional between a sodium carbonate area to the west and the calcium sulphate area to the east.

The Y.M.C.A. well No. 179 is an extremely interesting case for it demonstrates that on the boundaries between two areas the transitional character of the water is caused to a certain extent at any rate, by an intermingling of two different kinds of waters rather than by a solution of salts already intermingled in the country rock. This well occurs on the boundary between a sodium area and the calcium chloride area south of the mountain. Water was struck at two levels. The upper one was high in sodium and obviously belongs to the sodium area; the lower water was high in calcium and is almost identical with the water of the Windsor Hotel well No. 178 which is high in calcium and within the calcium chloride area. There is evidence that indicates that these two wells are actually connected, for the water in the Y.M.C.A. well normally stands at 10 feet below the surface, but, on the day pumping was started at the Windsor Hotel well, the water level was noticed to have fallen 30 feet below the surface. This intermediate character of the Y.M.C.A. water is well brought out in Figure 3 in which one water is seen to approach the sodium carbonate type and the other water to resemble wells like Nos. 122, 178, and 135 with their high content in calcium derived from the calcium chloride area.

On the boundaries between areas typified by the presence of a distinct salt, completely transitional forms are not found but generally the influence of either the acid or the basic part of one of the salts upon the other salt is very pronounced, whilst the influence of the other part of the salt is not apparent.

The Molson Park Estate wells Nos. 143 to 145 contain water high in calcium carbonate. Their proximity to the calcium sulphate area makes it extremely probable that they derive their high calcium content from this source, otherwise the coincidence would be rather remarkable. These wells are near wells containing sodium carbonate and some sodium sulphate and the calcium carbonate they contain may be supposed derived by a double decomposition on mixing of these two kinds of waters as represented by the following equation:

$Na_2CO_3+CaSO_4 = Na_2SO_4+CaCO_3$

If there is any excess of CO_2 in the water the calcium carbonate would remain in solution, but it is necessary to get rid of the sodium sulphate and there is no known process for doing this.

A si ar difficulty, however, arises in other cases. Well No. 122 is another instance of a water very high in calcium carbonate and where it must be assumed that the high calcium content is derived from calcium chloride, and that the calcium carbonate content arises from a double decomposition according to the equation:

$CaCl_2+Na_2CO_3 = CaCO_3+2\ NaCl.$

In this case a means of getting rid of soluble sodium chloride is demanded.

Again, it has been pointed out already that in the region east of Mount Royal, the sodium area is characterized by waters high in sodium sulphate, wells Nos. 157, 30, and the Y.M.C.A. water which is high in sodium are here referred to. An examination of the analyses of the waters of wells in proximity to these which are high in calcium, shows that in these too the sulphate predominates over the chloride, wells Nos. 122, 157, 178, and the other analyses of the Y.M.C.A. well No. 179 may be referred to in this connexion.

In other words these wells may be regarded as having acquired their high calcium content from the calcium chloride area but have "*come under the influence of*" the high sulphate of the sodium area to the northwest and the usual relations between sulphate and chloride have been reversed.

It must be confessed that no chemical explanation can be given of this as it necessitates the removal of sodium chloride in some unknown way as the equation for the double decomposition shows:

$CaCl_2+Na_2SO_4 = CaSO_4+2NaCl$

It is sometimes the acid and sometimes the basic influence which remains, regarded from the point of view of the two calcium areas. The Pensionnat well No. 160, for example, retains very markedly the predominance of sulphate over chloride as Figure 4 shows. But its high sodium content shows it to have "*come under the influence of*" the sodium carbonate area. In this case the removal of calcium carbonate is necessary in the process of the double decomposition and this is understandable under suitable conditions. The following is the equation for the double decomposition:

$$CaSO_4 + Na_2CO_3 = Na_2SO_4 + CaCO_3$$

Again wells Nos. 96 and 127 suggest high sodium chloride in the west part of the main sodium area. Well No. 158, however, which still is high in sodium, has been influenced by the high sulphate of the calcium sulphate area. This necessitates the removal of calcium chloride in the double decomposition according to the equation

$$2NaCl + CaSO_4 = Na_2SO_4 + CaCl_2$$

Again well No. 95 has already been referred to as being transitional between a sodium carbonate area and the calcium sulphate area. The preponderance of sulphate over chloride is very evident but at the same time there is a balance between the sodium and calcium contents. This, like well No. 160, involves chiefly the precipitation of calcium carbonate in the double decomposition.

The above facts indicate that in the course of underground circulation there is some means of eliminating certain soluble salts from their solution in water, but there is no forthcoming explanation. But neither is it known how and why potassium[1] is extracted from solution and not sodium when waters containing sodium and potassium salts circulate through soils.

Whether it is a process of absorption or chemical replacement has not yet been definitely established. The laws of adsorption and absorption are little understood[2] but there seems every probability that in the process of underground circulation

[1] Veber den Chemismus der tonigen Sedimente. G. Linck. Geologische Rundschau IV, Heff. 5 and 6, 1913, p. 289.

The effect of water on rock powders: Cushman, U.S. Dept. Agriculture, Bull. 92.

[2] Trouton, F. T., Presidential Address to Physical and Mathematical Sect. A. Brit. Ass. Australia, 1914.

soluble salts may be removed and chemical interactions occur which are as yet unexplainable.

It must be remembered too that these underground solutions are not saturated and in all probability they did not remain in contact with the salt long enough to completely dissolve it, and further the important chemical replacements may occur in the pores of the rock where the water is more nearly stagnant and concentrated and the main flow pick up just a small part of the concentrated portion.

It is very likely that the proportion of free carbon dioxide may play an important part in these chemical interchanges. This proportion is not obtainable for most of the analyses of Montreal waters.

From the above facts a few generalizations of interest may be made.

On the south, west, and east of the calcium sulphate area, the sulphate is found to have "influenced" the surrounding sodium wells, but on the north the carbonate of the sodium area has influenced the calcium wells.

In the calcium chloride area it is the sulphate or carbonate of the surrounding sodium wells which has "influenced" the calcium wells and the chloride of the calcium wells has not influenced the sodium wells.

In this latter case sodium chloride is removed from solution whilst sodium sulphate increases, and to the east of the calcium sulphate area calcium chloride is removed whilst sodium sulphate increases. To the north of the calcium sulphate area sodium sulphate is removed from solution whilst calcium carbonate increases.

In connexion with the highly saline water containing sodium sulphates and chlorides, and which has been shown to arise in two distinct areas around wells No. 88 on the one hand and No. 92 on the other, a very significant inference can be drawn.

Wells Nos. 174 and 175 occur in the same district as well No. 88 and are very remarkable as they contain entirely sodium sulphate and chloride to the total exclusion of calcium and carbonate. Well No. 118 is probably of the same nature too. But whereas well No. 88 is very concentrated and contains 530 grains of salt per gallon these wells only contain 40 grains per gallon which is the normal content for Montreal waters. These well waters, which are of the same chemical nature and occur in the same district and, therefore, have presumably a similar origin, nevertheless have concentrations one of which is ten times as great as the other.

Another instance of the same thing occurs near well No. 92. This is very saline and high in soda and strong acids and has a decidedly high concentration of 130 grains per gallon. Well No. 129 in its neighbourhood is also remarkable in containing soda to the exclusion of all calcium and at the same time being very high in strong acids. The salt concentration of well No. 129 is 80 grains per gallon which is much above the average and belongs to the saline class. It seems almost certain that wells Nos. 92 and 129 must have something to do with one another in the sense that the waters are derived from the same source.

In both of the above cases it is interesting to notice that the sulphate-chloride ratio is higher in the diluter well waters than in the more concentrated ones.

The above facts may be expressed by saying that a change in concentration may occur in the water without any great concomitant change in its composition. This may be due to an irregular distribution of the salts in the rocks or to a change in concentration of the water occurring in the process of the underground circulation.

To sum up then; when the different types of waters intermingle, reactions take place between them and one or more of the products of the interaction is removed. Sometimes the process of removal can be explained on chemical grounds as when sodium carbonate waters act on waters containing calcium and precipitate the latter as insoluble calcium carbonate. Sometimes a soluble salt formed in the process of intermingling is removed, perhaps by some process of absorption in the rock mass. Further, there is some process in the course of underground circulation by which a change of concentration occurs without any great concomitant change in composition.

Amount of Magnesium in the Waters.

So far, any consideration of magnesium has been omitted because it generally occurs in much smaller quantity than calcium and the two are more or less associated. A few very interesting relations, however, have been made out. In this connexion Figure 5 has been constructed in which the abscissae

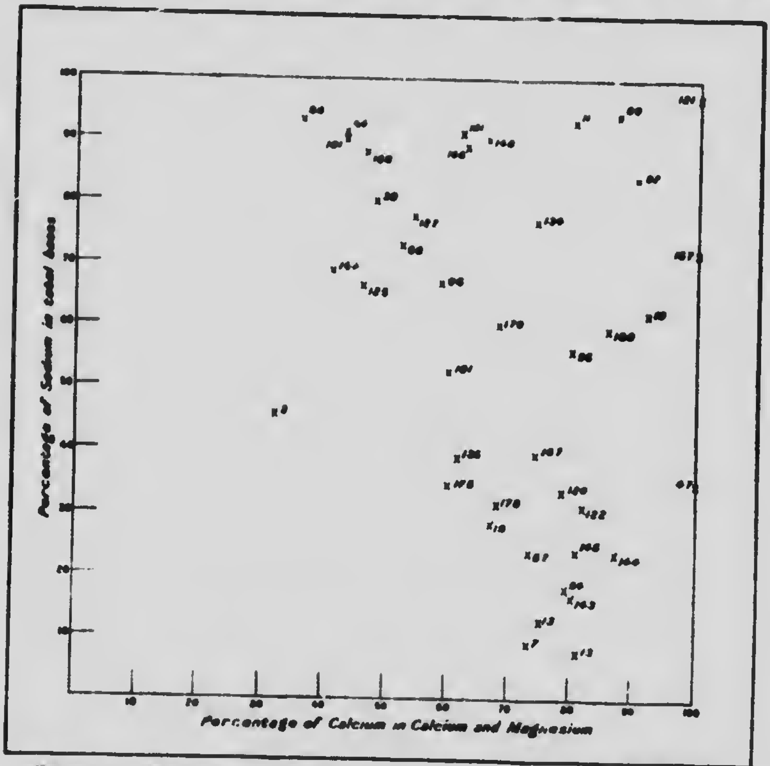

Figure 5. Shows ratios existing between calcium and magnesium and sodium in the underground waters of Montreal.

represent the percentage of calcium in the combined calcium and magnesium content, while the ordinates represent the percentage of sodium in the total bases.

It is at once apparent that starting in the right hand bottom corner the tabulated wells spread out in a V-shaped area and, moreover, there is a decided tendency for the wells to congregate around the line drawn obliquely across the diagram. This indicates that as the proportion of sodium increases in the water the magnesium gains at the expense of the calcium.

Well No. 3 stands out as being a very remarkable exception. Connected with this is a most odd fact best described as a case of chemical piracy. Wells Nos. 89, 92 and 10 and 157 are seen to occupy an exceptional position in the top right hand corner of the diagram and these are all situated near well No. 3 in Montreal. But it must be admitted, however, that No. 167 is quite normal and yet is situated very close to No. 3 and also that the above wells have a curious distribution. Nevertheless, the above curious relation would seem to be more than a coincidence and it looks as if the water of well No. 3 had stolen the magnesium from the waters of wells Nos. 89, 92, 10, and 157, but no explanation can be given of it.

Of the other wells in the right hand top corner of the diagram which show abnormally low magnecium content, well No. 121 contains a very high sodium content indeed, but the chance of error in the chemical analysis in determining the ratio between magnesium and calcium is very considerable. The same thing might be said also for wells Nos. 11, 148, and 146.

Well No. 134 which is low in magnesium is exceptional. It is high in sodium but not so high as No. 121 and occurs on the outskirts of Montreal. Until more analyses are obtained in this part of the city it is impossible to suggest any explanation of the abnormal characters. Wells Nos. 160, 95, 101, and 47 are all low in magnesium content and it is perhaps no coincidence that these wells which stand out in this way, are on the boundary between two different types of water. It has already been shown that the waters of wells Nos. 160 and 95 are produced by the intermingling of sodium carbonate and calcium sulphate waters and that in the process calcium carbonate was deposited. It appears, then, that magnesium carbonate is precipitated at the same time but in greater amount than the calcium carbonate.

As well No. 101 contains much sodium the relation between magnesium and calcium is more uncertain, but it is significant that it too and well No. 47 should appear exceptional and that they are both in a region where a calcium influence arises in a sodium area. The calcium influence here is probably calcium carbonate as has already been shown, but in this case the relations are not so clear as before, since well No. 57 high in calcium is rather high if anything in magnesium, well No. 101 high in sodium is rather low in magnesium, and well No. 47 high in calcium is also low in magnesium. The important thing to notice is that on a boundary between two areas like this, the magnesium ratio is upset.

The fact that well No. 88 is high in magnesium and wells Nos. 92 and No. 54 low, suggests the possibility that magnesium salts are derived from the same source as the saline salts of sodium and calcium and that the wells which arise in the northern sodium area should have a high content in magnesium, while those which arise east of Mount Royal in the sodium and calcium areas, should have a low content in magnesium. A study of Figure 1 shows that in a general way this is the case if the wells Nos. 100, 154, 125, 64, and 146 are contrasted, for example, with the wells Nos. 135, 178, 167, 10, 134, but more analyses are necessary to substantiate any inference of this sort because irregularities occur as in the case of well No. 3 described above.

In summation, the facts at present to hand, show that by a study of the waters in the above manner some very interesting inferences can be drawn with regard to the proportion of magnesium in the waters.

(1.) As the sodium content increases the proportion of magnesium to calcium increases too.

(2.) It is possible some of the magnesium chloride arises from the same source as the saline salts of sodium and calcium and in one area of origination the content of magnesium is high and in the other, low.

(3.) On the boundary between the areas characterized by the pure types of water and where these mingle, the calcium magnesium ratio is often upset and this can sometimes receive a satisfactory chemical explanation.

(4.) A most curious relation described as chemical piracy occurs in one area in which one well seems to have stolen the magnesium from several neighbouring wells.

Potassium in the Waters.

Little can be said regarding the occurrence of potassium as ordinarily this constituent is not determined.

In only four wells has the potassium been determined.

Well 13,	potassium	forms	3·1	per cent of the alkalis.
" 56,	"	"	2·1	" " " " "
" 120,	"	"	2·0	" " " " "
" 10,	"	"	30·0	" " " " "

In three of the four cases, then, the potassium is only 2 or 3 per cent of the sodium and little error arises from considering it as sodium. It is a quite general phenomenon to find potassium lower in artesian waters than in surface waters. For example, in the Ottawa river, Sterry Hunt found the potassium to constitute 25 per cent of the alkalis, and in the St. Lawrence, Dr. Ruttan found it to be 10 per cent. The reason for this relation is that soil or clay or finely divided or colloidal material, has the property of absorbing potassium but not sodium. This fact is of enormous importance in agriculture as the potassium which is much in demand by plants is retained in the soil, and sodium which is of little importance, remains in solution in the waters percolating into the ground. In consequence, underground waters have usually a low content of potassium. The process of absorption of the potassium is not definitely known.

The very exceptional nature of well 10 must be mentioned. It has already been noted as having an exceptionally low content in magnesium. Sodium has been shown to favour on the whole a large magnesium content. Potassium seems here to do the reverse. But whether this is of any significance or whether there is some independent origin in this neighbourhood for waters high in potassium, can only be discovered when more well waters are analysed with regard to their potassium content.

Variations in Composition of the Same Well at Different Times.

An extreme series of analyses extending over a period of years has been obtained for the Laurentian Spring Water well 48 and also for the Canadian Pacific Railway Angus shop wells Nos. 11 and 100.

The analyses are shown graphically in Figure 1.

Considering well No. 48, it is at once apparent that the concentration varies much more than the relative proportion of the constituents—a fact already referred to, to show that the concentration of a water often varies without any accompanying variation in the proportion of the constituents. The proportion between sulphate and chloride remains fairly constant all the way through with one exception. The water which is most dilute, contains the highest amount of carbonate (October, 1892) and the well with the highest amount of strong acids is one of the more concentrated. This seems quite in accordance with the mingling of saline waters from below and dilute sodium carbonate waters higher up.

Turning to the Canadian Pacific Railway wells the remarkable uniformity noticeable in the case of the Laurentian analyses is not quite so noticeable here. Well No. 100 is higher in calcium than well No. 11, its water is more concentrated, and it is the deeper well. The analysis made on December 6, 1911, is very high in calcium and strong acids and has also the highest concentration.

There seems to be, therefore, a calcium sulphate influence in depth, and this is only another illustration of the independence of the constituents as it were and we can speak for example of a sulphate influence or of a calcium influence and only sometimes conjointly of a calcium sulphate influence.

Analyses 11 appears fairly uniform with only one exception.

It is again noticeable here that the concentration varies much more than the relative proportion of the constituents and the analysis with the lowest concentration contains the highest percentage of carbonate. The analysis of March 16, 1908, is exceptional in its large amount of calcium and in that, unlike other areas, the concentration is still low. It is also noticeable that the well with the highest concentration of strong acids is also the most concentrated.

The variations suggest that in time the strong acids increase slightly with respect to the carbonate. In both cases the first analysis of the well water made was the most dilute and contained the most carbonate. I was informed that at the Pensionnat well 161 the hardness increased somewhat with time. Finally it must be admitted that the analyses are perfectly in accord with the view that these waters are mixtures of a rather dilute water containing sodium carbonate on the one hand, and a more saline water on the other hand which arises low down and which is higher in strong acids.

There is a slight indication that on continued pumping this lower water is drawn upon to a greater extent in time.

CHAPTER V.

DESCRIPTIONS OF WELLS.

1.—R. B. Angus, Esq.—Ste. Anne de Bellevue.

This well is 222 feet deep. It has a diameter of 4½ inches and yields 48,000 gallons a day, the water rising to within 12 feet of the surface. The water is said to be of good quality.

2.—Messrs Armstrong and Cook—Cadastral No. 140, subdivision lot 293, Montreal West.

In boring this well water was struck at 350 feet, the flow increasing in quantity with depth. At 500 feet boring operations were discontinued.

Fifty feet of clays and gravels were first penetrated, then 25 feet of a shaly rock possibly an outlier of the Utica. The remainder is a limestone of uniform hardness, and gave sufficient water to keep the drill working easily.

In November 1893, the water was 50 feet below the surface after having been pumped from a depth of 100 feet for 10 hours. In December 1894, the water stood at the 100 foot level after a rest of 6 hours, the pump then being 350 feet from the surface. The water is of good quality, with "traces of iron and sulphur," 10,000 gallons per diem have been pumped.

3.—Messrs Belding, Paul, and Company—On the canal near the Seigneur Street bridge.

The well is 548 feet deep. It is 6 inches in diameter and yields 91,000 gallons per diem. The water rises to within 10 feet of the surface and is hard. The rock was encountered 64 feet from the surface.

The following are the results of an analysis of the water which was made for the company in February 1903:

	Parts per million.	Grains per Imp. gallon.
Calcium carbonate	47	3·29
Magnesium "	90	6·30
Sodium "	35	2·45
" sulphate	17	1·19
" phosphate	17	1·19
" chloride	90	6·30
Silica	10	0·70
Organic matter	80	5·60
	386	27·02

4.—The Bushnell Oil Company—Ville St. Louis.

The well is 305 feet deep. It is in the solid rock and the diameter is 4 inches. The water level is from 20 to 30 feet below the surface and is lowered somewhat on pumping. The water is rather hard, slightly sulphurous, and holds a small amount of suspended clayey material. One thousand gallons are pumped daily but the maximum capacity is much greater.

5.—C. S. Campbell, Esq.—Dorval.

This well is 480 feet deep and yields 500 gallons of water per hour. The hole is 4½ inches in diameter. The water is of good quality and rises to within 20 feet of the surface.

6.—The Canadian Brewing Company—218 Delorimier avenue, Cadastral number lot 502, St. Mary's ward.

In boring this well, water was struck at a depth of 580 feet. Before rock was reached the drill went through 50 feet of drift, 35 feet of which was "hard-pan."

The water level is 28 feet below the surface. Present requirements only necessitate the pumping of 5,000 gallons per diem, although the tested capacity is at least 24,000 gallons.

The following partial analysis of the water was made by Mr. Baker-Edwards on October 20, 1890.

	Grains per imp. gallon.
Sodium bicarbonate	38·00
Sulphur as H_2S or sulphides	not determined
Sulphur as SO_3	3·36
Chlorine as NaCl	2·705
Nitrogen as nitrates	0·004
Nitrogen as nitrites	none
Free and saline ammonia	0·0025
Albumenoid ammonia	0·0033
Organic carbon	none
Hardness	4·2° (Clarke's)

This well and No. 99 are connected underground as they are found to pump one another dry. Boring the second well gave a combined capacity larger by one-half than that of well No. 6 alone.

7 and 8.—The Canada Malting Company—St. Henri, lot 104781, near Lachine canal.

Two wells were sunk on this property a short distance from one another. The first of these is 6 inches in diameter down to a depth of 36 feet, the diameter being then reduced to 4½ inches. In it water was obtained at a depth of 300 feet and rose to within 6 feet of the surface, the well yielding 500 gallons per hour. The water is stated to be of good quality but has not as yet been analysed. The solid rock was reached 32 feet from the surface. After striking water at a depth of 300 feet, the boring was continued to a depth of 678 feet, without any appreciable increase in the quantity of water being observed.

The second well was sunk to a depth of 506 feet and yields 700 gallons per hour. The rock was reached at a distance of 18 feet from the surface and the water, which was of good quality, rose to within 30 feet of the surface.

9.—The Canada Malting Company—C.P.R. property, "Abattoir site," near St. Henri.

In this well, highly saline water was struck at 350 feet and rose to within 10 feet of the surface. The well yielded 750 gallons per hour. Boring was then continued to a depth of 1,281 feet, when, no additional supply of water being obtained, operations were discontinued. The hole is 4½ inches in diameter and the rock was reached at a depth of 31 feet from the surface.

10.—Canada Sugar Refining Company—150 Montmorency street.

This well is 312 feet deep and yields 5,000 gallons an hour. The water rises to within 18 feet of the surface, and is of good quality. The drift here is very thick, the solid rock lying 70 feet below the surface.

The following is an analysis of the water by the chemist of the company, the results being given in grains to the imperial gallon:

	Grains per imp. gallon.
Calcium bicarbonate	4·521
Magnesium "	0·160
Sodium "	1·330
" sulphate	1·049
" chloride	3·720
Mineral solids	10·780
Organic "	4·57
Total hardness	12·40
Temporary hardness	1·60
Permanent hardness	10·80

11 and 12.—Canadian Pacific Railway workshops, Hochelaga.

Wells Nos. 11 and 12 are situated in the power house and are 86 feet apart. They are connected underground and some details concerning their estimated capacity under different conditions are important as affording some interesting light upon the conditions of underground water circulation.

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

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Rochester, NY 14609 USA
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Well No. 11 was started with 8 inch casing and then 6 inch casing was used for 125 feet. The water rose to within 6 feet of the surface, but on starting to pump with a 6-inch duplex pump the water soon fell below the suction level and an air lift was put in. The 6 inch casing was utilized and an air pipe 1½ inches in diameter and 101 feet in length was put down. The discharge given was 12,000 gallons per hour.

Well No. 12 had 186 feet of 4-inch casing. An air lift was necessary in this case too and 150 feet of 1½-inch pipe was employed. A flow of 4,700 gallons per hour resulted with well No. 11 shut down. When Nos. 11 and 12 were running together No. 11 only gave a flow of 8,000 gallons per hour and the combined flow was 12,700 gallons per hour or only 700 gallons more than when No. 11 alone was pumped.

Next 50 feet more of air pipe was tried in No. 11 well. The result was that mud and grit were forced into No. 12 well, the discharge from which was greatly discoloured. This was due to air being delivered below the casing. The flow from No. 11 was not increased in this way, and that from No. 12 was practically zero when running concurrently. No. 12 was shut down then and No. 11 left running and it gave a steady discharge of 12,000 gallons per hour.

To increase the flow from No. 12 it was planned to substitute 200 feet of 5-inch well casing for the 4-inch casing, but only 101 feet could be put down as the pipe stuck in a bed of boulders. Further the lift was reduced 13 feet 4 inches from a height of 42½ feet which the receiving tank originally stood at. This gave a lift of 29 feet 2 inches. With 120 feet of 1½-inch pipe and with No. 11 shut down the discharge was 10,600 gallons per hour. This was an increase of 5,900 gallons on the original flow. At 11 a.m. on June 21, No. 11 was started again. The combined flow was 18,000 gallons per hour. At 5 p.m. the discharge had fallen to 16,700 gallons and on June 22 to 15,000 gallons per hour. The combined capacity seemed to remain constant at 15,000 gallons and this flow is regular. The water level in No. 11 fell 21 feet after seven days continuous working and rose 6 feet in a rest interval of 33 minutes.

The following analyses were made upon the water from well No. 11 by Milton Hersey Company and are given in grains per imperial gallon.

	1908		1908	1909		1903
	March 16	March 17	June 11	March 19	July 20	Feb. 6
Calcium carbonate	6·26	1·29	1·87	2·68	1·35	0·43
Calcium sulphate	5·24	......	......	......	......	......
Calcium chloride	......	......	......	......	......	1·17
Magnesium carbonate	5·68	1·14	1·27	2·30	1·22	0·31
Silica, etc.	0·59	0·35	0·25	0·48	0·42	0·00
Total encrusting solids	17·77	2·78	3·39	5·46	2·99	1·91
Sodium carbonate	0·00	23·53	22·09	15·34	21·67	18·00
Sodium sulphate	10·74	11·61	10·29	27·64	7·45	8·20
Sodium chloride	3·54	2·08	2·42	10·07	2·20	0·00
Sodium nitrate	0·71	......	......	......	......	......
Organic matter	3·59	1·15	3·77	trace	5·83	3·67
Non-encrusting solids	18·58	38·37	38·57	53·05	37·15	29·87
Encrusting solids in 1,000 imp. gals	2·34	0·39	0·47	0·78	0·43	......
Total solids	36·35	41·15	41·96	58·51	40·14	31·78

13. Canadian Pacific Railway—Outremont, north end of Cadastral lot No. 35, Parish of Montreal.

After traversing 25 feet of clay, the drill struck rock and the boring was continued to the depth of 410 feet. The water level is 8 feet below the surface, but on pumping at the rate of 8,000 gallons per hour the level is lowered to 22 feet, 6 inches. The diameter of the hole for the first 300 feet is 5½ inches, and is then reduced to 4 inches.

The water is not pure, being "charged with sulphur and salts" and is unsuitable for use in locomotives. An analysis supplied by the company shows it to have the following composition in grains per imperial gallon:

Calcium carbonate	15·133
Magnesium carbonate	4·347
Potassium chloride	1·34
Sodium silicate (Na_2SiO_3)	2·56
Sodium sulphate	3·21
Calcium sulphate	9·09
Oxides of iron and alumina	0·42
Total	36·090

14. Convent of the Sisters of the Precious Blood—Notre-Dame de Grâce.

This well was sunk to a depth of 296 feet. Water was obtained, the well yielding 1,500 gallons an hour. The water rose to within 20 feet of the surface and is said to be of good quality. The solid rock was reached at 42 feet from the surface.

15. M. Cousineau, Esq.—Lot 251, St. Laurent.

This well is interesting in that it is one of the few flowing ones of the district, the water rising to a height of 7 feet above the surface of the ground. The well is 128 feet deep, 40 feet in clay, and 88 feet in limestone; the water is pure and of medium hardness.

16.—Dr. Robert Craik—Lot 192, Petite Côte.

In the boring of this well, water was struck first at 250 feet, but not in sufficient quantity to keep the drill wet. At 305 feet, however, additional water was obtained which rose to within 10 feet of the surface.

The water-bearing stratum is shaly in character and the water was at first impure and sulphurous; but these qualities disappeared on continued pumping, giving a pure, soft water. No analysis was made beyond a few qualitative tests which confirmed the excellent quality of the water.

In order to test the capacity of the well an engine was used which pumped 5,000 gallons per hour without lowering the water level more than 20 feet below the normal position. A windmill with a 6 inch stroke is now used; the pump is down 80 feet, while the piping (4 inch), continues 30 feet below the pump.

17.—Mr. Curran's farm.

The well is situated about halfway between Montreal and Back river, about one mile east of the hotel. It was sunk to a depth of 260 feet and yields 1,000 gallons an hour. The water rises to within 6 feet of the surface. The hole is 6 inches in diameter, and the solid rock was met with 16 feet from the surface.

18.—The Thomas Davidson Manufacturing Company—187 Delisle street, Ste. Cunégonde.

Water was obtained at a depth of 150 feet, the hole having a diameter of 6 inches. The well is pumped every day at the rate of 50 gallons per minute without exhausting the supply of water. The solid rock was reached at a depth of 50 feet from the surface. An examination of the water has been made by Mr. Milton L. Hersey with the following results:—

"Total solids—600 parts per million (42 grains to the gallon.)

Observations on ignition—No charring whatever.

Residue—Alkaline, on account of small amount of bicarbonate of soda naturally present in the water.

Chlorine—30·4 parts per million (2·13 grains to the gallon.)

Oxygen consumed—·155 parts per million.

The water although hard is entirely satisfactory for drinking purposes."

19.—Messrs. Dawes and Company—Lot 202D, Lachine.

At a depth of 1,003 feet, water was obtained which rose to within 10 feet of the surface. At first, pumping was carried on daily for 3 or 4 hours at 60 pounds pressure, through a 2 inch pipe, without lowering the level. The temperature of the water was constant at 48 degrees F. throughout the year. An examination of the water was made by E. B. Kenrick, Esq., of Winnipeg, with the following results:—

The water was somewhat turbid.

Solids dried at 100 degrees C., 4670 parts per million = 326·9 grains per imperial gallon.

Loss on ignition 1,050 parts per million.

	Grains per imp. gallon.
Nitrogen as albuminoid ammonia	0·06
" as free and saline	0·31
" as nitrates and nitrites	0·21
Chlorine as chlorides	640·00
Phosphates	trace.
Oxygen absorbed at 80° F. in 15 minutes	0·336
" " 4 hours	0·744

On ignition, there was no blackening of the total solids, 'I am of the opinion that the sample is fairly free from organic impurities, but contains too much saline matter to be a first class water.'

An analysis made by Frank Faulkner, Esq., is as follows:—

Free ammonia	0·720 parts per million.
Albuminoid ammonia	0·170 " "

	Grains per imp. gallon.
Chlorine	44·80
Nitric acid	None.
Sulphuric acid	110·28
Calcium carbonate	20·58
Lime otherwise combined	51·83
Magnesia	22·36
Soda	undet.
Saline residue	271·60
Organic and volatile matter	54·46
Total solid residue	326·06

The following represents, according to Mr. Faulkner, the most probable composition of the saline residue.

Calcium carbonate	20·58
Calcium sulphate	125·84
Magnesium sulphate	67·86
Sodium chloride	73·92
Total	288·23

Well No. 19 is about 100 feet from well No. 112. The two wells apparently are not connected underground though the water from both wells is contaminated and quite unfitted for drinking. It is interesting to note that water derived from such a depth as 1,000 feet should be contaminated with surface water, but it must be remembered that the limestone is cut by a series of irregular cracks and fissures through which the water circulates and that water is not subjected to such a satisfactory filtering process in such strata as it is in passing through sandstones and porous rocks. A fissure may very well lead straight down from the surface and contaminate the underground supply. The brewery uses the water for cooling purposes only.

20. W. B. Dickson, Esq.—Lot 21 Longue Pointe.

This well is 170 feet deep, 100 feet being in drift and 70 feet in limestone. The water rises to within 13 feet of the surface. It is impure, saline, and strongly impregnated with sulphuretted hydrogen. The water pumped during the first two days was perfectly black, but it gradually became clearer.

21.—The Dominion Wadding Company—Corner of William and Vinet streets, Ste. Cunégonde.

This well is within 400 feet of the Lachine canal. Water was struck in 'a hard rock crevice' at a depth of 160 feet from the surface and the boring was continued for an additional 15 feet, when the work was stopped as a sufficient supply of water had been obtained. The hole is 6 inches in diameter and the water rose to within 8 feet of the surface. The boring first passed through drift containing "boulders," rock being reached at a depth of 90 feet. An abundant supply of good water is obtained, but now it is only used as a reserve.

22-25.—Messrs. William Dow and Company—186-188 Colborne street.

Well drilling on this property has been a failure. All the wells except No. 24 are blocked up and the water from this well is only used for cooling purposes. The water is stated to be disagreeable and sulphurous. None of the wells appear to be connected. The first (No. 22) was sunk to a depth of 360 feet and yielded 24,000 gallons a day of water which rose to within 50 feet of the surface. It was stated to be pure.

The second (No. 23) was bored to a depth of 420 feet, but the amount of water obtained was too small to make the well of any value. It, however, rose to within 40 feet of the surface.

The third (No. 24) is 430 feet deep and yields 60,000 gallons per day. This is the only well which is used. The water is disagreeable—sulphurous; it rises to within 30 feet of the surface.

The fourth well (No. 25) is 830 feet deep and is practically dry.

A fifth well (No. 116), situated on this property, was also abandoned at a depth of 1,525 feet.

26.—Alexander Drummond, Esq.—Petite Côte.

This well is 500 feet deep and yields 350 gallons an hour, the water rising to within 50 feet of the surface. The rock lies 5 feet below the surface.

27.—Sir George A. Drummond—Beaconsfield.

In boring this well, the drill first passed through 10 feet of drift, followed by 415 feet of limestone. At 425, water was obtained which rose to within 10 feet of the surface. It is abundant but hard. A partial log of the borings, from 215 to 360 feet, was preserved, and these have been examined with the following results:

From 215 to 320 feet the rock is a dark grey semi-crystalline limestone, somewhat impure and bituminous.

At 325 feet the rock is a light-grey dolomitic limestone which is followed at 340 feet by a light grey highly siliceous bed with practically no carbonates.

The rock at 350 feet is a light-grey dolomitic limestone which is succeeded at 360 feet by a dark grey bituminous limestone.

From this examination it is evident that this well at the 360-foot level has not passed out of the Chazy formation, there being no beds comparable to the Calciferous sand-rock which underlies the Chazy.

The well yields 1,500 gallons per hour.

28.—J. N. Drummond, Esq.—Lot 199, Petite Côte.

This well was sunk to the depth of 223 feet in the limestone. At the 200-foot level a bed of very hard rock was encountered, beneath which was the water-bearing stratum or band. This had a honeycombed character, representing either a bed of impure limestone rendered porous by the removal of the soluble portion of the rock, or, possibly, a shattered zone filled by a friction breccia. The water rises to within 25 or 30 feet of the surface, and continued pumping fails to lower it below that level. The water is clear and soft with a slight sulphurous taste. (*See* No. 84.)

29.—H. A. Ekers, Esq.—Lot 208, Petite Côte.

In this well, water was struck at 325 feet, limestone being the only rock encountered. The water is of a medium hardness and maintains a constant level at 33 feet below the surface. The well yields 600 gallons per hour.

30.—Ekers' Brewery—409 St. Lawrence street.

This well is 600 feet deep, the first 70 feet being in boulder clay or "hardpan." The water rises to within 10 feet of the surface, but on pumping the level is lowered to 40 feet. Continued pumping fails to lower it further. The well has yielded as much as 25,000 gallons in 24 hours, but its maximum capacity is unknown. A partial analysis of the water, by Dr. Ruttan of McGill University, made on a sample collected on May 25, 1892, gave the following results:—

	Parts per million.	Grains per imp. gallon.
Total solids	392	27·44
Ash after ignition	234	16·35
Organic and volatile	158	10·99
Chlorine	40	2·80
Nitrogen as free and saline ammonia	0·057	.....
Albumenoid ammonia	0·066	.....
Nitrates	0·799	.....

The following analysis was made on March 25, 1913, by the First Scientific Station for the Art of Brewing in the United States of America, No. 200, Worth street, New York.

	Parts per million	Grains per imp. gallon
Total residue	54·00	37·8
Loss by calcination	5·20	3·64
Residue after calcination	48·80	34·16
Lime	3·20	2·24
Magnesia	2·16	1·51
Sulphuric acid	9·60	6·72
Chlorine	3·55	2·49
Carbonates of alkalis	18·13	12·69
Nitrous acid	none	.....
Nitric acid	none	.....
Ammonia	none	.....
" (albumenoid)	none	.....
The organic substances require oxygen	0·14	.....
Iron	traces	.....
Temporary hardness	6·21 (Engl.)	.....
Permanent hardness	1·58 "	.....
Total hardness	7·79 "	.....

The following analysis was made by the Wahl-Henius Institute of Fermentology, 1135-1147 Fullerton avenue, Chicago, Ill., on March 22, 1913.

	Parts per million.	Grains per imp. gallon.
Sodium oxide	221	154·7
Calcium oxide	22	15·4
Magnesium oxide	17	11·9
Iron and aluminium oxides	none	none
Chlorine	28	19·6
Sulphuric acid	94	65·8
Silicon oxide	5	3·5
Total solids	510	357·0

Oxygen consumed in moist combustion:

In filtered water	2·24	1·57
In unfiltered water	2·40	1·68
Free ammonia	0·10	0·07
Albumenoid ammonia	trace	trace
Nitrates	none	none
Nitrites	none	none

In probable combination:

Sodium chloride	47	3·29
Sodium sulphate	167	11·69
Sodium silicate	10	0·7
Sodium carbonate	201	14·07
Calcium carbonate	39	2·73
Magnesium carbonate	36	2·52
Total		35·00

31, 32, and 33.—Excelsior Woollen Mills—967 Ontario street.

The Montreal Lithographic Company now occupies this site but none of the wells are being used.

Three wells were sunk on this property within a distance of about 200 feet from one another. The results obtained, however, in the three cases, were very different.

The first well, No. 33, was sunk to a depth of 300 feet and yielded practically no water. The second well No. 31 was sunk to a depth of 812 feet, 60 feet of "hard pan" being penetrated before the limestone was reached. Water was first obtained at about 600 feet, but the boring was continued to a further depth of 212 feet in the hope of obtaining a larger quantity. The water is pure and free from sulphur and is pumped from an 80-foot level. The maximum quantity which the well yields, however, is only about 5,000 gallons a day. In the morning, when the pump is started, the water level is 100 feet below the surface, but during the pumping it is gradually lowered to 180 feet, at which it remains constant. The diameter of this hole is 6 inches in the drift, after which it is reduced to 4 inches in diameter, the hole being lined to a depth of 400 feet. Samples of the borings from this well were obtained down to the 340-foot level, the rock on examination proving to belong to the Trenton limestone. Before the heavy earthquake which was experienced in the year 1897, the flow of this well was about double the present flow.

The third well, No. 32, was sunk at a depth of 754 feet. Some water was struck at 500 feet and a further supply was obtained at 740 feet. The well yields 3,600 gallons an hour, or about 86,000 gallons a day. In this well the water rises to within 20 feet of the surface. The hole has a diameter of 10 inches at the surface, after which it decreases to 6 inches. The rock is 35 feet from the surface.

These wells are interesting as showing the great variations encountered within a very limited area, not only in yield of water but also in the height to which the water rises, as well as in the thickness of the drift covering. Mr. William Bell, who drilled the holes, states that there was distinct evidence of the existence of fissures and crevices in the limestone through which these borings passed.

34.—The Fenlin Leather Company—141 Frontenac street.

This well is 1,025 feet deep and might be classed as a dry well, the amount of water obtained (4,800 gallons in 24 hours) being too small to warrant the well being pumped. The rock lies 60 feet from the surface.

35.—M. Galibert, Esq.—929 St. Catherine street.

This well is 454 feet deep, of which the upper 56 feet is in drift. The water rises to within 5 or 6 feet from the surface, and the amount obtained daily (not the maximum capacity) is 25,000 gallons. The diameter of the bore is 4 inches.

A partial analysis of the water was made by Mr. Milton Hersey, and gave the following results, stated in grains per imperial gallon:

Bicarbonates of sodium, magnesium and lime, and sodium sulphate	52·20
Chlorides of sodium and potassium	6·25
Silica	1·65
Oxides of iron and alumina	trace
Total solids per imperial gallon	60·10

The water has a distinct alkaline reaction, a slight mineral taste, and was somewhat turbid from suspended clayey matter. The temperature is constant at 51 degrees F. throughout the year.

36.—H. Gatehouse, Esq.—808-810, Dorchester street.

The well is 750 feet deep and has a capacity of 20,000 gallons of water per day (24 hours). The water is of good quality and rises to within 30 feet of the surface. The solid rock was reached at a depth of 46 feet from the surface.

37.—The Globe Woollen Mills Company—219 Delorimier avenue (Cadastral No. 1,492) St. Mary's ward.

The well is 410 feet deep, 35 feet in the boulder clay and the remainder in a limestone of uniform hardness. The water rose to within 10 feet of the surface and 2,800 gallons were pumped per hour. The original owners no longer occupy the site and the well is not now used. A chemical examination made by Prof. J. T. Donald, on November 13, 1890, gave the following results, the figures being grains per imperial gallon:—

"Mineral matter, consisting principally of calcium sulphate, with a small amount of magnesium sulphate, 49·63. The sulphates render the water hard, but, apart from these, it contains nothing to render it unsuited for use in dyeing."

38 and 39.—The Gould Cold Storage Company—corner Grey Nun and William streets. Two wells have been put down on this property. The first of these was sunk to a depth of 500 feet, at which level the drill was lost, having become jammed in a crevice in the rock. It was found impossible to recover it and operations were not resumed. The well, therefore, was abandoned, no water having been obtained.

In the second well, water was struck at 360 feet, a yield of 10,000 gallons per day being obtained. The boring was then continued to a depth of 1,301 feet in the hope of securing an additional supply, but without success. The water is said to be pure and it rises to within 40 feet of the surface. The drift covering here is heavy, being 73 feet thick.

40.—A. Goyer, Esq.—Frontenac Cadastral No. 1,697, Hochelaga ward.

In boring this well, water was obtained at a depth of 375 feet, the upper 30 feet being through drift. The water is soft. It rises to within 10 feet of the surface. The maximum capacity of the well is about 9,000 gallons per day.

41.—F. Goyer, Esq.—Côte-des-Neiges village.

This well is 250 feet deep, limestone being struck about 25 feet below the surface. The water, which is very hard, rises to within 10 feet of the surface. The maximum capacity of the well is not known, but at present from 8,000 to 9,000 gallons are pumped daily.

42.—M. Grosboyau, Esq.—1,675 Papineau avenue.

Cadastral No. 161 Delorimier municipality. This well is 350 feet deep and is wholly in limestone. The water which is soft rises to within 12 feet of the surface.

43.—Chas. Gurd, Esq.—39-42 Jurors street. Lot 696.

In sinking this well, limestone was struck 18 feet from the surface, and water was first obtained at 440 feet, but the supply was very limited, becoming exhausted in 8 hours when pumped through a 2 inch pipe. Boring was then continued to 512 feet and water was struck which rose to the surface and flowed at the rate of 800 gallons in 24 hours. On pumping, however, it will yield 4,000 gallons in the same time, but if forced above that the well is drained below the 360 foot level where the pipe ends, and some hours elapse before it refills. The water is strongly impregnated with sulphuretted hydrogen gas, resembling in this respect the water obtained at Viau's well, Maisonneuve.

44.—Mr. Hampson—Lot 40, Longue Pointe.

This well was sunk in limestone to the depth of 502 feet, when an impure saline water strongly impregnated with sulhuretted hydrogen was struck. The water is unfit for use.

45.—A. Hobbs, Esq.—Outremont—Near Canadian Pacific Railway Company's roundhouse.

This well is 240 feet deep and has a capacity of 48,000 gallons in 24 hours. The water is of good quality and rises to the surface. The hole is 6 inches in diameter and the rock was met with 5 feet below the surface.

46.—Edward Hughes, Esq.—Lot 487, Côte St. Michel.

The well is 75 feet deep, wholly in limestone. The water-level is 20 feet below the surface. The water is soft and can be obtained in considerable quantity.

47.—Messrs. Laing and Sons—Corner of St. Catherine and Parthenais streets.

The well has a depth of 325 feet, of which the upper 56 feet is in the boulder clay, and the lower 269 feet in limestone.

The water rises to within 30 feet of the surface, and the well is fitted with a pump having a 36 inch stroke which delivers a regular supply at the rate of 36,000 gallons per day.

In 1891, a few weeks after the well had been completed, the water was examined by Prof. J. T. Donald, and the following is the result of a partial analysis, stated in grains per imperial gallon:

Calcium carbonate with a little $MgCO_3$	14·32
Alkaline carbonates with a little silica	5·31
Sodium chloride	9·38
Calcium sulphate	12·65
Suspended matter	2·04
Total	43·70

The suspended matter shown in the analysis caused a turbidity which continued even after the well had been pumped for several weeks. Later on, however, this disappeared and a perfectly clear water was obtained.

48.—The Laurentian Baths, Messrs. Robert White and Company—208 Craig street.

The well is 285 feet deep, of which the upper 60 feet is in drift—clays and gravels—and the lower 225 feet in limestone. Water was struck at 270 feet. The water rose in a pipe to a height of 20 feet above the surface of the ground, and flowed at the rate of 10,000 gallons in 24 hours. At times, however, the pressure has been found to vary somewhat. On one occasion shortly after the boring was completed the water level at 6 p.m. barely reached the surface, but during the night the water overflowed the 20-foot pipe and flooded the building. The well is now pumped and yields 40,000 gallons per day.

Four analyses, showing the composition of the water at intervals during a period of twelve years, have been made by Prof. J. T. Donald, and together with a more recent analysis (1908) by Milton Hersey are given below, in grains per imperial gallon.

Constituents	October 28, 1891	August 26, 1892	March 31, 1896	January 1903	March 17, 1908
Calcium bicarbonate	Heavy trace	....	1·98	1·78	....
Calcium carbonate	....	....	....	....	2·57
Magnesium bicarbonate	....	....	1·72	1·13	....
Magnesium carbonate	....	....	....	....	1·82
Sodium bicarbonate	27·25*	26·74*	32·37	22·37	....
Sodium carbonate	....	....	....	....	16·32
Sodium sulphate	6·85	0·23	9·30	9·44	19·31
Calcium sulphate	....	3·47	....	....	....
Magnesium sulphate	....	1·69	....	....	....
Sodium chloride	2·32	9·59	5·40	5·38	9·38
Potassium chloride	....	....	0·77	0·43	....
Silica	....	....	0·43	0·49	0·25
Total	36·42	41·72	51·97	41·02	49·65
Organic matter	....	....	....	....	2·59

*Alkaline carbonates with a little silica.

An interesting point in connexion with this water is the very small amount of the carbonates of lime and magnesia, and the large proportion of the alkaline salts present which makes it such a suitable drinking water. This is of especial interest in view of the fact that in the water from the wells of Messrs. Laing & Co., a short distance away, the relative proportion of these constituents is reversed. No samples of the borings were preserved with the exception of a small fragment brought up from the level at which the water was struck. This on examination proved not to be limestone but a soft black shaly rock traversed by a few veinlets of a light coloured impure dolomite. Before the blowpipe both the rock and veins fuse on the edges to a blebby glass. This shale is evidently part of one of the beds which occur interstratified with the Trenton limestone.

The earthquake which occurred in the autumn of 1893 produced a very perceptible turbidity in the water, which lasted for about a day and a half.

Part of the water pumped from this well and the neighbouring well No. 132 is drawn off immediately and used in the manufacture of soda water and ginger ale, or used for drinking purposes, under the trade name of Laurentian water, but the greater part is used to supply the large and well equipped swimming bath, Turkish baths, etc., on the premises. This well, considering the short distance which it was necessary to bore, and the character and the volume of the water obtained, must be regarded as one of the most successful borings which has yet been made on the Island of Montreal. This well is 150 feet distant from well No. 132, while well No. 123 is just across the street.

49 & 50.—The Laurie Engine Company—1020 St. Catharine street.

Well No. 49 is now on the property of the St. Lawrence Foundry Company and No. 50 is on that of the Canadian Boomer and Bos[illegible]t Press Company. Neither are now (1913) used.

In the first well, water was struck after boring through 65 feet of drift and 85 feet of limestone, but boring was continued to a depth of 300 feet. The water is clear and sparkling with a faint chalybeate taste and rises to within 15 feet of the surface. It is too hard to be used for boilers. At one time 27,000 gallons were pumped daily.

The second boring which is 700 feet deep, struck no water.

51.—The Longue Pointe Asylum—Longue Pointe.

Water was obtained at a depth of 300 feet from the surface, the well yielding nearly 9,600 gallons per diem. The boring was then continued to a depth of [illegible] feet, but no further supplies of water were secured. The rock here is about 4 feet from the surface.

An interesting fact in connexion with this well is that about half a mile to the north of the spot where the boring was located, a spring issues from the country rock with a flow of 2,500 gallons an hour, or 60,000 gallons per diem, the water rising through a rather large fissure which here reaches the surface; while along the line of the boring, although 2,000 feet of strata are traversed, only a single small water-bearing crevice was encountered.

52.—Messrs. Lovell and Christmas—63 William street.

This hole is 612 feet deep and has a diameter of 6 inches. The water is slightly sulphurous and rises to within 30 feet of the surface. The well has a capacity of 60,000 gallons a day, and the firm in 1903 was regularly pumping 43,200 gallons per diem. When pumping, the water level is lowered to 168 feet, below the surface. The rock is met with at a depth of 62 feet. This water was examined by Milton L. Hersey, who reports upon it as follows:

'Odour of water	Sulphuretted hydrogen.
Appearance of water	Turbid, when pumping is stopped.
Temperature of water	50° F.
Total solid matter on evaporation	600 parts per million.
Solids volatile on ignition	130 parts per million.
Odour of solids on ignition	none.
Charring of solids on ignition	none.
Organic matter (oxygen consumed)	1·35 parts per million.

(This is really not due to organic matter but to the presence of sulphuretted hydrogen and other sulphur compounds.)

Chlorine as chlorides	127·71 parts per million.
Free ammonia	0·784 parts per million.

(This quantity of free ammonia is more apparent than real on account of the presence of sulphuretted hydrogen.)

Albuminoid ammonia	0·051 parts per million.
Total ammonia	0·835 parts per million.
Nitrogen as nitrites	very faint traces.
Nitrogen as nitrates	none.
Gas producing bacteria in phenol-dextrose broth	none whatever.

I consider this water free from objectionable contamination so far as its sanitary properties are concerned.'

53.—A. Martin, Esq.—Lot 1010, Parish of Lachine.

In sinking this well, gas and water were struck at 460 feet below the surface. The gas burned for 12 hours, when the supply became exhausted. Boring was then continued to 740 feet without obtaining any greater volume of water. The drift consists mainly of "hardpan" and is 65 feet thick. Between the hardpan and the limestone a thin layer of quicksand was encountered. The water rises to within 11 feet of the surface. It is of a good quality but very hard. If it is covered for some time, a faint sulphurous odour is detected. The supply is limited, the well yielding only about 100 gallons per hour. The diameter of the hole is 6 inches.

54.—Messrs. A. S. and W. H. Masterman—2082½ Notre Dame street, Cadastral No. 1303, St. Anne's ward.

In the case of this well rock was struck 68 feet from the surface, and water was obtained at 750 feet. Boring was continued to 800 feet, the last 50 feet being to provide a sink-hole for the sediment. The water level is 10 feet, 10 inches, below the surface, and the supply is stated to be undiminished when pumped at the rate of 3,000 gallons per hour.

An analysis by Dr. G. P. Girdwood is given below:

	Grains per Imp. gallon
Calcium carbonate	23·35
Ferrous carbonate	0·44
Sodium chloride	15·36
Magnesium chloride	13·11
Calcium chloride	26·80
Calcium sulphate	1·28
Silica	3·08
Total	83·42
Free ammonia	20 parts per million.
Albuminoid ammonia	11 parts per million.
Some sulphuretted hydrogen is also present.	

The earthquake of 1897 did not affect this well, but that of 1895 broke the iron casing 40 feet below the surface and necessitated its removal.

55.—Mrs. J. McIntosh—Lot 429, Côte St. Michel.

The well is 120 feet deep and the water rises to within 4 or 5 feet of the surface. It is soft with slight chalybeate and sulphurous taste. The latter, however, disappears on allowing the water to stand for some time. A steam pump is used to raise the water, the pipe being an inch in diameter.

56.—Messrs. J. H. R. Molson and Brothers—1006 Notre Dame street.

The well is situated on Cadastral No. 28 of St. Mary's ward, being the south corner of Notre Dame and Monarque streets, at what is known as Molson's brewery. Water was obtained at a depth of 420 feet. The boring was then continued to a depth of 672 feet without obtaining any increased supply. The water rises to within 24 feet of the surface, but is lowered by pumping to 83 feet, the well yielding 4,700 gallons per hour. The hole is 8¼ inches in diameter down to the solid rock, then 6 inches for the next 42 feet, when it is reduced to a diameter of 4¾ inches. As usual in the wells in this lower part of the city, the drift covering is very thick, here amounting to 83 feet. The temperature of the water is 52 degrees F.

The results of an analysis of the water, made for Messrs. J. H. R. Molson & Brothers, are as follows:

	Parts per 100,000	Grains per imp. gallon
Calcium carbonate	11·35	7·95
Magnesium carbonate	8·83	6·18
Sodium sulphate	40·77	28·54
Sodium chloride	22·23	15·56
Sodium carbonate	16·44	11·51
Potassium sulphate	3·01	2·11
Silicates of iron and alumina	2·13	1·49
Fixed mineral salts	104·76	73·34
Total solid residue at 127° C.	107·64	75·35
Loss on gentle ignition of residue	2·88	2·02
Free ammonia	0·018	.....
Albuminoid ammonia	0·005	.....
Nitrates	Nil	.....
Nitrites	Nil	.....
Chlorine	13·49	9·44
Phosphates	Trace	.....
Iron in solution	Nil	.....

Total hardness (soap test)	24·40
Temporary hardness (soap test)	11·60
Permanent " "	12·80

The water has a saline taste, a marshy odour, and an opalescent colour. It gives an alkaline reaction with litmus paper. The "biological condition" of the water is stated by the analyst to be "unsatisfactory," but this fact as well as the saline character of the water is of little consequence, since the firm requires the water merely for cooling purposes.

57.—Canadian Pacific Railway—Place Viger station.

This well and well No. 101, 50 feet distant, formerly belonged to the Montreal Brewing Company. The water of well No. 57 is no longer used.

This well is 502 feet deep, the first 80 feet being in "hardpan." Water was first struck at 497 feet, and from the working of the drill it would seem that the water rose from a fissure about 8 inches wide. The water level is 36 feet below the surface. The maximum capacity of the well is not known, but it has yielded 126,000 gallons in 24 hours. The bore is 4⅝ inches in diameter.

An analysis of the water taken from the well on April 9, 1895, was made by Prof. J. T. Donald; the results are as follows:

	Grains per imp. gallons.
Calcium carbonate	15·03
Magnesium carbonate	8·19
Ferrous carbonate	1·43
Sodium carbonate	3·75
Sodium chloride	11·51
Calcium sulphate	25·80
Silica	1·31
Total	67·02
Free and loosely combined carbon dioxide	17·35
Hardness	21·50

58.—Mount Royal Cemetery, near the Crematory.

This well is 354 feet deep and has a capacity of 36,000 gallons in 24 hours. The hole is 4⅝ inches in diameter and the water, which is of good quality, rises to within 25 feet of the surface. The boring starts in solid rock.

59.—The Montreal Cold Storage Company—604-610 St. Paul street.

This well is 1020 feet deep, the first 60 feet being in drift. Water was obtained which rose to the surface, but the flow was irregular owing to the escape of gas. A pump arranged to take water from the 400 foot level was then fitted in the well. The first water obtained was dark in colour, owing to the distribution through it of minute flecks of sulphide of iron. At the time the well was visited the water was running alternately darker and clearer at intervals of a few minutes, giving off gas which when ignited burned with a bright flame. After pumping for a time the pressure of the gas became so great that the pump rod could not be forced down, and operations had to be discontinued until the gas escaped. If the well were fitted with a pump properly constructed for the purpose, this difficulty arising from the presence of the gas would disappear. It is quite probable that the sulphide of iron is produced by the action of the sulphuretted water upon the pump rods and iron casing, and that by continuous pumping its amount would greatly decrease.

60 and 61.—The Montreal Gas Company—Hochelaga.

Two borings were made, about 600 feet apart, the respective depths being 1,850 and 2,550 feet. Of the deeper well a set of 20 specimens was obtained from Mr. W. Bell for examination. They were taken from between the 2,200 and 2,373 foot levels. Without exception they were found to be fine-grained, impure, siliceous, dolomites, associated with thin beds of dolomitic shale. At the 2,373 foot level the limestone was so impure that the chips retained their original forms after boiling in dilute hydrochloric acid.

For purposes of comparison, typical specimens of the rock of the Calciferous from Lachute and Ste. Anne's were examined, as well as some from the Chazy and Trenton formations. It was found that the Calciferous specimens were identical in character with the rock obtained from the boring, and it seems highly probable that the Gas Company's borings terminated in the Calciferous sandrock formation.

At 2,200 feet and 2,325 feet respectively, chips were found which are evidently of igneous origin, one a dark basic mica trap, and the other a much decomposed porphyrite. These two are probably fragments of dykes which are connected with the intrusion of Mount Royal.

62.—Montreal Gas Company—Ottawa street.

After boring through 90 feet of "hardpan" and 960 feet of limestone without obtaining water, operations were discontinued.

63.—The Montreal Hunt Club—Outremont.

This well was started on rock at surface and was drilled to a depth of 226 feet. The boring is 6 inches in diameter and yields 36,000 gallons of good water in 24 hours; the water rises to within 10 feet of its surface.

64.—Structural Steel Company—Longue Pointe.

This well is 514 feet deep and yields 1,200 gallons an hour, the water rising to within 25 feet of the surface and having a strong odour of sulphuretted hydrogen. The solid rock was encountered 27 feet from the surface.

Two analyses of this water were made by Milton L. Hersey, the first being a sample collected on July 23, 1903, being pumped from a depth of 25 feet below the surface, and the second collected on September 14, 1903, being pumped from a depth of 125 feet.

The results of these analyses are as follows in grains per imperial gallon:

	July 23, 1903	Sept. 14, 1903
Calcium carbonate	1·39	none
Magnesium carbonate	1·57	trace
Sodium sulphate	2·52	4·72
" chloride	1·51	10·39
" carbonate	29·00	41·86
Silica	0·21	0·66
Ferric oxide } Alumina }	0·50	trace
Total solid matter	36·70	57·63

This well is 1,200 feet from well No. 172

65.—Montreal Milling Company—Park avenue, Outremont.

This well is 345 feet deep, and is wholly in limestone. Water was struck at 337 feet, but boring was continued 8 feet farther, the last foot being in a rock with a honeycombed or porous structure.

The water level is 25 feet below the surface, and this was not lowered after pumping 1,700 gallons per hour for 144 hours. The water is saline and is unfit for use.

The diameter of the well is 5 inches. In boring it was found that the rock varied somewhat in hardness, the progress of the drill varying from 5 feet to 20 feet in 12 hours.

66.—Mount Royal Park.

This well was sunk on the Mountain opposite the water tank. It is 66 feet deep, 4 feet being in drift and 62 feet in the essexite rock which composes the greater part of the mountain. The diameter of the hole is 4 inches. The water is pure and abundant; in the springtime it rises to the surface but does not overflow.

67.—Montreal Weaving Company—595 Clarke street, Ville St. Louis.

This well is 420 feet deep and with the exception of 5 feet of drift it is wholly in the limestone. At the 200 foot level a bed of very hard rock was struck through which the drill went very slowly. This bed was probably an intercalated sill of igneous rock. The water rises to within 125 feet of the surface. It is pure and soft. Eight hundred gallons a day are now pumped, but the well has a capacity of 12,000 in 24 hours.

68.—G. Nantel, Esq.—Terra Nova, Côte-des-Neiges.

This well was bored to the depth of 600 feet, of which the first 5 feet were in drift and the rest in limestone. The water is very pure and abundant. It does not rise to the surface.

69.—Outremont Milling Company—Outremont.

The well has a capacity of 43,000 gallons in 24 hours. This boring is 4 inches in diameter and has been carried to a depth of 335 feet. The water is very hard and rises to within 25 feet of the surface.

70.—Judge Pagnuelo—Pagnuelo avenue, Outremont.

This well has been sunk in limestone to a depth of 700 feet. Only a comparatively small amount of water being obtained, work was discontinued at that level. The well is stated to have a capacity of about 7,000 gallons in 24 hours.

71.—Mrs. Quiggley—South end of lot 9, Longue Pointe.

The well is 100 feet deep, 90 feet being in drift and 10 feet in limestone. It yields 200 gallons per hour. The water is of medium hardness, and rises to within 9 feet of the surface.

72.—A. Ramsay, Esq.—Inspector street (Cadastral No. 1758 St. Antoine ward.)

Water was struck at 800 feet and rose to within 14 feet of the surface. The Troy Steam Laundry attempted to use it for washing but it was found to be too hard. The well has a capacity of about 2,000 gallons per hour.

73.—A. Ramsay, Esq.—Cadastral No. 282, lot 4, Westmount.

This well was sunk through solid rock to a depth of 880 feet, water being first struck at 700 feet. The water rises to within 18 feet of the surface; it is of good quality although somewhat harder than that of the St. Lawrence river, but it is quite suitable for all domestic purposes. The capacity of the well is about 15,000 gallons per diem.

74.—M. Rhéaume, Esq.—Foundry, Intersection of Canadian Pacific Railway track and Carrière street, Ville St. Louis.

In boring this well, 10 feet of sandy drift and 290 feet of limestone were passed through before water was obtained. The water is rather hard; it rises to the surface but does not overflow. At the time of inquiry only 100 gallons were being used daily, but the capacity of the well is about 24,000 gallons in 24 hours.

75.—Messrs. Rowan Brothers, Ginger Ale Manufacturers—618 Beaudry street.

This boring has a depth of 600 feet, of which the first 70 feet was through boulder clay and gravels. The water rose to within 60 feet of the surface and the well had a tested capacity of 5,000 gallons per hour. The water was pure and the amount used daily in the manufacture of ginger ale, soda water, etc., varied from 1,500 to 2,000 gallons. This is sometimes referred to as the Mooney well. Private houses are now (1913) being built on this property.

76.—The Royal Golf Club—Dixie.

This well is 450 feet deep and yields 28,800 gallons per day, the water rising to within 15 feet of the surface. The water is stated to be of good quality. The drift covering here is 37 feet thick.

77.—The Salvador Brewing Company (Reinhardt's brewery)—617 St. Paul street.

This hole is 550 feet deep and has a diameter of 4½ inches. The rock was met with 62 feet from the surface. The well gives too little water to be of much value, and like other wells of this yield might be classed as a dry well. The actual yield is from 300 to 400 gallons an hour, or about 8,000 gallons per diem.

78.—The Sault au Recollet College—Back River.

In boring this well 35 feet of drift was first traversed when the solid rock was reached. The boring was continued in this, the hole being 6 inches in diameter, and at a depth of 100 feet from the surface water was struck which could be pumped at the rate of 2,000 gallons per hour. This water, however, was hard, and it was, therefore, decided to continue boring in the hope of obtaining a supply of better water. At a depth of 490 feet from the surface, a second water-bearing crevice or band was struck, and in this the water was soft. The upper hard water was accordingly cut off the hole, and the soft water derived from the lower source alone was used. This rises to within 30 feet of the surface and when pumped yields 500 gallons per hour.

79.—Shawinigan Water and Power Company—Maisonneuve.

This hole is 1,017 feet deep, but yields only 4,800 gallons a day, the quantity being too small to be of value. Rock lies 60 feet from the surface. The neighbouring wells, Nos. 169 and 170, distant respectively 300 and 800 feet, are also failures.

80.—Convent of the Sisters of Providence—Notre Dame de Grâce.

The drilling was carried to a depth of 320 feet. The hole is 4½ inches in diameter. The rock was encountered 22 feet from the surface. The well yields 48,000 gallons per diem and the water is said to be pure.

81.—The Stanley Dry Plate Company—613 Lagauchetière street.

The well is 1,300 feet deep and yields about 8,400 gallons of good water in 24 hours. This hole is 4¾ inches in diameter, and the water rises to within 30 feet of the surface. The drift is here 40 feet thick.

82.—St. Laurent Convent—St. Laurent.

In this well water was obtained at 250 feet. The water rose to the surface. It is hard, with a slight sulphurous taste, and the supply is abundant.

83.—St. Laurent College—St. Laurent.

The well is 487 feet deep. In boring, the drill first passed through 31 feet of "hardpan" and then through 456 feet of limestone. The normal water level is 13 feet below the surface. On pumping, this is lowered to 27 feet, where it remains until pumping is suspended. The water is pure and soft. A rough analysis at the college gave small amounts of lime and magnesia. The capacity of the well is not known, but it easily yields 10,000 gallons a day.

84.—Mr. Stewart—Lot 195, Petite Côte.

This well is similar to No. 28 in every particular and doubtless has its source in the same water-bearing zone or bed.

85.—T. A. Trenholme, Esq.—Cadastral No. 141, Côte St. Pierre.

In this well water was obtained at the depth of 185 feet, the drill passing through 100 feet of drift and 85 feet of limestone. The water rises to within 25 feet of the surface; it is very pure and 6,000 gallons are pumped daily.

86.—T. A. Trenholme, Esq.—Thorne Hill, Côte St. Pierre.

This well is 175 feet deep, 75 feet of drift and 100 feet of limestone being penetrated. The water is pure and abundant.

87.—Turkish Bath Hotel—140 Ste. Monique street. (C. N. R. depot.)

This well is 1,550 feet deep, of which the first 50 feet is in "hardpan." Water was struck which rose 6 feet above the surface. Although a flowing well, it is necessary to pump it in order to obtain the amount of water required. The capacity, without lowering the water level much below the surface, is between 4,000 and 5,000 gallons per day. The water is soft and slightly sulphurous.

Specimens of the drillings from different levels were obtained and these have been examined by Dr. Adams with a view to ascertaining the character and thickness of the formations penetrated by the boring. The results show that the well is wholly in the limestone series. Here and there, however, igneous rocks have been encountered, which are of the nature of dykes or intercalated sills.

At a depth of 50 feet from the surface Trenton limestone was struck, which formation continued down to about the 525 foot level, when fossils determined by Dr. Ami as referable to the Lowville formation were found. At 640 feet, fossils of the Chazy were detected. Judging from the scanty evidence obtained from fossil remains, combined with the results of a chemical examination of the rock, it seems that this formation extends downwards to about the 1,425 foot level. At this depth magnesian limestones, more or less impure and siliceous, were met with, and these continued down to the 1,540 foot level. The last 10 feet consisted of sandstones which represent the more siliceous beds of the Beekmantown, to which formation the magnesian limestones presumably belong.

The formations traversed and their thicknesses may be represented in tabular form as follows:

Pleistocene (drift)	50 feet
Trenton and Lowville limestone.....	590 "
Chazy limestone	785 "
Beekmantown (Calciferous) limestone	125 "
Total........................	1,550 feet

The Potsdam sandstone was not reached in this boring and it is probable from the thickness of the Beekmantown traversed that the sandstone is considerably below the 1,550 foot level. At the Windsor hotel, the Beekmantown extends below this.

88.—Viauville Mineral Springs—Maisonneuve, Subsection of lot 5, Longue Pointe.

This well belonged originally to Messrs. Viau et Frère but has been sold by them and the water is being bottled and sold under trade mark, Radium Water.

This boring was made in the hope of striking natural gas. Bed-rock was encountered after the drill had passed through 90 feet of drift. At 450 feet good water was met with which rose to within 10 or 12 feet of the surface. The boring was continued to a depth of 1,190 feet, when water strongly impregnated with sulphuretted hydrogen was struck, which rose to the surface, and flowed at the rate of 5,000 gallons in 24 hours.

The final depth reached was 1,500 feet and it is stated that the only rock encountered was limestone.

On the completion of the well a sample of the water was collected. This was analysed in 1890, by Dr. Frank D. Adams. The water when received for analysis had a faint, yet decided odour of sulphuretted hydrogen, and contained a trifling amount of sediment. The colour of the clear water in a column 2 feet in height was light yellow; the taste mildly saline; the reaction faintly alkaline. The specific gravity at 15·5 degrees C. was 1·00631. The total dissolved matter by direct experiment, dried at 180 degrees C. in 1,000 parts by weight of water, was 7·4129.

The water contained for 1,000 parts by weight:

Potassa	0·190
Soda	3·3899
Lithia	undetermined
Lime	0·836
Strontia	undetermined
Magnesia	0·1165
Ferrous oxide	undetermined
Alumina	trace
Sulphuric acid	1·6636
Boracic acid	undetermined
Carbonic acid	0·3819
Phosphoric acid	undetermined
Chlorine	2·4623
Iodine	0·000027
Bromine	undetermined
Silica	0·0135
Organic matter	undetermined.
Total	8·130327
Less oxygen equivalent to chlorine	0·5555
	7·574827
Sulphuretted hydrogen—when received	0·0098

The constituents may be assumed to exist in the water combined as follows; the carbonates being calculated as mono-carbonates, and all the salts being estimated as anhydrous.

Calcium carbonate	0·0855
Magnesium carbonate	0·2447
Potassium chloride	0·0301
Sodium chloride	4·0358
Sodium sulphate	2·8624
Calcium sulphate	0·0867
Alumina	trace
Silica	0·0135
	7·3587
Carbonic acid—half combined	0·1658
Carbonic acid—free	0·0503
	7·5748

These quantities if calculated for purposes of comparison with the other waters, as grains per imperial gallon, would be as follows:

Calcium bicarbonate	8·617
Magnesium bicarbonate	26·103
Potassium chloride	2·107
Sodium chloride	282·506
Sodium sulphate	200·368
Calcium sulphate	6·069
Silica	0·945
Alumina	trace
	526·715
Free carbonic acid	3·521
Total	530·236

Dr. McIntosh, of McGill University, has examined this water for radium emanation but he finds that it is no higher in this content than ordinary St. Lawrence water.

89.—The Wire and Cable Company—Corner Guy and St. James streets.

Water was struck 960 feet from the surface, and sinking was then continued to a depth of 1,055 feet in hope of obtaining a large supply of water, but without success. The water just rises to the surface. The yield of the well was tested by pumping for 14 consecutive hours, at the rate of 3,000 gallons an hour. This resulted in the lowering of the level of the water by 16 feet, which lowering took place when the pumping began, after which time the water level sank no further. The hole is 6 inches in diameter down to a depth of 40 feet from the surface, below which the diameter is 4¾ inches. The solid rock was met with 57 feet from the surface.

An analysis of the water by Dr. J. T. Donald gave the following results in grains per imperial gallon:

Carbonate of lime	22·09
Carbonate of magnesia	2·79
Carbonate of iron	0·53
Carbonate of soda	12·20
Sulphate of lime	1·24
Chloride of sodium	1·55
Total solids	40·40

90.—L'Air Liquide Société—First avenue, Maisonneuve.

This well is situated about three-quarters of a mile from the Viauville Mineral Springs. The well is 658 feet deep and its capacity is 157,000 gallons per day. There is no analysis of the water but it is described as very salty and high in scale forming matter and it contains much sulphuretted hydrogen.

This well probably struck the same kind of water as found at the Viauville well and probably also the same as that of the Montreal Locomotive Company's well No. 172, which struck salt water at 340 feet. The sulphuretted hydrogen content is said to vary very much from time to time. It is probable that if the well were pumped regularly this would not be observed as the gas has a tendency to accumulate in water on standing.

There is a complete set of chippings preserved from different depths in this well. The boring goes through 22 feet of drift and then strikes the Trenton limestone. From 265 to 320 feet are signs of some igneous rock and at 275 feet a specimen of kaolinized bostonite was found. From a specimen from a depth of 265 feet, a thin section was made and it proved to be a limestone full of fragments of brachiopod shells and one or two crinoid remains. At 310 feet a piece of dyke rock was found and this proved to be an altered camptonite containing vesicles filled with zeolites and calcite.

91.—J. B. Abott—Ste. Anne de Bellevue.

This well has a depth of 301 feet. In boring, solid rock was struck at 112 feet. The well yields water at the rate of 38,400 gallons per day.

92.—Walter Baker Company—1000 Albert Street.

Water was struck at two horizons. At 205 feet a supply of 8,600 gallons a day was obtained. The rest of the water was obtained between 840 and 845 feet, there being no further increase in supply on boring to 1,207 feet.

The water is useless to the company as it is very high in salts and impregnated with sulphuretted hydrogen. The only other water in Montreal with a higher concentration of salts is that of the Viauville springs which is four times as concentrated. Both are high in soda, high in chlorides and sulphates, and low in carbonate.

An analysis by Milton Hersey, made March 7, 1912, gave the following results.

Colour	colourless
Odour	smells of H_2S.
Transparency	turbid
Sodium as free ammonia	1·2 pts. per million
" " albuminoid	0·130 " "
" " total	1·330 " "
" " nitrates	trace
" " nitrates	trace
Chlorine as chlorides	0·392 pts. per million
Reg. oxygen	2·75
Total solid on evap	782·0
Solids volatile on ignition	1760·8
Observed on ignition of solids	no charring.

	Grains per imp. gallon
$CaCO_3$	15·00
$CaSO_4$	none
$CaCl_2$	none
$CaNO_3$	none
$MgCO_3$	1·32
Mg_2SO_4	none
$MgCl_2$	none
AlO_3 and Fe_2O_3 } SO_3 }	1·75
Suspended matter and sed.	none
Incrusting solids	18·07
Na_2CO_3	0·98
Na_2SO_4	65·86
NaCl	45·28
$NaNO_3$	none
Organic matter	none
Non-incrusting solids	112·12
Total solid on evap.	130·19

A complete set of chippings from this well have been kept. At a depth of 23 feet from the surface the Trenton limestone was struck. Specimens brought up from 230 and 240 feet, show that the boring must have gone through quite an extensive intrusion of igneous rock. The specimens are all decomposed, but on warming the powdered rock with acid it gelatinizes and the rock is probably a nepheline syenite. From 290 feet was obtained a specimen of limestone full of fragments of crinoid stems. From a specimen from a depth of 660 feet, a pygidium of a trilobite identified as *Dalmanites* was found and from 950 feet *Rhynchonella* sp. was obtained in a piece of black calcareous shale. At 1,060 feet a typical specimen of the Chazy limestone was brought up. *Dalmanites* does not occur lower than the Trenton and this proves that the Trenton here is at least 637 feet thick.

93.—Bank of Montreal—St. James street.

The surface covering of drift is 49 feet which is low for this part of the town. It is described as extra hard and as containing many boulders. All the water was struck at 200 to 300 feet.

There was no increase between this point and 1,000 feet at which point boring was discontinued. The well has a capacity of 124,800 gallons per day and the water rises to within 57 feet of the surface.

It was originally intended to sink a very deep well here with the hope of obtaining a very large supply of water. The diameter is unusually large being 12 inches for the first 202 feet, 6 inches from 202 feet to 566 feet, and after that 4½ inches.

94.—E. L. Baugh and Company—Just north of C.P.R. subway on St. Denis street.

This well has only been put down (1913). A large artificial ice plant is being built here called the Hygeia ice plant and this artesian water is to be used by this establishment. The water is good and the well has the large capacity of 122,000 gallons. The water rises to within 5 feet of the surface. The well is 525½ feet deep.

95.—Brandram, Henderson Company—Mile End.

All the water was struck at 500 feet and the well is 510 feet deep. The supply pumped during a day of 10 hours was 50,000 gallons, but probably it could be increased if necessary. The natural level of the water is 18 feet below the surface, but on heavy pumping it is lowered to 26 feet. The water is used for all purposes except in boilers for which the city supply is preferable. It is used for drinking too but is slightly sulphurous.

I am indebted to Mr. Monk, the chemist of the company, for the following analysis.

	Grains per imp. gallon
Iron and alumina	0·5
Calcium carbonate	14·14
Magnesium carbonate	3·35
Silica	trace
Total encrusting solids i.e. temporary hardness	17·99
Sodium sulphate	11·00
Sodium chloride	5·58
Sodium carbonate	3·19
Organic matter	0·79
Total solids i.e. permanent hardness	38·55

96.—Canada Bread Company—611 Rivard street.

The water from this well at one time was sold under the name of "Emerald water." But the above company now possesses the well and the water is no longer sold. The water is of excellent quality and it is stated that the supply is very constant and good. The well is 508 feet deep. At a depth of 250 feet a supply of water with a yield of 38,400 gallons per day, was obtained. At 500 feet an additional supply of 38,200 gallons was struck.

The following analysis was made several years ago by Dr. J. T. Donald.

	Grains per Imp. gallon
Sodium chloride	18·48
" sulphate	6·27
Carbonate of lime	7·80
" " magnesia	4·60
Iron oxide and alumina	0·73
Alkaline carbonates	6·08
	43·96

97.—Canada Car and Foundry Company—Turcot Works.

This well is 601 feet deep. It yielded water at the rate of 24,000 gallons per day. The water is slightly sulphurous and is not used.

98.—Canada Car and Foundry Company—St. Pierre.

This well is 599 feet deep. The water supply is saline and yielded 12,000 gallons per day.

99.—The Canadian Brewing Company—218 Delorimier, Cadastral No. lot 502, St. Mary's ward.

This well was sunk to a depth of 830 feet. The hole is 6 inches in diameter to a depth of 71 feet and 4½ inches below this depth. In boring, solid rock was reached at 67 feet below the surface. Water was obtained, the well yielding 36,000 gallons per day. The water rose to a level 112 feet below the surface.

This well and No. 6 are about 50 feet apart and the two wells are connected underground as they are found to pump one another dry.

100.—Canadian Pacific Railway—Hochelaga.

Well No. 100 is several hundred feet distant from well No. 11 and is situated near the lunch room. It is 8 inches in diameter to the rock which is 8 feet below the surface. It is then 6 inches to 658 feet and 4½ inches to 870 feet. At 657 feet a pocket of loose clay and stone was encountered and the drill kept jamming. The top portion of the well has since been reamed to 8 inches for 205 feet.

The capacity was originally 10,000 gallons per hour, but it has since fallen to 7,000 gallons per hour. Water was found at two levels, namely 610 feet and 860 feet.

101.—Canadian Pacific Railway—Place Viger Station.

This well and well No. 57, 50 feet distant, formerly belonged to the Montreal Brewing Company. The water of well No. 57 is no longer used, but that from No. 101 is still used and furnishes excellent drinking water to the Place Viger hotel.

The well is 1,004 feet deep. Water was struck twice. At 610 feet, the capacity was 20,000 gallons per day and there was a large increase in supply between 975 and 980 feet. When tested the capacity was equal to the full capacity of the pump, or 57,000 gallons per day, but the well is said to have a capacity of 108,000 gallons a day.

The following analyses were made by Mr. Milton Hersey, and are stated in grains per imperial gallon.

	March 17, 1908	Nov. 4, 1910	Sept. 30, 1912
Calcium carbonate...	2·44	2·28	12·73
" sulphate.....	none	none	none
" nitrate....	....	none	none
" chloride...	none	none	none
Magnesium carbonate....	1·32	2·51	6·94
" sulphate......	none	none	none
" nitrate......	....	....	none
" chloride...	none	none	0·90
Silica, etc	0·43	0·896	none
Total encrusting solids..	4·19	5·69	20·62
Sodium carbonate....	17·67	15·37	4·70
" sulphate......	23·62	35·33	17·25
" nitrate	....	none	none
" chloride........	7·85	9·31	8·20
Organic matter..........	2·54	....	none
Total non-encrusting solids.	51·65	60·02	30·15
Total solids..............	55·84	65·72	50·77
Lbs. of solid per 1,000 gals...	0·59	0·81	2·94

On September 30, 1912, the following drinking analysis was made by Mr. Milton L. Hersey.

Examination showed the water to be free from pathogenic germs. The water is colourless and clear, odourless, and tasteless.

Nitrogen as free ammonia........................	0·04	pts / M
" " albumenoid........................	0·00	"
Total nitrogen........................	0·05	"
Nitrogen as nitrates........................	trace	
" " nitrates........................	trace	
Chlorine as chlorides........................	71·2	pts / M
Oxygen required........................	0·85	"
Total solids on evap........................	760	"

102.—Canadian Pacific Railway—Windsor station.

This well is a failure, the supply of water being far too small to be of any value. The well was drilled to a depth of 1,492 feet. The water supply obtained was 13,200 gallons per day and the water was sulphurous. A complete set of specimens of this well has been kept. The limestone is uniformly dark down to 480 feet. At 90, 300, and 345 feet and especially at 480 feet, several bits of black shale were brought up. Then follows lighter coloured limestone. From 830 to 860 feet the limestone is very shaly and at 1,200 feet there is a shaly band. Shale is quite common throughout. At 1,492 feet a sample was tested for magnesium and as the amount was small probably the Beekmantown has not been reached, but we have not yet satisfied ourselves on this point.

103.—Canadian Rubber Company—Papineau and Notre Dame streets.

This well is 1,210 feet deep and in boring, solid rock was first struck at a depth of 70 feet. The water rose to a height of 15 feet below the surface. The well has a capacity of 1,740 gallons per hour; the supply being insufficient, the well is not used. The water was struck first at a depth of 215 feet, a small increase was obtained at 265 feet, another increase at 470 feet, and at 920 feet there was an estimated yield of 800 gallons per hour. No further water supply was found below 920 feet.

The following are details regarding the sinking of this well:

Boring operations commenced Sept. 1, 1906.
Boring operations completed March 1, 1907.
Total depth, 1210 ft. 8 in.
Depth of 8 inch hole, 78 ft. (0 to 78 ft.).
Depth of 4¾ inch hole, 1132 ft. 8 in. (78 ft. to 1132 ft. 8 in.).
Cost of 8 inch hole, $273.
Cost of 4¾ inch hole, 922 ft., $1,844.
Cost of 4¾ inch hole, 210 ft. 8 in., $630.

104.—Canadian Spool Cotton Company—Notre Dame street, Maisonneuve.

The depth of the well is 1,078 feet, solid rock was first struck at 168 feet. A supply of 21,600 gallons per day of very sulphurous water was obtained.

105.—Carter White Lead Company—91 Delorimier avenue.

The depth of the hole is 507 feet. Solid rock was encountered at a depth of 85 feet. The well has a capacity of 36,000 gallons per day of good water free from sulphur.

106.—Convent—Pointe aux Trembles.

This well has a depth of 280 feet. It furnishes 28,800 gallons per day. The water is soft and rises to within 31 feet of the surface.

107.—A. F. Copperthwaite—St. Lambert.

The well is 367 feet deep and yields 15,600 gallons of good drinking water per day. The water rises to a height 10 feet below the surface. Solid rock was first struck at a depth of 40 feet.

108.—Crown Shoe and Leather Company—356 Moreau street.

This well is 1,500 feet deep and only very little water (2,400 gallons per day) was struck. It is noticeable that on both sides of this well are other unsuccessful wells—two at the gas works, Nos. 60 and 61, and No. 34, belong to the Fenlin Leather Company. On the other side are three borings of the Shawinigan W. and P. Co. (wells Nos. 79, 169, and 170) which failed to give sufficient supplies of water.

A complete set of specimens from this boring was kept. It starts in Trenton but it must be very near the top. The limestone which occurs throughout the boring is all of the same uniform grey colour. At 1,040 feet a specimen of Laurentian granite was found. An exactly similar specimen was found at 420 feet in the shallow well at the Maisonneuve baths. With no further evidence it is safest to assume they were accidentally introduced. Several samples from the bottom were chemically tested, but there is no sign of the Beekmantown dolomite.

As bed-rock is 32 feet below the surface, the combined thickness of the Trenton and Chazy must be over 1,468 feet. This supports the evidence obtained in the case of the deep boring at Dow's brewery.

109.—T. Cushing—Parc Lafontaine.

This well is 1,453 feet deep. Water was struck at two levels. At 890 feet the flow was 36,000 gallons per diem and at

1,020 feet it was 64,800 gallons. This is one of the few cases where much water has been struck as low as 1,000 feet. The water is good in quality.

A set of specimens from this boring has been preserved. From 750 to 810 feet, the limestone appears shaly. From 1,050 to 1,070 feet occurs decomposed dyke material. At 1,175 feet a fragment of a trilobite was found, identified as *Trinucleus fimbriatus*. From 1,300 feet to 1,440 feet at the bottom, the limestone gets distinctly shaly.

110.—Daoust, Lalonde, and Company—Just north of Canadian Pacific Railway subway on Iberville street.

This well is 995 feet deep. It yields a water supply of 21,600 gallons per day. The water is soft and good for tanning purposes in consequence. It is slightly sulphurous.

According to Mr. A. Daoust the water contains 0·397 parts of solid matter in 1,000 parts. This is 27·79 grains per imperial gallon. The specific gravity of the water at 15 degrees C. is 0·9997.

A complete series of chippings was kept from this well. The limestone is very shaly throughout and from 370 to 390 feet is an almost pure shale. At 465 feet a specimen of very pure limestone was found. Two fragments of *Conularia trentonensis* and *Beyrichia* sp. were recognized. Fragments of trilobites were common and a plate of *Glyptocystites logani* occurred. The latter is known to occur both in the Trenton and Black River. From 480 feet a specimen of a shaly rock, very like the Black River, was brought up and in it five specimens of Leperditia were discovered.

111.—Wm. Davies Company—Mill street.

This well is 707½ feet deep. Two pockets of gas were struck at 240 to 245 feet and 270 to 275 feet.

The estimated water capacity is 3,200 gallons per hour or 76,800 gallons per diem, but this supply could only be obtained for an hour or two at a time after which the supply ceased. The water is not used at present as the supply is not sufficient even if it were constant.

Quite a lot of gas seems to have been struck in this well and when lighted the flame rose quite high. The company collected some in a tank above water but an explosion unfortunately occurred and since then the well has been capped. The engineer thinks it could be used for power purposes with advantage.

112.—Messrs. Dawes and Company—Lot 202 D, Lachine.

This well was sunk to a depth of 1,220 feet. The hole is 8 inches in diameter to a depth of 26 feet, and 4¾ inches from there to the bottom. In boring, solid rock was reached at 26 feet below the surface. Water was obtained with a yield at the rate of 76,800 gallons per day, but the well is quickly pumped dry. The water is contaminated, quite unfitted for drinking, and is used only for cooling purposes. This well is only about 100 feet from well No. 19.

113.—Dominion Ice Company—La Salle and Girard streets, Maisonneuve.

The well is 600 feet deep and affords a very constant water supply of 72,000 gallons per diem. The water is slightly sulphurous and the quantity of sulphur is stated to vary considerably from time to time. The well is used only in winter as between here and "Les Frères chrétriennes" there is a fine spring used in common. But the spring dries up in the winter especially after a dry summer or during a cold winter. The spring water contains no sulphur and is markedly cool.

114.—Dominion Light, Heat, and Power Company—Aird avenue, Maisonneuve.

This well is 610 feet deep and affords a water supply of 60,000 gallons per day. The water rises to a point 20 feet below the surface. The water is not saline but is very sulphurous and the sulphur content varies markedly from time to time.

115.—Dominion Park Company—Longue Pointe.

This well is 150 feet deep and yields 8,400 gallons per day. The following analysis of the water was made by the Milton Hersey Company, in July 1907. The results are stated in parts per million:

	July 15	July 17	July 19
Total solid on evaporation...	293	466	360
Volatile solids............	166	89	75
Chlorine or chlorides.......	10	11·8	10·8

116.—Messrs. William Dowand Company—186-188 Colborne street.

This well was sunk to a depth of 1,525 feet. The hole is 8 inches in diameter to a depth of 82 feet, and 5 inches below this depth. In boring, water was struck at depths between 600 and 700 feet. The yield was at the rate of 36,000 gallons per day. The boring was continued to a depth of 1,525 feet when, as no more water was obtained, the boring was abandoned. Four other wells, Nos. 22 to 25, situated on this property, were failures and all except one are now blocked up.

Specimens were kept from the borings of this well from 1,205 to 1,525 feet. At 1,235 the limestone is shaly. Samples from 1,495 and 1,525 feet were chemically analysed to see if the Beekmantown dolomite had been struck. No magnesium was detected in the 1,495 foot sample. The 1,525 foot sample was very impure, a residue amounting to 54 per cent being left undissolved. There was 41 per cent of calcium carbonate present and the magnesium carbonate amounted to only 1½ per cent of the calcium carbonate. Clearly then the Beekmantown dolomite has not been struck at this depth. As there is about 60 feet of surface drift the combined thickness of the Chazy and Trenton at this locality must be over 1,465 feet. This is 90 feet thicker than that found by Dr. Adams at the Turkish bath well. It is probable that the boring starts here very near the top of the Trenton.

117.—A. L. Drummond—Beaconsfield.

This well is 340 feet deep. Water rises to a point 13 feet below the surface and the supply is 52,800 gallons per day. The water is of a good quality.

118.—Dufresne et Locke—Ontario and Desjardins streets, Maisonneuve.

The well is 751 feet deep. The water supply was tested by Mr. Bell and found to give a capacity of 300 gallons per hour, but according to Mr. Locke 1,000 gallons could easily be obtained from it if required. There is no analysis available; the water is very good for all purposes—drinking, boiler, etc. Only a small amount of scale is deposited in the boiler. Probably the water is similar to that of Warden Kings' and Watson Foster Companys' wells, Nos. 175 and 176.

119.—J. D. Duncan—Mountain street.

This well is 885 feet deep and has a capacity of 40,100 gallons per day of water of a good quality.

120.—Frontenac Breweries—Opposite Mile End depot.

This well is 490 feet deep. Water was first struck at 340 feet when the tested capacity was 40,800 gallons per diem. An additional flow was struck at 478 feet and the combined supply is at the rate of 432,000 gallons per day.

This boring was a very fortunate one. The well has the greatest capacity of any well hitherto bored in Montreal. The character of the water is exceptionally good. It has two interesting features, viz., it is not alkaline and it contains an excess of sulphate to combine with the calcium.

The following analysis was made by Dr. J. T. Donald on January 7, 1913:

Total solids	81·340
Sodium chloride	6·232
Sodium sulphate	22·925
Potassium sulphate	0·432
Iron oxide and alumina	0·084
Calcium sulphate	25·208
Calcium carbonate	14·714
Magnesium carbonate	7·762
Silica	0·924
Sodium nitrate	0·014
Sodium nitrate	0·085
Free ammonia	0·008
Albuminoid ammonia	0·004
Oxygen required	0·087

A complete set of chippings from this boring has been kept. At 470 feet occurs a very hard, fine-grained, light grey rock. As water was struck at 478 feet or just below this the underground circulation was probably governed by this hard band. A section was cut from it and it proved to be a sedimentary rock full of rather angular crystals of quartz in a fine-grained groundmass. A fragment was tested for dolomite but it gave the calcite reaction. The rock must, therefore, be described as a very siliceous limestone. Below this the limestone appears quite shaly.

121.—F. Galibert—Amity and Parthenais streets.

This well has a yield of 108,000 gallons per day and all the water was struck at the bottom, namely 577 feet. The water is of a character very similar to that of the wells of the Montreal Abattoir and the Ice Manufacturing Company. The water, like these, is very high in sodium carbonate and, therefore, good for tanning purposes. This district must be looked upon as an extraordinarily favourable one for drilling operations if this kind of water is desired.

The well of Daoust, Lalonde, and Company (No. 110) probably falls into the same category and perhaps also that of T. Cushing, Parc Lafontaine (No. 109).

A complete set of chippings from this well was kept. A light coloured limestone occurs down to 185 feet and at 365 feet a fragment of a fine-grained camptonite (?) dyke was discovered. At the same depth occurred a brown bituminous limestone in which *Strophomena* sp. and a crinoid plate were found.

The results of a chemical analysis made by Dr. J. T. Donald on June 10, 1912, is as follows, stated in grains per imperial gallon:

Calcium carbonate	0·68
Magnesium carbonate	0·06
Aluminum, iron, and silica	0·42
Suspended matter and sediment	0·00
Encrusting solids	1·16
Sodium carbonate	31·83
Sodium sulphate	5·64
Sodium chloride	10·25
Non-encrusting solids	47·72
Total salts	48·88

122.—Guaranteed Pure Milk Company—St. Catherine street west.

Water was struck at the bottom of this well at a depth of 151 feet and flows naturally with a head of 15 feet. The capacity is 67,200 gallons per day. The water is high in calcium carbonate and belongs to a group of wells which are all high in calcium and situated in this part of the city.

The result of an analysis of this water, made by Dr. J. T. Donald, September 29, 1909, is as follows, stated in grains per imperial gallon:

Total solids	30·48
Sodium chloride	4·34
Calcium carbonate	15·625
Magnesium carbonate	2·825
Sodium sulphate	6·825
Oxygen required	0·031

123.—Chas. Gurd—112 Beaudry street.

This well is 318 feet deep. Water was struck at the bottom and rises to 50 feet from the surface. The capacity is 48,000 gallons per day. The water is good.

124.—T. Hannah—Back River.

This well is 61 feet deep. The water rises to a height 61 feet below the surface and yields water at the rate of 21,600 gallons per day. The water is described as being of excellent quality, free from sediment, and only slightly hard.

125.—Ice Manufacturing Company—Frontenac street.

This well, situated close to the Montreal Abattoirs, is 995 feet deep. Water was struck at 500 feet and at 700 feet. The well has a capacity of 132,000 gallons per day.

The water is very similar to the water of the Montreal Abattoir wells, Nos. 147 and 148. The proportions of the salts are almost identical with those in the water of the Angus shop well No. 12. It is more concentrated it is true, but as analyses of the same water taken at different times show, the absolute concentration seems to be of small moment as it often varies greatly; but for the same well the relative proportion of salts in the water seems to remain much more constant.

The only other water like it is that of the Canadian Pacific Railway Place Viger well No. 101.

Of the following analyses, No. 1 was made by W. B. Scaife and Sons Company, Pittsburgh, Pa.; No. 2 by Laurie and Lamb, Montreal; and No. 3 by Ferguson Laboratories, New York. All the results are stated in grains per imperial gallon:

No. 1, February 17, 1913.	
Volatile and organic matter	2·58
Silica	0·90
Iron and aluminium oxide	trace
Calcium carbonate	8·26
Magnesium carbonate	8·07
Sodium carbonate	11·61
Sodium sulphate	23·50
Total solids	63·50
Suspended matter	0·78
Free carbonic acid	0·00
Encrusting solids	17·22
Non-encrusting solids	43·60

No. 2, March 7, 1913.	
Sodium chloride	8·747
Sodium sulphate	24·369
Calcium bicarbonate	13·659
Magnesium bicarbonate	13·873
Iron and aluminium oxide	0·140
Silica and insoluble matter	0·840
Alkaline carbonates	1·372
Total solids	63·000

No. 3, February 14, 1913.	
Calcium oxide	5·62
Magnesium oxide	3·75
Chlorine	5·54
Equivalent in sodium chloride	9·15
Sulphur trioxide in sulphates	13·61
Iron and aluminium oxides	0·14
Silica	1·03
Total solids	63·00
Scale-forming solids	17·30
Hardness equivalent in calcium carbonate	
Temporary	16·10
Permanent	0·00

126.—Imperial Tobacco Company of Canada, Ltd.—900 St. Antoine street.

All the water was struck at the comparatively shallow depth of 150 feet. Sulphurous water was obtained which flowed naturally at the rate of 1,000 gallons per hour. There was no increase to 502 feet when the boring was abandoned. The water was very sulphurous and rose to the surface.

127.—Independent Breweries—600 Rivard street.

Water was struck at 500 feet with a flow of 21,000 gallons per day and again at the bottom, at a depth of 805 feet, the combined flow being 76,800 gallons per day.

A complete set of chippings from this boring was kept.

From a depth between 160 and 170 feet a specimen of leached pseudo-vesicula bostonite was brought up. From 580 to 610 the limestone is very impure and probably mixed with dyke material. From a depth of 795 feet two specimens of crystallized fluorite were brought up. The crystals are very small but with a lens the cubes are distinctly visible. It is of a light purplish violet colour. A section was cut from the rock chip upon which this occurred. The section consists almost entirely of kaolin with little specks of quartz and pyrite scattered through it. The rock is almost certainly an altered bostonite. This seems to be another instance of the water being found closely associated with a bostonite dyke. Another instance was that at the La Reina Mineral Water Company's well.

Fluorite has been found associated with these dykes in other parts of Montreal. Probably the igneous material contained fluorine and this acting on the limestone caused the formation of calcium fluoride. In the excavation for the new reservoir at Outremont it is found exactly under these conditions.

The following analysis of the water from this well was made by the Milton Hersey Company, on March 26, 1913:

	Grs. per imp. gallon
Calcium carbonate	4·27
Calcium sulphate	none
Calcium chloride	none
Calcium nitrate	none
Magnesium carbonate	3·12
Magnesium sulphate	none
Magnesium chloride	none
Silica, etc	0·35
Suspended matter	none
Total encrusting solids	7·74
Sodium carbonate	12·71
Sodium sulphate	10·18
Sodium chloride	9·85
Sodium nitrate	none
Organic matter	none
Non-encrusting solids	32·74
Encrusting solids in 1,000 imp. gals	1·10 lbs.
Total solids	40·48

128.—T. J. Joubert—975 St. André street.

The well is 490 feet deep. A tested water supply at the rate of 100,800 gallons per day was obtained. The water is pure and does not contain sulphur.

The following analysis was made by J. A. Chopin on January 24, 1910:

	Pts. per million.
Ammoniaque libre	0·080
Ammoniaque albuminoide	0·140
Chlore des chlorures	13·00
Acide nitrique des nitrates	0·025
Oxygene absorbe a 100° C en milien acide	0·80
Oxygene absorbe a 100°n C en milien alcalin	1·20
Degres de durete	21·00
Rendu volatil	86·00
Rendu fixe	384·00

129.—La Reina Mineral Water Company—Vinet and Notre Dame streets.

This well is 441 feet deep. All the water was struck at a depth of 250 feet. The capacity of the well is 8,600 gallons per day. The water is used in the manufacture of soda water, etc., for which it is very suitable by reason of its high content in sodium chloride and sulphate.

The following analysis was made by Mr. Nadan on January 6, 1913:

Chloreurs	0·117 grs. per litre
Carbonates	0·794 en CO_2 litre
Sulphates	0·391 grs. au litre
Phosphates	absent
Calcium	absent
Nitrates	absent
Nitrites	absent
Sodium } Potassium }	present

Matières organiques presence en milieu acide 0·001 au litre: en milieu alcalin 0·0029 au litre.

A series of specimens from this boring has been kept. At 232 feet the limestone becomes mixed with a white pure kaolin or china-clay. This increases in quantity to 268 feet and the specimens brought up from 261 feet to 268 feet, consist almo. . entirely of this. As the water was struck at 250 feet this material probably had a very close connexion with the underground circulation of the water. The kaolin is almost certainly derived from a bostonite dyke such as are so common about Montreal. Probably these dykes have a very considerable influence upon the circulation; and it has been especially noticed while the Canadian Northern Railway Company was boring the tunnel through the mountain that the large supplies of water were often struck in association with these bostonite dykes.

130.—Lacroix et Piché—Longue Pointe.

This well is 556 feet deep. The capacity of the well is 45,600 gallons per day of good water with little sulphur. The water level is 40 feet below the surface.

131.—D. Lalonde—St. Lawrence street.

This well is 810 feet deep. The water rises to a point 10 feet below the surface and furnishes a supply of 18,240 gallons per day. The water is of a good quality.

A complete set of chippings from this boring has been kept. From a depth between 70 feet and 80 feet a fragment of *Platystrophia biforata* var *links* was brought up. This fossil is characteristic of the Trenton. From a depth between 120 and 130 feet another fragment of limestone containing the above fossils was obtained.

132.—The Laurentian Baths, Messrs. Robert White and Company—208 Craig street.

The earthquake which occurred in the autumn of 1893 produced a very perceptible turbidity in the water which lasted for about a day and a half.

Well No. 132 is 150 feet distant from No. 48, and is 457 feet deep. At 250 feet, water was first struck and the capacity was 1,500 gallons per hour. Water was struck again at 450 feet and the combined capacity was 4,500 gallons per hour. The water in this well does not flow naturally, but rises 52 feet from the surface. There seem to be two water-bearing horizons and not a general zone of leakage between the two levels as the capacity was tested at 295 feet, for example, and there was no change in it.

The water from this well and from well No. 48 (150 feet distant) supplies the now famous Laurentian water which is bottled and has a very considerable consumption in Montreal. The supply is drawn chiefly from well No. 132.

133.—O. Limoges—Chambord street.

This well is 313 feet deep. The water rises to 1 foot above the surface. It yields water of a good character at the rate of 3,600 gallons per day.

134.—Lower Canada College—Royal Avenue, Notre Dame de Grâce.

This well is 435 feet and has a capacity of 10,320 gallons per day of good water.

The following results are taken from an analysis and report made by Dr. Starkey, dated March 29, 1912:

	Parts per 100,000
Colour	nil
Turbidity	slight
Total solids	35·9
Fixed solids	33·8
Volatile solids	2·1
Free ammonia	0·044
Albuminoid ammonia	0·01
Chlorine as Cl	1·9
Nitrates as NO_3	0·0
Nitrites as NO_2	0·0
Sulphates as SO_4	4·03
Carbonates as CO_3	14·97
Calcium	2·18
Magnesium	0·50
Sodium	10·23
Iron	trace
Silica	1·1

Substances combined as	Parts per 100,000
Calcium carbonate	1·250
Magnesium carbonate	1·725
Calcium sulphate	5·713
Sodium carbonate	23·000
Sodium chloride	3·135
Silica	1·100
Total	35·923
Oxygen absorbed in 4 hours	0·249

Bacteriological examination.
Average number of colonies per cc. of water in agar at 37·5°C. = 129.
Colon-typhoid group, none whatever.
Nature of organisms, surface or dust organisms.

"This sample shows an alkaline water rather of the hard variety, but quite suitable for culinary and potable purposes.

Bacteriologically the sample contains rather too many organisms for a deep well water. None of the bacteria are dangerous though, and I am of the opinion they have crept into the sample via the compressed air, and possibly at the time of collection. This surmise is favoured by the very nature of the bacteria; they are all the common varieties found floating round in the air and dust. Their exclusion from the water supply ought not to be a matter of any great difficulty."

135.—W. Lowney and Company—169 William street.

This well occurs in a district where many unsuccessful wells have been put down. Water was first struck at 200 feet and the capacity was 36,000 gallons per diem. Water was again struck at the bottom (302 feet) and the combined capacity was 94,000 gallons. The water was highly charged with sulphuretted hydrogen when pumping was started, the odour even causing a nuisance to neighbours. But after about six weeks pumping the odour disappeared to a large extent and now causes no trouble. The water is only used for cooling purposes in summer.

The following analysis was made by Milton Hersey Company, June 17, 1907:

Calcium carbonate	15·85
" sulphate	none
" chloride	none
Magnesium carbonate	8·29
" sulphate	none
" chloride	none
Silica, etc.	0·12
Suspended matter	none
Total encrusting solids	24·26
Sodium carbonate	3·68
" sulphate	3·83
" chloride	10·88
" nitrate	none
Organic matter	1·43
Total non-encrusting solids	19·82
Total solid on evap.	44·00

136 and 137.—Maisonneuve Baths—Market Place, Maisonneuve.

Well No. 136 is 1,031 feet deep. All its supply of water (4,600 gallons per diem) which is too small to be of any use, was obtained at a depth of 400 feet.

Well No. 137 is situated about 500 feet from well No. 136. It is 776 feet deep and gives a supply of 76,800 gallons per diem.

A complete set of specimens from this boring has been kept. The surface drift is about 36 feet deep. No Utica shale appears to occur here and Trenton limestone was struck first. It must be very near the top of the Trenton as a contact between the Utica and Trenton can be seen a short distance away. At 420 feet a piece of typical Laurentian granite was found mixed with the shaly limestone. A very similar specimen was found at 1,040 feet in the Crown Shoe and Leather Company's boring. Without any further evidence on the subject it is best to assume these have been accidentally introduced. The limestone is of a uniform grey tint all the way through. A considerable amount of shale is in evidence dispersed through the rock, especially is this so at the following depths: 480 feet to 500 feet; 660 feet; 800 feet to 820 feet; 900 feet; 990 feet to 1,020 feet.

138.—Maisonneuve Quarry Company—Rosemount avenue.

This well is 400 feet deep and has a capacity of 5,800 gallons per day. The water rises to within 15 feet of the surface, is hard, and slightly sulphurous.

139 and 140.—Martineau et fils.—Quarry at Corner of Papineau and Carriere sts.

These two wells are about 50 feet apart and are connected underground with one another. Well No. 139 is 428 feet deep and has a capacity of 34,000 gallons per day. Well No. 140 is 1,000 feet deep and yields water at the rate of 10,000 gallons per day.

The water of both wells is sulphurous but is used for drinking purposes. It is said to deposit much scale when used in boilers. It is probably very similar to the waters of the Molson Park estate, wells Nos. 143–145, which are very much higher in calcium than the average artesian waters.

A complete set of specimens from this well has been kept. The limestone appears to be of a lighter colour than usual. In the quarries occurs a fine exposure of a sheet of tinguaite capping the Trenton limestone. This is one of the igneous rocks intruded in connexion with the essexite of Mount Royal. The chippings from the well indicate that dyke rocks were penetrated at various horizons as at 90 and 110 feet; at 420 to 430 feet; and at 470 to 490 feet.

141 and 142.—Militia Department—Longueil.

Each of these wells is 1,020 feet deep. Well No. 141 yields water at the rate of 3,600 gallons per day, and No. 142, at the rate of 2,400 gallons per day. The water is saline and contains gas.

Specimens from one of the borings to a depth of 660 feet have been kept. Down to 380 feet shale and limestone alternate. Below this depth a purer limestone occurs and continues to the bottom. The boundary between the Utica and Trenton is placed, therefore, at 380 feet.

143, 144, and 145.—Molson Park Estate—Carrière and Iberville streets.

These wells are situated fairly close together and are of a much more uniform character than most neighbouring wells in the city of Montreal. The capacity of each is 36,000 gallons per day. They all struck water at comparatively shallow depths, well No. 143 is 100 feet deep, No. 144 is 224 feet deep, and No. 145 is 300 feet deep. Again the analyses of the waters show them to be nearly identical. The water is characterized by being very high in calcium and carbonate, and in all three it is of about the same concentration. The water is comparable with those of shallow spring waters, and is very similar to the water of the Canadian Pacific Railway well, No. 13. They belong to a group of wells which are high in calcium in this part of the city. The water in all the wells is sulphurous and rust collects if the water is left over night in metal pails.

The following analyses, each sample from a different well, were made by Dr. J. T. Donald on November 15, 1911, and expressed in grains per imperial gallon:

Total solids	38·15	59·50	41·40
Sodium chloride	0·82	0·91	4·60
Sodium sulphate	6·10	6·82	4·45
Carbonate of lime	24·40	25·00	24·10
Carbonate of magnesia	5·20	2·99	5·24
Oxides of silicon, iron, and alumina	0·47	0·62	0·36
Alkaline carbonates	1·31	3·12	2·60
O_2 required	0·10	0·45	0·11

A complete series of specimens from the deeper of these wells was kept. No special evidence that igneous material was passed through was noticed and the strata appear to be limestone.

146, 147, and 148.—Montreal Abattoirs—Frontenac street.

This is an instance of three wells put down close together which have all struck satisfactory supplies of water. The district seems a very favourable one. Two other wells have been put down in quite close proximity and obtained adequate supplies of water too. This location may be described as the centre of a district which yields waters of a similar kind, high in sodium and in carbonate, and in which there have been no failures. The wells within this area are Nos. 110, 11, 100, 121, and 40. It is at present premature to attempt to extend this district farther but wells Nos. 109, 128, 48, 132, 101, 30, 96, 74, and 133 seem to belong here. There are unsuccessful wells in this larger area, but within it the waters, so far as the analyses go, all belong to the same general type. On the outskirts of the area are waters transitional in type.

Well No. 148 is the deepest of the three wells and in it water was struck at three levels, 475 feet, 890 feet, and 1,175 feet; the supplies were 2,140, 5,040, and 7,000 gallons per hour, respectively. Well No. 146 is 577 feet deep and has a capacity of 216,000 gallons per day. Well No. 147 is 810 feet deep and its capacity is 45,600 gallons per day. The supply from the three wells is used in the glue factory and in the abattoir.

The following are analyses of two of the waters:

Analysis of well No. 148 by Dr. Bruno Terne, March 31, 1913, in grains per imperial gallon.

Total substance	44·22
Volatile substance	4·69
Sodium carbonate	28·33
" sulphate	7·94
" chloride	3·86
Calcium carbonate	2·86
Magnesium carbonate	1·23

Analysis of well No. 146 by Dr. J. T. Donald, June 7, 1905, in grains per imperial gallon.

Total solids	36·98
Volatile solids	3·787
Sodium carbonate	23·744
Sodium sulphate	6·585
Sodium chloride	3·166
Calcium carbonate	2·375
Magnesium carbonate	1·171
Oxygen required	0·084

149.—Montreal Dairy Company—290 Papineau avenue.

This well is 620 feet deep. It has a capacity of 55,200 gallons per day. The water is good in character and has a temperature of 48 degrees F. The supply is used for cooling purposes.

150 and 151.—Montreal Jockey Club—Bluebonnets.

Well No. 150 is 203 feet deep and yields water at the rate of 132,000 gallons per day. Well No. 151 is 108 feet deep and has a capacity of 48,000 gallons per day. The two wells are about 100 feet apart. There are, in this neighbourhood, six other wells, but these are shallow obtaining their supply from the boulder clay or at the contact of the boulder clay with the solid rock. None of these wells penetrates solid rock more than a few feet, and all, save one, give good supplies of water.

An analysis of the water from well No. 151 showed that the contained matter was about 95 per cent alkaline carbonates.

152.—Montreal Light, Heat, and Power Company—St. Henri.

This well has a depth of 1,201 feet and a water capacity per day of 3,800 gallons.

153.—A. J. Munro—123 Britannia street.

This well is 1,125 feet deep and yields only 2,000 gallons per day, which is too small a supply to be of any use. What water there is, is hard, cold, and contains no sulphur.

A set of specimens from this well has been kept. There was 50 feet of surface drift below which Utica shale was struck. From experiments on the specimens with acid the shale seems remarkably pure down to 225 feet. The specimens after this effervesce vigorously with acid. The contact with the Trenton on this evidence is, therefore, placed at 225 feet.

154.—S. Nesbitt—2501 Rosemount boulevard.

This well is 300 feet deep and has a capacity of 6,000 gallons per day.

The following are the results of an analysis of the water from this well, by Milton Hersey, December 29, 1910. The results are stated in grains per imperial gallon.

Calcium carbonate	4·50
Magnesium carbonate	5·41
Iron and aluminium oxides, silica	0·31
Sodium carbonate	13·34
Sodium sulphate	13·37
Sodium chloride	3·99
Total solids	40·92

The character of this water is very similar to that of the water from the Montreal Abattoir well No. 146 and is intermediate both with respect to concentration and proportion of its constituents between the water of the Ice Manufacturing Company's well No. 125 and that of the Montreal Abattoir wells Nos. 146 and 148. It is good for drinking though slightly sulphurous. It is very much less sulphurous than some of the neighbouring wells. Its high content of sodium carbonate gives it a somewhat laxative effect.

155 and 156.—A. E. Ogilvy—Cartierville.

Well No. 155 is 580 feet deep and furnishes good water at the rate of 15,600 gallons per day. Well No. 156 is 520 feet deep and has a capacity of 52,800 gallons per day.

Specimens brought up during the boring of the wells show that the rock penetrated is limestone.

157.—Jas. A. Ogilvy and Son—St. Catherine street.

This well is 993 feet deep and has a capacity of 76,800 gallons per day. Of this supply, 12,000 gallons were struck at 300 feet and the rest at 875 feet.

The well at first flowed naturally with an 11-foot head, but on pumping to full capacity it falls fairly soon below the surface to the suction limit.

Lately the supply seems to have diminished as the suction limit is reached much more quickly. The capacity is said to vary; after a wet season it rises, while after a heavy frost it seems to fall. On the whole it seems to have fallen considerably since the well was bored. The water at first was very sulphurous but after pumping a week it was freed from this and now the sulphur cannot even be tasted. The water is very like that of the Montreal Abattoir wells Nos. 146 and 148, being high both in soda and carbonate, but it contains no magnesium. The following analysis of the water was made by J. T. Donald, July, 16, 1912. The results are stated in grains per imperial gallon:

Total solids	47·32
Sodium chloride	9·05
Sodium sulphate	19·04
Calcium carbonate	10·94
Magnesium carbonate	0·04
Iron, alumina, and silica	0·39
Alkaline carbonates	7·86

Bacteriological analysis showed the water to be pure and altogether it is a very desirable drinking water.

158.—Paterson Manufacturing Company—Mile End.

This well is 493 feet deep and has a capacity of 10,800 gallons per day.

The analysis of the water shows that it is very high in soda and somewhat comparable to Laurentian water, but it contains more carbonate and less chlorides and sulphates than the latter.

The water is used in boilers and mixed with the Montreal Water and Power Company's water it is found to give better results than either of the waters when used alone. The Montreal Water and Power Company water is high in calcium, the scale forming ingredient, but, of course, is very dilute. The introduction of sodium carbonate into the well water prevents the formation of a hard scale and causes the calcium carbonate to be deposited either in the boiler or in the feeder as a suspended powder which is easily blown off.

The following analysis of the water from well No. 158 was made by Mr. Spencer, chemist of the company, on August 6, 1912. The results are stated in grains per imperial gallon.

Sodium carbonate	27·65
Sodium sulphate	23·48
Calcium sulphate	4·42
Magnesium sulphate	4·62
Sodium chloride	6·04
Silica	0·78

159.—J. W. Peck.—2275 St. Lawrence boulevard.

Water was first struck at 300 feet where the capacity was 13,200 gallons. The rest occurred at the bottom or 602 feet, the total capacity being 24,700 gallons per diem.

From the accompanying analysis, the water is seen to belong to the group of waters high in calcium and carbonate and to be in strong contrast to that of the Paterson Manufacturing Company's well, No. 158, close by. It is comparable to the water from well No. 13 on the one hand and to the water of the Molson Park Estate wells on the other.

The following is the analysis of the water from well No. 159 made by Dr. J. T. Donald, June 10, 1912.

Total solids	50·470
Sodium chloride	7·123
Sodium sulphate	7·430
Calcium carbonate	18·690
Magnesium carbonate	10·800
Al_2O_3 } SiO_2 }	0·756
Alkaline carbonates	5·671

The following analysis by Dr. J. T. Donald was made of the same water to test it for drinking purposes; the results are stated in parts per million.

Total solids	721·00
Chlorine	62·48
Free ammonia	0·006
Albuminoid ammonia	0·072
Oxygen required	0·90

A series of specimens from this boring was kept. From 270 feet to 330 feet the rock is a rather pure, light coloured limestone. At 420 feet and 480 feet the limestone is rather shaly, but there is no trace here of any hard arenaceous limestone such as was found at a depth of 470 feet in the Frontenac Brewery's well, No. 120. At 550 to 602 feet where water was struck, it is a remarkably pure shale.

160 and 161—Pensionnat du Saint Nom de Marie—Outremont.

These two wells are situated about 100 feet apart and are interesting as in them water was found at different depths and of different kinds. Well No. 160 is 354 feet deep and the water level is 130 feet below the surface. The capacity is only 360 gallons per hour (8,600 gallons per day). Well No. 161 is 897 feet deep; all the water was struck at 890 feet and the water level is 150 feet below the surface. The low levels to which the water rises are worth noticing as being distinctly below the average for the artesian wells of Montreal.

The water in the first well has not been analysed but it is said to be very good for drinking, to contain no sulphur, and to be much softer than that of well No. 161.

To raise the water in well No. 161 an air lift 240 feet long is used. The water is hard and a special softening process is necessary before using it in boilers. According to the engineer it has got harder with time. At first it showed 35 degrees of hardness, after three months 42 degrees, after a year 58 degrees, and then in three years more it rose to 62 degrees. This water also contains no sulphur but it is described as too hard for drinking.

A series of specimens from both of these borings has been kept. As shown by them the limestone is noteworthy as being of a remarkably pure white nature. In well No. 161, at 675 feet and also at 735 feet, a brown decomposed dyke was penetrated. In well No. 160 the specimens from depths of 120 feet to 230 feet show much decomposed dyke material as is also the case with those from depths of 230 to 270 feet.

The following analysis of the water from well No. 161 was made by the Dodge Manufacturing Company, Mishawaka, Ind., January 27, 1910. The results are stated in grains per gallon.

Encrusting solids:	
Calcium carbonate	6·55
Calcium sulphate	12·93
Calcium chloride	0·00
Magnesium carbonate	2·20
Magnesium sulphate	0·00
Magnesium chloride	0·00
Iron and aluminium oxide	0·35
Organic matter	trace
Silica	0·32
Total	22·35
Non-encrusting solids:	
Sodium sulphate	31·44
Sodium chloride	5·91
Total	59·70

162.—Rifle Range—Pointe aux Trembles.

This well is 242 feet deep and has a capacity of 24,000 gallons per day. The water is very sulphurous.

163.—Royal Victoria Hospital.

The well is 1,151 feet deep with a capacity of 12,000 gallons per day. The water was found at first to be contaminated, a bacteriological examination showing bacillus coli to be present. This contamination was got rid of, however, by putting cement down the well, blocking out the source of contamination, and then redrilling. The side of a hill often, though not always, seems to be an unfavourable location for a well. The well of the Union Brewing Company, No. 173, situated below the Sherbrooke Street terrace, is another such example.

164. St. Bruno Floral Company.

This well is 410 feet deep and has a capacity of 10,200 gallons per day. Gas was struck at 320 feet. The well apparently was sunk in Utica shale only.

165.—St. Gabriel College—Sault-au-Ricollet.

This well is 104 feet deep and has a capacity of 17,300 gallons per day. The water is described as being very good though it is probably sulphurous.

166.—St. Patrick Orphan Asylum—Outremont.

The well is 378 feet deep. The capacity is 120,000 gallons per diem, and the water rises to 5 feet from the surface. This is very much above the level to which the water rises in wells Nos. 160 and 161 close by. This well is situated only about 80 feet from the line of the Canadian Northern Railway tunnel through the mountain and a very large flow of water was struck when the tunnel reached this point. The strata in the tunnel were much broken.

167.—F. Schnaufer—107 Shearer street.

This well is 660 feet deep. It has a capacity of 12,960 gallons per day, all coming from the 450-foot level. There is a small flow of gas from the well and, therefore, a cistern is provided to let the gas escape from the water.

The following analysis was made by Dr. J. T. Donald on December 5, 1905. The results are stated in grains per imperial gallon:

Calcium sulphate	1·78
Calcium carbonate	3·19
Magnesium carbonate	4·70
Sodium chloride	8·59
Alkali carbonates, etc	6·87
Total solids	25·13

The water is high in calcium and in carbonate like other artesian waters in this part of the town. Thus it is very similar to the water of wells Nos. 3 and 135 and is intermediate between those of Nos. 89 and 10.

168.—Shamrock Athletic Association—Mile End.

This well is 75 feet deep and has a daily capacity of 8,600 gallons.

169 and 170.—The Shawinigan Water and Power Company—Maisonneuve.

These two wells, Nos. 169 and 170, situated respectively 300 and 800 feet east of well No. 79, are, like No. 79, failures. Well No. 169 is 701 feet deep and has a capacity of 430 gallons per hour. The water is sulphurous. In boring solid rock was struck at 21 feet. Well No. 170 lies 500 feet east of No. 169. It is 401 feet deep and has a capacity of 500 gallons per hour. According to Mr. Bell, the two wells are connected underground.

171.—Smith Bros. Company—Van Horne avenue, Montreal Annex.

This well is 435 feet deep and has a daily capacity of 64,800 gallons.

The following analysis of the water was made by Milton Hersey, on January 27, 1909. The results are stated in parts per million:

Free ammonia	0·1875
Albuminoid ammonia	0·1500
Total ammonia	0·3375
Nitrogen as nitrites	0·005
Nitrogen as nitrates	none
Chlorine as chlorides	28·40
Oxygen requires	5·80
Total solid matter on evap	484·0

The water contains sufficient sodium carbonate to prevent the formation of scale if used for steam raising purposes.

172.—Structural Steel Company—Longue Pointe.

This well is 1,200 feet from well No. 64. It is 340 feet deep. Good water was struck at 95 feet, but the water struck at 340 feet was sulphurous and saline. The lower water is now shut off and only the upper water used. The boring went through 15 feet of clay and 15 feet of quicksand, the rest was rock. Another example of this kind where two distinct classes of waters were struck at two depths in one well occurred in boring the Viauville well, No 88.

The following analyses of the water from the upper part of this well were made by Mr. Milton L. Hersey:

	Nov. 13, 1907		Jan. 10, 1910	
	Parts per million	Grains per gallon	Parts per million	Grains per gallon
Total solid on evaporation....	1126	78·82	1064	74·48
Solid volatile on ignition..........	74	5·18	185·00	12·95
Chlorine as chlorides............	414·80	29·03	351·3	24·59
N_2 as nitrites	0·03	....	....	....
N_2 as nitrates..................	none	....	....	....

173.—Union Brewing Company—420 Cadieux street.

This well is 757 feet deep and has a capacity of 12,000 gallons per day. It is situated at the base of the Sherbrooke Street terrace which is very steep here. A creek used to run along the bottom some 30 or 40 years ago and the ground is very sodden even at the present day. The water is absolutely condemned for brewing purposes. It is used to a certain limited extent in summer for cooling purposes. It is cloudy in appearance, tastes of ammonia, and is clearly contaminated. In dry summers the well dries up altogether. It seems, in many cases to be inadvisable to sink a well at the bottom of a steep hill. Under such conditions the chances of contamination are increased.

174.—Union Soap Company—Bennett avenue, Maisonneuve.

This well is 719 feet deep and has a capacity of 38,900 gallons per day.

175.—Warden King Bros.—Bennett avenue, Maisonneuve.

This well is 604 feet deep. Water was struck at 500 feet where the capacity was 52,300 gallons per diem. The remainder of the supply was struck at the bottom at 604 feet; the combined capacity is 120,000 gallons per diem, and the supply is quite constant.

The water is remarkable since it contains neither calcium nor carbonate. It is of the same type as the water at the Viauville Mineral Springs well No. 89, though far more dilute. The water is probably very similar to that of wells Nos. 118 and 176 as these, though not analysed, produce very little scale in boilers. The fact that this class of water has been found in these places in this district, should be of considerable importance to manufacturers.

The following analysis was made on May 2, 1907, by J. A. De Cew; the results are stated in grains per imperial gallon:

Total scale forming solids	3·92
Iron and alumina	0·00
Calcium	0·00
Magnesium	trace
Alkaline sulphates	31·5
Alkaline chlorides	5·18
Total solids	40·10

176.—Watson Foster Company—Ontario and Pie IX streets, Maisonneuve.

This well is 750 feet deep. The water is slightly sulphurous but in this respect is not as bad as when it was first used. It is remarkably free from scale and, therefore, it is probably like that of well No. 118 close by and also that of well No. 175.

177 and 178.—Windsor Hotel—Dominion Square.

Well No. 177 is a failure. It is 1,505 feet deep and the supply of water (600 gallons per hour) is too small to be of any use.

The second well, No 178, is situated at the Power House on Stanley street. It is 608 feet deep and yields 154,000 gallons a day of excellent water. Water was first struck at 198 feet when the supply given was 60,000 gallons per day. A second supply was struck at 575 feet and the combined capacity is 154,000 gallons per diem.

The water is almost identical with that from the Guaranteed Pure Milk Company's well, No. 122, and the Y.M.C.A. well, No. 179. There are reasons for thinking that the two latter are connected. The waters are characterized by being high in calcium and carbonate. They are more closely allied to wells in the lower part of the city like No. 167 (F. Schnaufer's) or No. 3 than to wells like those of Jas. Ogilvy, No. 157, or Eker's Brewery, No. 30, which are high in sodium. These waters approach in character the shallow spring waters and it is suggestive that these waters were struck in the case of the Guaranteed Pure Milk Company's well and the Windsor Hotel well, at comparatively shallow depths.

The following analysis was made by Milton Hersey, December 7, 1912. The results are stated in grains per Imperial gallon:

Calcium carbonate	10·43
" sulphate	0·80
" chloride	none
" nitrate	none
Magnesium carbonate	4·02
" sulphate	none
" chloride	none
Alumina, iron oxide / Silica	0·07
Suspended matter and sediment	none
Encrusting solids	15·32
Sodium carbonate	none
" sulphate	6·51
" chloride	2·69
" nitrate	none
Org. matter, etc.	none

A complete set of specimens from the borings of well No. 177 was kept. At 550 to 570 feet the boring went through a dark decomposed dyke material. At 750 to 770 feet it passed through a bed of calcareous shale. From a depth between 995 and 1,000 feet a specimen of a dark fine-grained camptonite was brought up.

The rock is vesicular, which is remarkable at a depth of 1,000 feet. The vesicles are filled with calcite and fibrous zeolites, probably natrolite. Strain shadows are evident in the calcite. There was also a white powdery material in the vesicles, perhaps leucoxene. No nepheline was detected. Between 1,000 and 1,005 feet, shale occurs. From a depth of 1,100 to 1,390 feet indeterminable brachiopod fragments were brought up and in material from a depth of 1,150 to 1,160 feet a Rhynchonella fragment was recognized and also a brachiopod looking very like *Platystrophia biforata*, but as this fossil is characteristic of the Trenton it seems unlikely that it has been correctly identified. A partial analysis was made of a specimen of the rock brought up from a depth of 1,500 feet. A residue amounting to 85 per cent, is left on treating this with acid, and magnesium carbonate occurs to the extent of 29 per cent of the calcium carbonate. The Beekmantown dolomite was, therefore, probably struck at this depth.

179.—Central Y.M.C.A.—Drummond street.

Water was struck mainly at two levels. At 520 feet the capacity was 48,000 gallons per diem and at 845 feet 96,000 gallons per diem. The well is 861 feet deep.

It is thought possible that this well is connected with the Windsor Hotel well, No. 178, on Stanley street. The water in the Y.M.C.A. well normally stands at 10 feet below the surface, but on the day pumping was started at the Windsor Hotel well the water level was noticed to fall to 30 feet below the surface. Another line of evidence is that one of the analyses of this water is almost identical with that of the Windsor Hotel water.

The well is situated about 1,500 feet from the Canadian Northern Railway tunnel through the mountain and shortly after tunnelling began the water become extremely muddy and remained so for three or four weeks, after which it got better.

There are two analyses of the water from this well. One was made after striking the water at 520 feet and before the lower water was struck. This water is high in sodium. The other was made after the lower source of water had been struck at 845 feet, and shows high calcium. The analyses were made by the Milton Hersey Company and the results which are given in grains per imperial gallon are as follows:

	Aug. 13, 1910	Oct. 22, 1910
Calcium carbonate	6·08	10·25
Magnesium carbonate	2·37	4·35
Silica, etc.	1·68	0·57
Suspended matter	none	....
Total encrusting solids	10·13	15·17
Sodium carbonate	6·67	0·56
Sodium sulphate	7·65	8·64
Sodium chloride	2·01	2·37
Organic matter	....	1·20
Non-encrusting solids	16·33	12·77

A set of specimens from this boring was kept. Down to a depth of 540 feet the rock is a dark coloured limestone. At 550 to 560 feet the boring passed through a decomposed bostonite dyke. At 610 feet a fragment of *Orthis* sp. was found and at 655 feet a fragment of what looks like *Orthis testudinaria*. At 750 feet, where water was struck, some specimens of shale were found.

TABULATED LIST OF WELLS

No.	Name of owner.	Location.	Depth in feet.	Diameter of hole in inches
1	R. B. Angus	Ste. Anne de Bellevue	222	4½
2	Armstrong & Cook	Montreal West	500	....
3	Belding, Paul & Co.	On Canal, near Seigneur St. Bridge	548	6
4	Bushnell Oil Co.	Ville St. Louis	305	4
5	C. S. Campbell	Dorval	480	4½
6	Canada Brewing Co.	218 Delorimier Ave.	580	....
7	Canada Malting Co.	St. Henri (lot 104781)	678	6 and 4½
8	" "	" "	506	....
9	" "	"Abattoir Site", near St. Henri	1281	4½
10	Canada Sugar Refining Co.	150 Montmorency St.	312	....
11	Canadian Pacific Railway	Hochelaga, Angus Shops, Power House	539	8 and 6
12	" " "	" " " " "	557	8 and 6
13	" " "	Outremont	410	5½ and 4
14	Convent of the Precious Blood	Notre-Dame de Grâce	296	....
15	M. Cousineau	St. Laurent	128	....
16	Dr. R. Craik	Petite Côte, lot 192	305	4
17	Mr. Curran's Farm	Between St. Laurent and Back river	260	6
18	The Thomas Davidson Manufacturing Co.	187 Delisle Ave., Ste. Cunégonde	150	6
19	Dawes & Co.	Lachine	1003	....
20	W. B. Dickson	Longue Pointe, lot 21	170	....
21	Dominion Wadding Co.	Cor. Williams and Vinet, Ste. Cunégonde	175	6
22	William Dow & Co.	186-188 Colbourne St.	360	4½
23	" "	" "	420	4½
24	" "	" "	430	4½
25	" "	Same property—cor. of Inspector St.	830	4½
26	Alex. Drummond	Petite Côte	500	....
27	Sir. G. A. Drummond	Beaconsfield	425	....
28	J. N. Drummond	Petite Côte, lot 195	223	....
29	H. A. Ekers	Petite Côte, lot 208	325	....
30	Eker's Brewery	409 St. Lawrence St.	600	....
31	Excelsior Woollen Mills	967 Ontario St.	812	6 and 4
32	" " "	967 Ontario St.	+754	10 and 6
33	" " "	967 Ontario St.	300	....
34	The Fenlin Leather Co.	141 Frontenac St.	1025	....
35	M. Galibert	929 St. Catherine St.	454	4
36	H. Gatehouse	808-810 Dorchester St.	750	....
37	Globe Woollen Mills	219 Delorimier St.	410	....
38	The Gould Cold Storage Co.	Grey Nun and William Sts.	1301	....
39	" " " " "	Grey Nun and William Sts.	500	....
40	A. Goyer	Frontenac St.	375	4½
41	F. Goyer	Côte-des-Neiges	250	4½
42	M. Grosl oyau	1675 Papineau ave.	350	....
43	Chas. Gurd	39 Jurors St.	512	....
44	Mr. Hampson	Longue Pointe, lot 40	502	....
45	A. Hobbs	Outremont (back of C.P.R. Round House)	240	6
46	Edward Hughes	Côte St. Michel	75	....

F WELLS ON THE ISLAND OF MONTREAL.

Diameter of hole in inches.	Capacity per diem in gallons.	Water level in feet.	Character of water.	Depth of rock surface.	Remarks.	No.
4½	48,000	-12	Good			1
	10,000	-100	Hard, slightly-sulphurous.	50		2
6	91,000	-10	Hard	64		3
4	1,000+	-20 to-30	Hard, slightly-sulphurous.	0		4
4⅝	12,000	-20	Good			5
	24,000	-28	Good	50	About 50 ft. from No. 99 and connected with it underground	6
6 and 4⅝	12,000	-6	Good	32	All water struck at 300 ft.	7
	16,800	-30	Good	18		8
4⅝	18,000	-10	Highly saline	30	All water struck at 350 ft.	9
	120,000	-18	Good	70		10
8 and 6	240,000	-6	Good	12	These two wells are about 50 feet	11
8 and 6	120,000	-8	Good	13	apart and connected underground	12
5½ and 4	192,000	-8	Hard and sulphurous	25		13
	36,000	-20	Good	42		14
	abundant	+7	Rather hard	40		15
4	120,000	-10	Soft			16
6	24,000	-6	Pure	16		17
6	72,000+	-8	Hard	50		18
	abundant	-10	Saline	26	All water struck at bottom	19
		-13	Saline and sulphurous.	100		20
6	abundant	-8	Pure	90	Water at 160 ft.	21
4⅝	24,000	-50	Not sulphurous			22
4⅝	too small to be of any value	-40				23
4⅝	60,000	-30	Slightly sulphurous			24
4⅝	hardly any water					25
	8,400	-50	Sulphurous	5		26
	36,000	-10	Hard	10		27
	24,000	-25	Soft, slightly-sulphurous			28
	14,000	-33	Rather hard			29
	25,000	-10	Good	70		30
6 and 4	5,000	-100	Good		Water obtained at about 600 ft.	31
0 and 6	86,000	-20		35	Some water at 500 ft.; further supply at 740 ft.	32
	no water					33
	4,800			60		34
4	25,000	-5	Good	56		35
	20,000	-30	Good	46		36
	65,000	-10	Hard	35		37
	10,000	-40	Good	73	All water obtained at about 360 ft.	38
	none					39
4⅝	9,000	-10	Soft	30		40
4⅝	72,000	-10	Very hard	25		41
	abundant	-12	Soft	0		42
	4,000	0	Sulphurous	5	Water at 440 and 512 ft.	43
			Saline and sulphurous.			44
6	48,000	0	Good	5		45
	19,000	-20	Soft	0		46

TABULATED LIST OF WELLS ON TH

No.	Name of owner.	Location.	Depth in feet.	Diameter of hole in inches.	Ca di
47	Laing & Sons..................	Cor. St. Catherine and Parthenais Sts..	325	....	
48	Laurentian Spring Water Co.....	208 Craig St..........................	280	6 and 4[illegible]	
49	Laurie Engine Company..........	1020 St. Catherine St..................	300	6 and 4[illegible]	
50	Laurie Engine Company..........	1012 St. Catherine St..................	700	....	no v
51	Longue Pointe Asylum...........	Longue Pointe..........................	2000	....	
52	Lovell and Christmas...........	112 William St.........................	612	6	
53	A. Martin......................	Lachine, lot 1010......................	740	6	
54	A. S. and W. S. Masterman......	2082 Notre Dame St.....................	800	....	
55	Mrs. J. McIntosh...............	Côte St. Michel........................	120	....	
56	J. H. R. Molson & Bros.........	1006 Notre Dame St.....................	674	8[illegible] and 4[illegible]	2
57	Canadian Pacific Railway.......	Place Viger, Notre Dame St.............	502	4[illegible]	1
58	Mount Royal Cemetry............	Near Crematory.........................	354	4[illegible]	
59	Montreal Cold Storage Co.......	610 St. Paul St........................	1020	....	....
60	Montreal Gas Co................	Hochelaga..............................	1850	....	non
61	" "	Hochelaga..............................	2550	....	non
62	" "	Ottawa St..............................	1050	....	non
63	Montreal Hunt Club.............	Outremont..............................	226	6	
64	Structural Steel Co............	Longue Pointe..........................	514	....	
65	Montreal Milling Co............	Park Ave., Outremont...................	345	5	
66	Mount Royal Park...............	"Park Well"............................	66	4[illegible]	
67	Montreal Weaving Co............	595 Clarke St..........................	420	....	
68	G. Nantel......................	Côte-des-Neiges........................	600	....	abu
69	Outremont Milling Co...........	Outremont..............................	335	4	
70	Judge Pagnuelo.................	Pagnuelo Ave., Outremont...............	700	....	7,00
71	Mrs. Quiggley..................	Longue Pointe..........................	100	....	
72	A. Ramsay......................	Inspector St...........................	800	....	48,0
73	" "	Westmount..............................	88)	....	
74	Paterson Manufacturing Co......	Carrière St............................	300	....	
75	Rowan Brothers.................	618 Beaudry St.........................	600	....	1
76	Royal Golf Club................	Dixie..................................	450	....	
77	Salvador Brewing Co............	617 St. Paul St........................	550	4[illegible]	
78	Sault au Recollet College......	Back river.............................	490	6	
79	Shawinigan Water & Power Co....	Maisonneuve............................	1017	....	
80	Sisters of Providence..........	Notre-Dame de Grâce....................	320	4[illegible]	
81	Stanley Dry Plate Co...........	613 Lagauchetière St...................	1300	4[illegible]	
82	St. Laurent Convent	St. Laurent............................	250	....	abu
83	St. Laurent College............	St. Laurent............................	487	....	
84	Mr. Stewart....................	Petite Côte, lot 195...................	223	....	
85	T. A. Trenholme................	Côte St. Pierre, lot 141...............	185	....	
86	" "	Thorne Hill, Côte St. Pierre...........	175	....	abu
87	Turkish Baths..................	140 Ste-Monique St.....................	1550	....	4,00
88	Viauville Mineral Springs......	Maisonneuve............................	1500	....	
89	Wire & Cable Co................	233-241 Guy St.........................	1055	6 and 4[illegible]	

…ter of … …hes.	Capacity per diem in gallons.	Water level in feet.	Character of water.	Depth of rock surface.	Remarks.	No.
......	36,000	–30	Hard.	56	......	47
4½	40,000	+20	Soft.	60	......	48
4½	72,000	–15	Hard; faint iron taste.	......	All water obtained at 150 ft.	49
......	no water	......	......	......	......	50
......	9,600	......	Good.	4	All water obtained at 300 ft.	51
6	60,000	–30	Slightly sulphurous.	62	......	52
6	2,400	–11	Very hard.	65	Water at 460 ft. associated with gas.	53
......	72,000	–10	Sulphurous and slightly saline.	68	Water at 750 ft.	54
......	14,000	–5	Soft, slight iron and sulphur taste.	......	......	55
4½	240,000	–24	Saline.	83	All water at 420 ft.	56
4½	126,000	–36	Hard.	80	......	57
4½	36,000	–25	Good.	0	......	58
......	......	0	Sulphurous.	60	Pocket of gas struck.	59
......	none	......	......	......	......	60
......	none	......	......	......	......	61
......	none	......	......	90	......	62
6	36,000	–19	Good.	0	......	63
......	29,000	–25	Somewhat sulph.	27	......	64
5	40,800	–25	Very hard.	0	......	65
4½		–5	Good.	4	Struck water at 66 ft.	66
......	12,000	–125	Soft.	5	......	67
......	abundant	–10	Good.	5	......	68
4	43,000	–25	Very hard.	......	......	69
......	7,000 (about)	......	......	......	......	70
......	4,800	–9	Rather hard.	90	......	71
......	48,000 (about)	–14	Hard.	......	......	72
......	15,000	–18	Rather hard.	......	Water struck at 700 ft.	73
......	24,000	0	Rather hard.	10	......	74
......	120,000	–60	Good.	70	......	75
......	28,800	–15	Good.	37	......	76
4½	8,000	......	......	62	......	77
6	12,000	–30	Soft at 490 ft. Hard at 100 ft.	35	......	78
......	4,800	......	......	26	......	79
4½	48,000	......	Good.	22	......	80
4½	8,400	–30	Good.	40	......	81
......	abundant	0	......	......	......	82
......	10,000	–13	Soft and slightly sulphurous.	31	......	83
......	10,000	–25	Soft and slightly sulphurous.	......	......	84
......	6,000	–25	Good.	100	......	85
......	abundant	......	Pure.	75	......	86
......	4,000 to 5,000	+6	Soft and slightly sulphurous.	50	......	87
......	5,000	+10	Saline and sulphur	90	Good water at 450 ft. sulphurous at 1190 ft.	88
4½	72,000	0	Hard.	57	Most of water at 960 ft., none lower.	89

TABULATED LIST OF WELLS ON THE

No.	Name of owner.	Location.	Depth in feet.	Diameter of hole in inches.
90	L'Air Liquide Société	First Avenue, Maisonneuve	658	6 and 5
91	J. B. Abbott	Ste. Anne de Bellevue	301	6 and 4½
92	Walter Baker Co.	1000 Albert St.	1207	8 and 5
93	Bank of Montreal	Place d'Armes, St. James St	1000	12, 6, and 4½
94	E. L. Baugh & Co.	St. Denis St.	525½	8
95	Brandram, Henderson Co.	2984 St. Urbain St., Mile End	510	6 and 5
96	Canada Bread Co.	611 Rivard St.	508	6 and 4½
97	Canada Car & Foundry Co	Turcot Works, St. Paul St.	601	8 and 4½
98	Canada Car & Foundry Co	St. Pierre St	599	4½
99	Canadian Brewing Co.	218 Delorimier Ave.	830	6 and 4½
100	Canadian Pacific Railway	Hochelaga, Angus Shops, Lunch Room.	870	8, 6, and 4½
101	Canadian Pacific Railway	Place Viger, Notre Dame St.	1004	....
102	Canadian Pacific Railway	Windsor Station	1492	8 and 4½
103	Canadian Rubber Co	Notre Dame St. East	1210	8 and 4½
104	Canadian Spool Cotton Co	Notre Dame St., Maisonneuve	1078	6 and 4½
105	Carter White Lead Co.	91 Delorimier Ave.	507	6 and 4½
106	Convent	Pointe aux Trembles	280	6 and 4½
107	A. F. Copperthwaite	St. Lambert, 3 miles from St. Lawrence	367	6 and 5
108	Crown Shoe & Leather Co.	356 Moreau St.	1510	6 and 5
109	T. Cushing	Parc Lafontaine	1453	6 and 4½
110	Daoust, Lalonde & Co	1704 Iberville St.	995	....
111	Wm. Davies Co.	Mill St.	707½	6 and 4½
112	Dawes & Co.	Lachine	1220	8 and 4½
113	Dominion Ice Co.	1113 La Salle St., Maisonneuve	600	6 and 4½
114	Dominion Light, Heat, & Power Co.	Aird Ave., Maisonneuve	610	4½
115	Dominion Park Co.	Longue Pointe	151	6 and 4
116	William Dow & Co.	186-188 Colbourne St.	1525	8 and 5
117	A. L. Drummond	Beaconsfield	340	6 and 5
118	Dufresne et Locke	Ontario and Desjardins Sts., Maisonneuve	751	6 and 4½
119	J. D. Duncan	Mountain St.	885	6 and 4½
120	Frontenac Brewery	Mile End station	490	8
121	F. Galibert	Amity and Parthenais Sts.	577	6 and 5
122	Guaranteed Pure Milk Co	St. Catherine St. West	151	6 and 4½
123	Chas. Gurd	112 Beaudry St	318	6 and 4½
124	T. Hannah	Back river	61	3½
125	Ice Manufacturing Co.	Frontenac St., near Abattoirs	994	8 and 5
126	Imperial Tobacco Co. of Canada	900 St. Antoine	500	4½
127	Independent Breweries	600 Rivard St.	805	8 and 5
128	T. J. Joubert	975 St. André St.	490	6 and 4½
129	La Reina Mineral Water Co.	Vinet and Notre Dame Sts.	441	....
130	Lacroix et Piché	Longue Pointe	556	6 and 4½
131	D. Lalonde	St. Lawrence St.	810	6 and 5
132	Laurentian Spring Water Co.	208 Craig St.	457	6 and 4½
133	O. Limoges	Chambord St.	313	6
134	Lower Canada College	Royal Ave., Notre Dame de Grâce	435	6 and 5
135	W. Lowney & Co.	169 William St.	302	6 and 4½
136	Maisonneuve Baths	Market Place, Maisonneuve	1031	8 and 5

…eter of …ole …ches.	Capacity per diem in gallons.	Water level in feet.	Character of water.	Depth [illegible] surface.	Remarks.	No.
…and 5	157,000	−27	Very salty and sulphurous.....	22	....	90
…and 4½	38,400	....	....	112	....	91
…and 5	28,800	−6	Saline and sulphur	23	8,[illegible] gals. at 205 ft., rest at [illegible]	92
…and 4½	124,800	−37	Good..........	49	Water all at 200 to [illegible] ft	93
8	122,000	−5	....	33	....	94
…and 5	60,000	−18	Good, slightly sulphurous.....	37	All water struck at [illegible] ft.	95
…and 4½	76,800	−37	....	19	38,400 gals. at 250 [illegible], rest at [illegible]	96
…and 4½	24,000	....	Slightly sulphurous. Not used.	20	....	97
4½	12,000	....	Salty..........	7	....	98
…nd 4½	36,000	−112	....	67	About 30 ft. from No. 6 and connected with it underground......	99
…nd 4½	96,000	−32	Good..........	8	Water struck at 610 ft. and [illegible]	100
....	108,000	....	....	120	20,000 gals. at 610 ft.; large in[illegible] 980 ft....................	101
…nd 4½	13,200	....	Sulphurous........	27	....	102
…nd 4½	41,800	−15	....	70	Water all from 200 to 920 ft..........	103
…nd 4½	21,600	....	Very sulphurous.	168	....	104
…nd 4½	36,000	....	Good..........	85	....	105
…nd 4½	28,800	−31	Soft..........	....	....	106
…nd 5	15,600	−10	Good..........	40	....	107
…nd 5	2,400	....	....	32	....	108
…od 4½	64,800	....	Good..........	68	36,000 gals. at 890 ft., rest at 1020 ft....	109
....	21,600	....	Soft, good for tanning........	27	....	110
…d 4½	76,800..	....	....	....	Supply very inconstant. Gas struck at 240 and 270 ft....................	111
…d 4½	76,800	−6	Contaminated....	26	Very quickly pumped dry......	112
…d 4½	72,000	....	Sulphurous.......	18	....	113
4½	60,000	−20	Very sulphurous but not salty..	12	Sulphur content varies much from time to time....................	114
…d 4	8,400	....	....	83	....	115
…d 5	36,000	....	....	....	Water at 600 to 700 ft., none lower....	116
…d 5	32,800	−13	Good..........	29	....	117
…d 4½	24,000	....	Very little scale and no sulphur.	40	Supply stated to have increased........	118
…l 4½	40,100	....	Good..........	41	....	119
8	432,000	−33	....	....	40,800 gals. at 340 ft., rest at 478 ft....	120
…l 5	108,000	−6	On standing gives off sulphur.....	38	All water struck at bottom............	121
…l 4½	67,200	+15	....	40	....	122
…l 4½	48,000	−50	....	40	....	123
3½	21,600	−25	....	7	....	124
…l 5	132,000	....	....	26	Water struck at 500 and 700 ft.......	125
4½	32,400	0	Very sulphurous..	20	Water struck at 150 ft. Natural flow 1000 gals per hour....................	126
5	76,800	....	....	10	21,000 gals. at 500 ft; remainder at bottom....................	127
4½	100,800	−50	Pure, no sulphur.	51	....	128
....	8,600	− 7	....	....	All water struck at 250 ft............	129
4½	45,600	−40	Good, with little sulphur........	35	....	130
5	18,240	−10	Good..........	....	....	131
4½	108,000	−52	....	67	36,000 gals. at 250 ft., rest at 450 ft....	132
6	3,600	+1	Good..........	....	150 gals. per hour were pumped on testing	133
5	10,320	....	Good..........	....	....	134
4½	94,000	−16	Very sulphurous.	63	36,000 gals. at 200 ft., rest at 300 ft....	135
5	4,600	....	....	31	4,500 gals. at 400 ft....................	136

TABULATE LIST OF WELLS ON THE ISLAN

No.	Name of owner.	Location.	Depth in feet.	Diameter of hole in inches.	Capacit diem gallo
137	Maisonneuve Baths	Market Place, Maisonneuve	776	8 and 5	76,8
138	Maisonneuve Quarry Co.	Rosemount Ave	400	4¾	5,8
139	Martineau et Fils	Carrière and Papineau Sts.	428	6 and 4¾	34,0
140	" " "	" "	1000	6 and 5	10,0
141	Militia Department	Longueuil	1020	6 and 4¾	3,0
142	" "	"	1020	6 and 5	2,4
143	Molson Park Estate	Carrière and Iberville Sts.	100	6, 5, and 4½	36,0
144	" " "	" "	224	6 and 5	36,0
145	" " "	" "	300	6 and 5	36,0
146	Montreal Abattoirs	Frontenac St.	577	6 and 4¾	216,0
147	" "	"	810	8 and 4¾	45,6
148	" "	"	1175	8 and 5	168,0
149	Montreal Dairy Co.	290 Papineau Ave.	620	6 and 5	55,2
150	Montreal Jockey Club	Bluebonnets Race Track	203	6 and 4¾	132,0
151	" " "	" "	108	...	48,0
152	Montreal Light, Heat, and Power Co.	St. Henri	1201	8 and 4½	3,8
153	A. J. Munro	123 Britannia St.	1125	8 and 5	2,0
154	S. Nesbitt	2501 Rosemount Boulevard	300	3½	6,0
155	A. E. Ogilvy	Cartierville	580	6 and 5	15,6
156	" " "	"	520	6 and 4¾	52,8
157	Jas. A. Ogilvy and Son	St. Catherine St.	993	6 and 4¾	76,8
158	Paterson Manufacturing Co.	Mile End	493	4¾	10,8
159	J. W. Peck	2275 St. Lawrence Boulevard	602	6 and 5	24,70
160	Pensionnat du St. Nom de Marie	Outremont	354	...	8,60
161	" " " " "		897	6 and 4¾	120,00
162	Rifle Range	Pointe aux Trembles	242	4¾	24,00
163	Royal Victoria Hospital	Pine Avenue	1151	6 and 4¾	12,00
164	St. Bruno Floral Co.	...	410	6 and 5	10,20
165	St. Gabriel College	Sault-au-Recollet	104	4½ and 4	17,30
166	St. Patrick Orphan Asylum	Outremont	378	6 and 4¾	120,00
167	F. Schnaufer	107 Shearer	660	6 and 4¾	12,90
168	Shamrock Athletic Association	Mile End	75	4	8,60
169	Shawinigan Water & Power Co.	Maisonneuve	701	6 and 4¾	10,32
170	" " " "	Maisonneuve	401	6 and 4¾	12,00
171	Smith Bros. Co.	Van Horne Ave., Montreal Annex	435	6 and 4¾	64,80
172	Structural Steel Co.	Longue Point	340	3	36,00
173	Union Brewing Co.	420 Cadieux St.	757	4¾	12,00
174	Union Soap Co.	Bennett Ave., Maisonneuve	719	6 and 4¾	38,90
175	Warden King Bros.	Bennett Ave., Maisonneuve	604	8 and 4¾	129,60
176	Watson Foster Co.	Ontario and Pie IX Sts., Maisonneuve	750	...	...
177	Windsor Hotel	Dominion Square	1505	8 and 4¾	14,40
178	" "	Power House, Stanley St.	608	8 and 5	154,00
179	Young Men's Christian Association	Drummond St.	861	8 and 4¾	144,00

"Chemical weight" of ions stated as though concentration of

E ISLAND OF MONTREAL—*Concluded.*

Capacity per diem in gallons.	Water level in feet.	Character of water.	Depth of rock surface.	Remarks.	No.
76,800	-12	Good.	36		
5,800	-15	Slightly sulphur-			137
		ous. Hard.	2		
34,000		Sulphurous and de-		These wells are 50 ft. apart and con-	138
10,000		posits much scale			139
3,600		Salty, with gas.		nected underground.	140
2,400			10		141
36,000			30		142
36,000	-12		21		143
36,000	-35		13		144
216,000			5		145
45,600			28		146
168,000	-86		25		147
55,200		Good. Temper-	25	Water struck at 475, 890, and 1175 ft.	148
		ature, 48°F.	42		
132,000	-12		15		149
48,000	-10		27		150
					151
3,800			34		
2,000		Hard. No sulphur	50		152
6,000		Good.	12		153
15,600	-19	Good.	21		154
52,800	-21		23		155
76,800	+11				156
10,800	-18			12,000 gals. at 210 ft., rest at 875 ft.	157
24,700	-22		5		158
8,600	-130	Good.	2	13,200 gals. at 300 ft. and rest at bottom.	159
120,000	-150		5		160
24,000	-10	Very sulphurous.		All water struck at 890 ft.	161
12,000		Good.	12		162
10,200			10		163
17,300	-15	Very good. Some	23	Gas struck at 320.	164
		scale.	25		
120,000	-5	Good.			165
12,960					166
8,600			47	All water struck at 450 ft.	167
10,320		Sulphurous.			168
12,000			21	These two wells are connected under-	169
64,800	-52		36	ground.	170
36,000			11		171
12,000			30	At 340 ft. water is sulphurous and saline.	172
38,900	-24		36		173
129,600	-14		28		174
		Soft, forms no	19	52,300 gals. at 500 ft; rest at 604 ft.	175
		scale.			
14,400					176
154,000	-14		25		177
144,000	-10		30	60,000 gals. at 198 ft., rest at 575 ft.	178
				48,000 gals. at 520 ft., rest at 845 ft.	179

tration of each well water was equal.

TABULATED LI

Analyses stated in ...

Well number	3	6	10	(a) 11	(b) 11	(c) 11	(d) 11	(e) 11	(f) 11	13	19	30	47	(l) 48	(m) 48	(n) 48	(o) 48	(p) 48	54	56	57	(t) 64	(u) 64	88	89
Calcium carbonate	3·29		4·52	0·43	6·26	1·29	1·87	2·68	1·3[illegible]	15·13	20·58	2·73	(j) 14·32	......	......	......	......	2·57	22·35	7·95	15·03	1·39	......	8·62	22·09
Calcium sulphate					5·24	......		......		9·09	125·84	......	12·65	......	3·47	......	......	......	1·28	......	25·80			6·07	1·24
Magnesium carbonate	6·30		0·16	0·31	5·68	1·14	1·27	2·30	1·22	4·35		2·52	......					1·82	......	6·18	8·19	1·57	trace	26·10	2·79
Magnesium sulphate	...						......	......			67·86	......	......	......	1·60				(q) 13·11						
Sodium carbonate	2·45	38·0	1·33	18·0	...	23·53	22·09	15·34	21·67			14·07	(k) 5·31	27·25	26·74	32·37	22·37	16·32	......	11·51	3·75	29·0	41·86	......	12·20
Sodium sulphate	1·19		1·05	8·20	10·74	11·61	10·29	27·64	7·45	3·21		11·60		6·85	0·23	9·30	9·44	19·31	......	28·54		2·52	4·72	200·37	
Sodium chloride	6·30	4·45	3·72	..	3·54	2·08	2·42	10·07	2·20		73·92	3·29	9·38	2·32	9·59	5·40	5·38	9·38	15·36	15·56	11·51	1·51	10·39	242·5	1·55
Etc	...	...	...	(g) 1·17	(h) 0·71		..	..		(i) 1·34	......	......	......				..		(r) 26·80	(s) 2·11	...		......	(v) 2·11	

(a) Feb. 6, 1903. (b) March 16, 1908. (c) March 17, 1908. (d) June 11, 1908. (e) March 19, 1909. (f) July 20, 190
(l) Oct. 28, 1891. (m) August 26, 1892. (n) March [illegible], 1896. (o) January, 1903. (p) Marc
(u) Sept. 14, 1903. (v) KCL = 2·11. (w) March 17, 1908. (x) Nov. 4, 191

Ionic concentration stated in

Well number	3	6	10	(a) 11	(b) 11	(c) 11	(d) 11	(e) 11	(f) 11	13	19	30	47	(h) 48	(i) 48	(j) 48	(k) 48	(l) 48	54	56	57	(n) 64	(o) 64	88	89
Calcium ion	1·32	......	1·13	0·59	4·02	0·52	0·75	1·07	0·54	38·69	44·75	1·09	9·4[illegible]	...	1·00	......	......	1·03	19·37	3·18	13·50	0·56	......	3·91	8·71
Magnesium ion	1·83	......	0·03	0·09	1·65	0·33	0·37	0·67	0·35	8·69	11·57	0·73	....	...	0·34	......	......	0·52	3·28	1·80	2·37	0·45	......	4·18	0·81
Sodium ion	3·93	12·75	2·22	10·35	5·05	14·65	13·77	19·49	12·00	1·26	29·50	11·23	6·[illegible]	1·13	11·66	14·63	11·67	16·92	6·15	20·20	6·21	13·90	23·66	177·0	8·87
Carbonate ion	7·84	27·0	4·46	10·73	7·79	15·01	14·61	11·98	14·01	1·03	12·33	11·30	11·63	9·35	18·99	22·87	15·80	12·15	14·00	15·66	17·03	18·45	23·86	28·39	22·67
Sulphate ion	0·81	......	0·71	5·60	11·02	7·89	6·99	18·79	5·07	12·17	143·64	7·94	8·95	4·65	3·96	6·33	6·42	13·15	0·91	20·65	18·30	1·72	3·21	140·31	0·88
Chlorine ion	3·8	2·7	2·23	0·75	[illegible]·12	1·25	1·45	6·03	1·42	....	44·42	2·01	5·58	1·39	5·75	3·24	3·23	5·63	36·19	9·31	6·91	0·91	6·24	170·35	0·93
Etc	...	......	...	...	(g) 0·52							..	......	......	......	......	......	......	......	(m) 0·98	.	......	......	(p) 1·05	......

(a) Feb. 6, 1903. (b) March 16, 1908. (c) March 17, 1909. (d) June 11, 1908. (e) March 19, 1909. (f) July 20, 1909.
(m) K = 0·98. (n) July 23, 1903. (o) Sept. 14, 1903. (p) K = 1·05. (q) March 17, 1

"Chemical weight" of ions stated o

Well number	3	6	10	(a) 11	(b) 11	(c) 11	(d) 11	(e) 11	(f) 11	13	19	30	47	(h) 48	(i) 48	(j) 48	(k) 48	(l) 48	54	56	57	(n) 64	(o) 64	88	89
Ca	17·1	.	36·7	5·9	36·1	3·9	5·5	5·5	4·5	72·3	48·2	9·2	64·5	6·0	36·1	3·9	5·5	5·5	64·2	13·2	59·2	4·1	......	2·4	57·7
Mg	37·6	....	1·3	1·5	24·2	4·0	4·5	5·8	4·[illegible]	17·1	23·7	10·0	......	1·4	24·2	4·0	4·5	5·8	17·8	12·1	17·0	5·5	......	4·1	8·9
Na_2	45·3	100·0	62·0	92·6	39·7	92·1	90·0	88·7	60·7	(g) 10·6	28·1	80·8	35·5	92·6	39·7	92·1	90·0	88·7	18·0	(m) 74·7	23·8	90·4	100·0	(p) 93·5	33·4
CO_3	69·5	86·0	49·0	72·0	46·7	71·5	72·0	41·5	76·4	67·0	8·8	63·0	53·0	72·0	46·7	71·5	72·0	41·5	30·8	42·0	49·5	90·5	76·5	5·7	94·0
SO_4	4·4	......	9·8	23·8	41·0	23·5	21·7	40·8	17·5	29·8	62·8	27·6	25·5	23·8	41·0	23·5	21·7	40·8	1·3	35·5	33·4	5·4	6·7	35·4	2·4
Cl_2	26·1	14·0	41·2	4·2	10·8	5·0	6·3	17·7	6·1	3·2	28·4	9·4	21·5	4·2	10·8	5·0	6·3	17·7	67·9	22·5	17·1	4·1	16·8	58·9	3·6

(a) Feb. 6, 1903. (b) March 16, 1908. (c) March 17, 1908. (d) June 11, 1908. (e) March 19, 1909. (f) July 20, 1909. (g) includes K_2 = 3·1. (h) Oct. 28, 1892. (i) August 26, 1892.
(s) Sept. 30, 1912. (t) Aug. 13, 19

LATED LIST OF ANALYSES.

stated in grains per imperial gallon.

88	89	92	95	96	(w) 101	(x) 101	(y) 101	120	121	122	125	127	129	134	135	143	144	145	146	148	154	157	158	159	160	167	175	178	(aa) 179	(bb) 179
·02	22·09	15·0	14·14	7·00	3·44	2·28	12·75	14·71	9·66	15·63	8·26	4·27	......	1·25	15·85	24·4	25·0	24·1	2·38	2·86	4·50	10·96	......	18·69	6·55	5·19	......	10·43	6·06	10·25
·07	1·24	......	......	......	......	......	......	28·21	......	......	......	......	......	5·71	......	......	......	......	......	......	......	......	4·42	......	12·95	1·78	......	0·80	......	......
·10	2·79	1·52	3·38	4·60	1·32	2·81	6·94	7·76	0·06	2·83	8·07	5·12	......	1·73	8·29	5·20	2·90	3·24	1·17	1·23	3·41	0·04	......	10·80	2·28	4·70	......	4·02	2·57	4·35
......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4·62	......	......	......	......	......	......	......
......	12·20	0·90	5·19	6·08	17·67	15·37	4·70	......	51·83	......	11·61	12·71	55·2	23·9	5·08	1·31	5·12	2·60	23·74	28·52	15·34	7·88	27·65	3·67	......	6·87	......	......	6·07	0·56
·57	......	65·86	11·00	6·27	23·62	35·33	17·25	25·92	3·64	6·83	23·80	10·81	27·2	......	5·83	6·10	6·82	4·45	6·39	7·94	15·37	19·06	23·48	7·43	31·44	......	51·3	6·51	7·65	8·64
1·5	1·55	45·20	5·38	18·48	7·85	9·51	8·20	6·23	19·28	4·34	8·50	9·85	8·15	3·14	10·88	0·82	0·91	4·60	5·17	5·86	3·99	9·08	6·64	7·12	3·91	8·39	5·18	2·60	2·01	5·57
(v) ·11						(z) 0·21																								
......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

July 20, 1909. (g) $CaCl_2$ = 1·17. (h) $NaNO_3$ = 0·71. (i) KCl = 1·34. (j) includes magnesium carbonate. (k) includes SiO_2.
(p) March 17, 1908. (q) $MgCl_2$ = 15·11. (r) $CaCl_2$ = 26·80. (s) K_2SO_4 = 2·11. (t) July 23, 1908.
Nov. 4, 1910. (y) Sept. 30, 1912. (z) $CaCl_2$ = 0·21. (aa) Aug. 13, 1910. (bb) Oct. 22, 1910.

n stated in grains per imperial gallon.

88	89	92	95	96	(q) 101	(r) 101	(s) 101	120	121	122	125	127	129	134	135	143	144	145	146	148	154	157	158	159	160	167	175	178	(t) 179	(u) 179
·91	8·71	6·00	3·54	5·12	0·98	9·91	5·10	13·22	0·27	6·24	5·30	1·75	......	2·21	6·35	9·75	10·00	9·60	0·93	1·15	1·00	47·32	1·28	7·50	6·37	6·42	......	4·17	2·43	4·10
·18	0·81	0·38	0·54	1·33	0·38	0·73	2·02	2·25	0·00	0·82	2·34	0·90	......	0·50	2·40	1·51	0·87	1·53	0·34	0·36	1·57	4·35	0·92	5·12	0·64	1·36	......	1·17	0·69	1·26
·0	3·87	39·52	6·66	12·01	18·29	21·72	10·82	9·83	19·60	5·88	15·94	12·70	36·17	11·32	7·15	2·84	5·89	4·40	15·57	16·54	11·69	......	22·07	7·76	12·41	6·38	12·18	5·16	6·18	3·93
·39	22·67	10·50	15·67	11·42	15·47	11·72	15·23	14·52	18·54	11·38	17·20	11·84	30·90	14·87	17·40	19·08	18·90	19·69	15·79	18·42	14·01	15·00	15·75	22·10	5·49	16·06	......	9·11	9·06	9·55
·51	0·88	44·86	7·50	4·27	16·07	24·03	11·73	33·46	3·84	4·60	5·90	6·92	18·50	4·00	2·61	4·15	4·63	5·02	4·48	3·40	9·10	10·99	25·82	4·96	30·57	1·26	21·40	5·00	3·20	3·88
·55	0·93	27·18	5·35	11·08	4·71	5·69	4·92	5·73	6·15	2·64	5·18	6·01	4·98	1·91	6·53	0·49	0·55	2·75	1·89	2·34	3·44	5·53	3·87	4·2[illegible]	3·55	3·17	5·10	1·61	1·22	1·43
(p) ·05																														
......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

ly 20, 1909. (g) NO_3 = 0·52. (h) Oct. 28, 1891. (i) August 26, 1892. (j) March 31, 1896. (k) January, 1903. (l) March 17, 1908.
March 17, 1908. (r) Nov. 4, 1910. (s) Sept. 30, 1915. (t) Aug. 13, 1910. (u) Oct. 22, 1910.

ns stated on the basis of equal concentration.

88	89	92	95	96	(q) 101	(r) 101	(s) 101	120	121	122	125	127	129	134	135	143	144	145	146	148	154	157	158	159	160	167	175	178	(t) 179	(u) 179
2·4	57·7	14·8	34·8	19·6	5·6	4·3	28·5	52·0	1·5	57·5	15·7	12·2	......	17·2	38·5	66·4	67·5	60·2	7·0	7·1	12·4	27·9	5·6	38·8	35·0	45·0	......	46·8	27·2	43·0
4·1	8·9	1·5	8·6	15·7	5·5	5·7	18·9	14·4	......	12·4	18·2	10·4	......	6·4	24·0	16·9	9·6	15·8	4·5	3·6	17·8	......	6·6	26·4	5·8	15·6	......	21·9	12·8	21·5
(p)																														
3·5	33·4	83·7	56·6	66·7	90·9	90·0	52·6	33·6	98·5	30·1	66·1	77·4	100·0	76·4	38·5	16·7	52·9	24·0	88·8	89·3	69·8	72·1	87·8	34·9	59·2	39·4	100·0	31·3	60·6	55·5
5·7	94·0	17·6	51·2	47·0	47·0	37·1	57·0	37·3	71·0	68·7	54·5	55·7	56·1	78·5	71·2	86·4	85·8	82·2	78·0	77·7	64·5	40·1	47·3	77·0	19·9	76·0	......	67·0	68·0	66·0
5·4	2·4	47·7	30·6	11·2	38·0	47·5	27·4	54·5	9·1	17·8	31·6	20·3	41·2	13·0	6·5	11·7	15·2	7·9	14·1	14·0	26·0	34·5	42·9	10·7	69·2	3·7	83·6	22·8	24·3	25·5
8·9	3·6	34·7	18·2	41·8	15·0	14·4	15·6	17·2	19·9	13·5	13·9	24·0	14·9	8·5	22·3	1·9	2·0	9·9	7·9	8·5	9·5	19·7	9·8	12·3	10·9	20·3	16·4	10·2	7·7	8·5

26, 1892. (j) March 31, 1896. (k) January, 1903. (l) March 17, 1908. (m) includes K_2 = 2·1. (n) July 23, 1908. (o) Sept. 14, 1908. (p) includes K = 0·8. (q) March 17, 1908. (r) Nov. 4, 1910.
Aug. 15, 1910. (u) Oct. 22, 1910.

INDEX.

A.

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R.

S.

V.

W.

Y.

LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers and, therefore, the following list has been prepared to prevent any misconceptions arising on this account. The titles of all other important publications of the Geological Survey are incorporated in this list.

Memoirs and Reports Published During 1910.

REPORTS.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont.—by W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ells. No. 1107.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories—by Joseph Keele. No. 1097.

Summary Report for the calendar year 1909. No. 1120.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 1. *No. 1, Geological Series.* Geology of the Nipigon basin, Ontario—by Alfred W. G. Wilson.

MEMOIR 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley mining district, British Columbia—by Charles Camsell.

MEMOIR 3. *No. 3, Geological Series.* Palæoniscid fishes from the Albert shales of New Brunswick—by Lawrence M. Lambe.

MEMOIR 5. *No. 4, Geological Series.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory—by D. D. Cairnes.

MEMOIR 6. *No. 5, Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario—by Frank D. Adams and Alfred E. Barlow.

MEMOIR 7. *No. 6, Geological Series.* Geology of St. Bruno mountain, province of Quebec—by John A. Dresser.

MEMOIRS—TOPOGRAPHICAL SERIES.

MEMOIR 11. *No. 1, Topographical Series.* Triangulation and spirit levelling of Vancouver island, B.C., 1909—by R. H. Chapman.

Memoirs and Reports Published During 1911.

REPORTS.

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902—by Alfred W. G. Wilson. No. 1006.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers—by W. McInnes. No. 1080.

Report on the geology of an area adjoining the east side of Lake Timiskaming—by Morley E. Wilson. No. 1064.

Summary Report for the calendar year 1910. No. 1170.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 4. *No. 7, Geological Series.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec—by W. J. Wilson.

MEMOIR 8. *No. 8, Geological Series.* The Edmonton coal field, Alberta—by D. B. Dowling.

MEMOIR 9. *No. 9, Geological Series.* Bighorn coal basin, Alberta—by G. S. Malloch.

MEMOIR 10. *No. 10, Geological Series.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in southwestern Ontario—by J. W. Goldthwait.

MEMOIR 12. *No. 11, Geological Series.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906—by Anton Handlirsch.

MEMOIR 15. *No. 12, Geological Series.* On a Trenton Echinoderm fauna at Kirkfield, Ontario—by Frank Springer.

MEMOIR 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick—by Heinrich Ries assisted by Joseph Keele.

MEMOIRS—BIOLOGICAL SERIES.

MEMOIR 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia—by William H. Dall and Paul Bartsch.

Memoirs and Reports Published During 1912.

REPORTS.

Summary Report for the calendar year 1911. No. 1218.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 13. *No. 14, Geological Series.* Southern Vancouver island—by Charles H. Clapp.

MEMOIR 21. *No. 15, Geological Series.* The geology and ore deposits of Phoenix, Boundary district, British Columbia—by O. E. LeRoy.

MEMOIR 24. *No. 16, Geological Series.* Preliminary report on the clay and shale deposits of the western provinces—by Heinrich Ries and Joseph Keele.

MEMOIR 27. *No. 17, Geological Series.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911.

MEMOIR 28. *No. 18, Geological Series.* The Geology of Steeprock Lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario—by Charles D. Walcott.

Memoirs and Reports Published During 1913.

REPORTS, ETC.

Museum Bulletin No. 1: contains articles Nos. 1 to 12 of the Geological Series of Museum Bulletins, articles Nos. 1 to 3 of the Biological Series of Museum Bulletins, and article No. 1 of the Anthropological Series of Museum Bulletins.

Guide Book No. 1. Excursions in eastern Quebec and the Maritime Provinces, parts 1 and 2.

Guide Book No. 2. Excursions in the Eastern Townships of Quebec and the eastern part of Ontario.

Guide Book No. 3. Excursions in the neighbourhood of Montreal and Ottawa.

Guide Book No. 4. Excursions in southwestern Ontario.

Guide Book No. 5. Excursions in the western peninsula of Ontario and Manitoulin island.

Guide Book No. 8. Toronto to Victoria and return *via* Canadian Pacific and Canadian Northern railways: parts 1, 2, and 3.

Guide Book No. 9. Toronto to Victoria and return *via* Canadian Pacific, Grand Trunk Pacific, and National Transcontinental railways.

Guide Book No. 10. Excursions in Northern British Columbia and Yukon Territory and along the north Pacific coast.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 17. *No. 28, Geological Series.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que.—by Morley E. Wilson.

MEMOIR 18. *No. 19, Geological Series.* Bathurst district, New Brunswick—by G. A. Young.

MEMOIR 26. *No. 34, Geological Series.* Geology and mineral deposits of the Tulameen district, B.C.—by C. Camsell.

MEMOIR 29. *No. 32, Geological Series.* Oil and gas prospects of the northwest provinces of Canada—by W. Malcolm.

MEMOIR 31. *No. 20, Geological Series.* Wheaton district, Yukon Territory—by D. D. Cairnes.

MEMOIR 33. *No. 30, Geological Series.* The geology of Gowganda Mining Division—by W. H. Collins.

MEMOIR 35. *No. 29, Geological Series.* Reconnaissance along the National Transcontinental railway in southern Quebec—by John A. Dresser.

MEMOIR 37. *No. 22, Geological Series.* Portions of Atlin district, B.C.—by D. D. Cairnes.

MEMOIR 38. *No. 31, Geological Series.* Geology of the North American Cordillera at the forty-ninth parallel, Parts I and II—by Reginald Aldworth Daly.

Memoirs and Reports Published During 1914.

REPORTS, ETC.

Summary Report for the calendar year 1912. No. 1305.

Museum Bulletins Nos. 2, 3, 4, 5, 7, and 8 contain articles Nos. 13 to 22 of the Geological Series of Museum Bulletins, article No. 2 of the Anthropological Series, and article No. 4 of the Biological Series of Museum Bulletins.

Prospector's Handbook No. 1: Notes on radium-bearing minerals—by Wyatt Malcolm.

MUSEUM GUIDE BOOKS.

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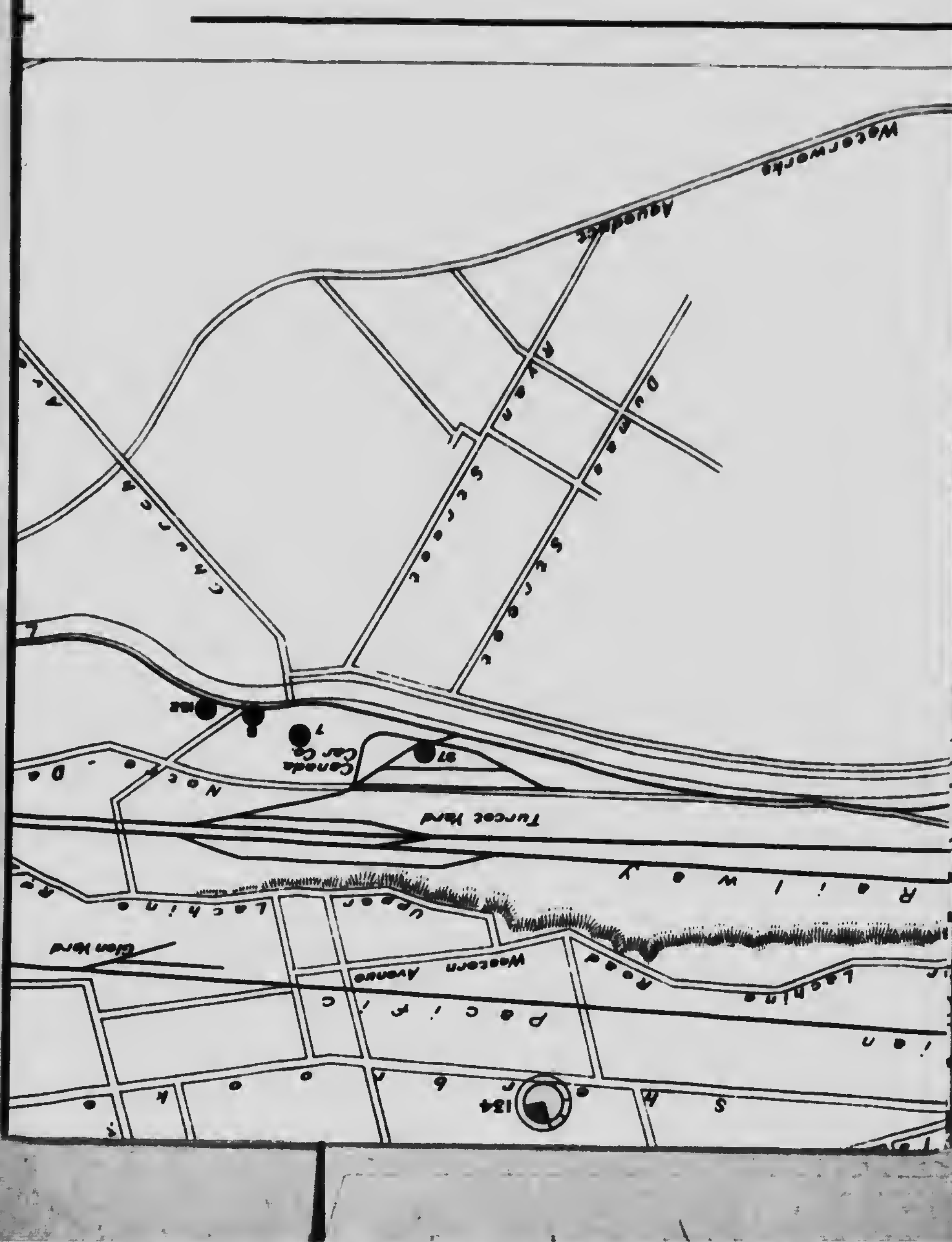
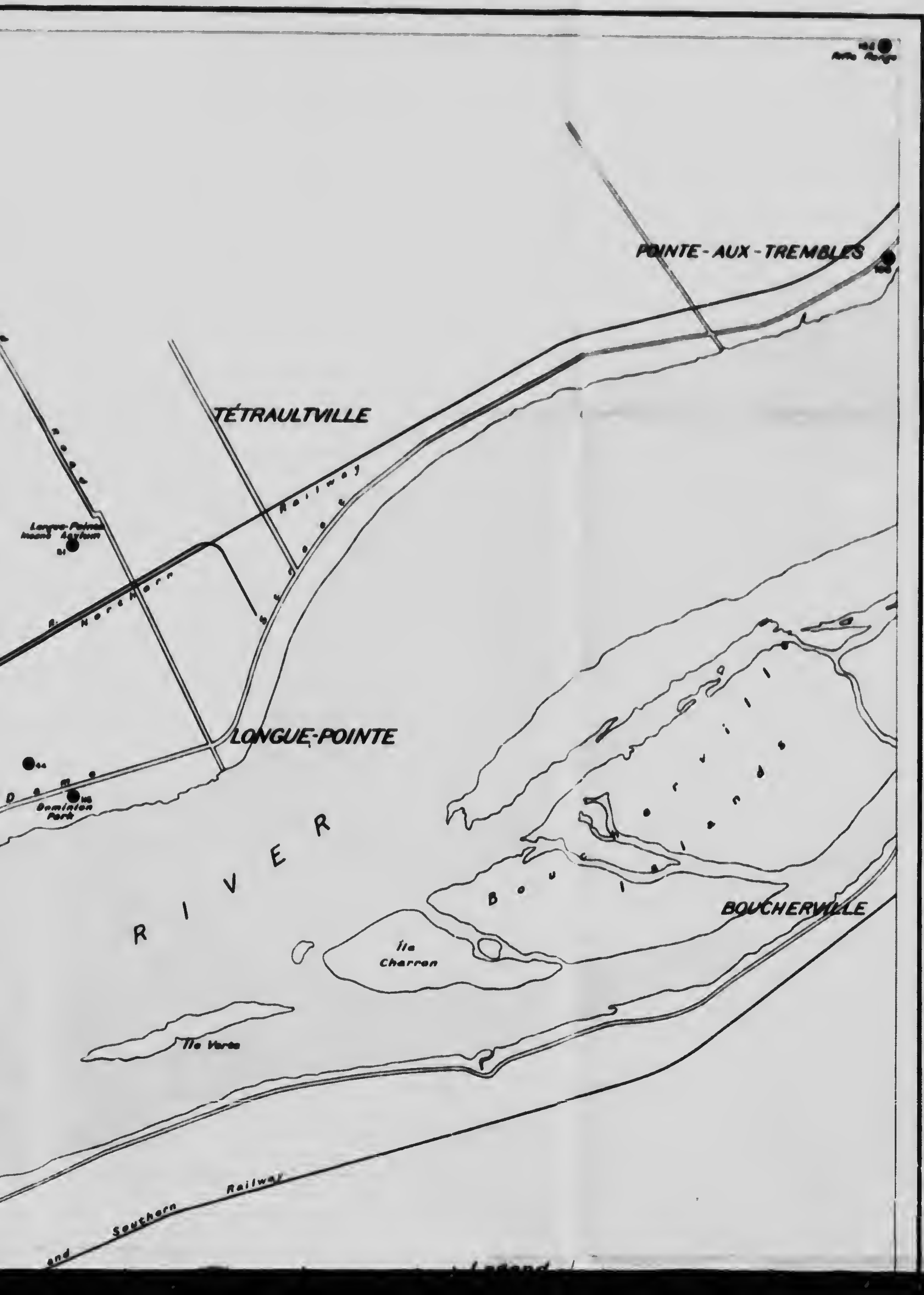

Waterworks
Aqueduct
Canada Car Co.
Turcot Yard
Railway
Upper Lachine
Glen Yard
Western Avenue
Road
Lachine
Pacific
134

Île Jésus
BACK RIVER
SAULT-AU-RECOLLET
AHUNTSIC
Jacques-Cartier Junction
Canadian Pacific Railway
Canadian Northern Railway
Jacques — Cartier Union Railway
Pacific
Canadian
Grand
Côte St Luc
Rosedale Avenue
MONTREAL WEST
Monkland

Jacques Cartier Junction
ST LAURENT
OUTREMONT
WESTMOUNT
MOUNT ROYAL
PARK
Montreal Jockey Club
Montreal Hunt Club
Mount Royal Cemetery
Notre Dame des Neiges Cemetery
Outremont Yard
McGill College
Graham Road
Maplewood Avenue
Queen Marys Road
Railway
St Michel Road
Laurier
Tunnel


MAISONNEUVE
AWRENCE
Michel Road
Daniel Street
Côte St. Louis Rd
Laurier Avenue
Mount Royal Avenue
Lafontaine Park
Sherbrooke Street
Ontario Street
Ontario Street
Hochelaga Street
St. Catherine Street
Notre Dame
Canadian Northern Railway under construction
Canadian
Angus Shops
Helen Street
Gas Works
Hochelaga Yard
Ile Ronde


POINTE-AUX-TREMBLES
TÉTRAULTVILLE
Railway
Northern
Longue-Pointe Insane Asylum
LONGUE-POINTE
Dominion Park
RIVER
Boucherville Islands
BOUCHERVILLE
Île Charron
Île Verte
and Southern Railway
Legend

Geological Survey, Canada.

To accompany Memoir by C. L. Cumming

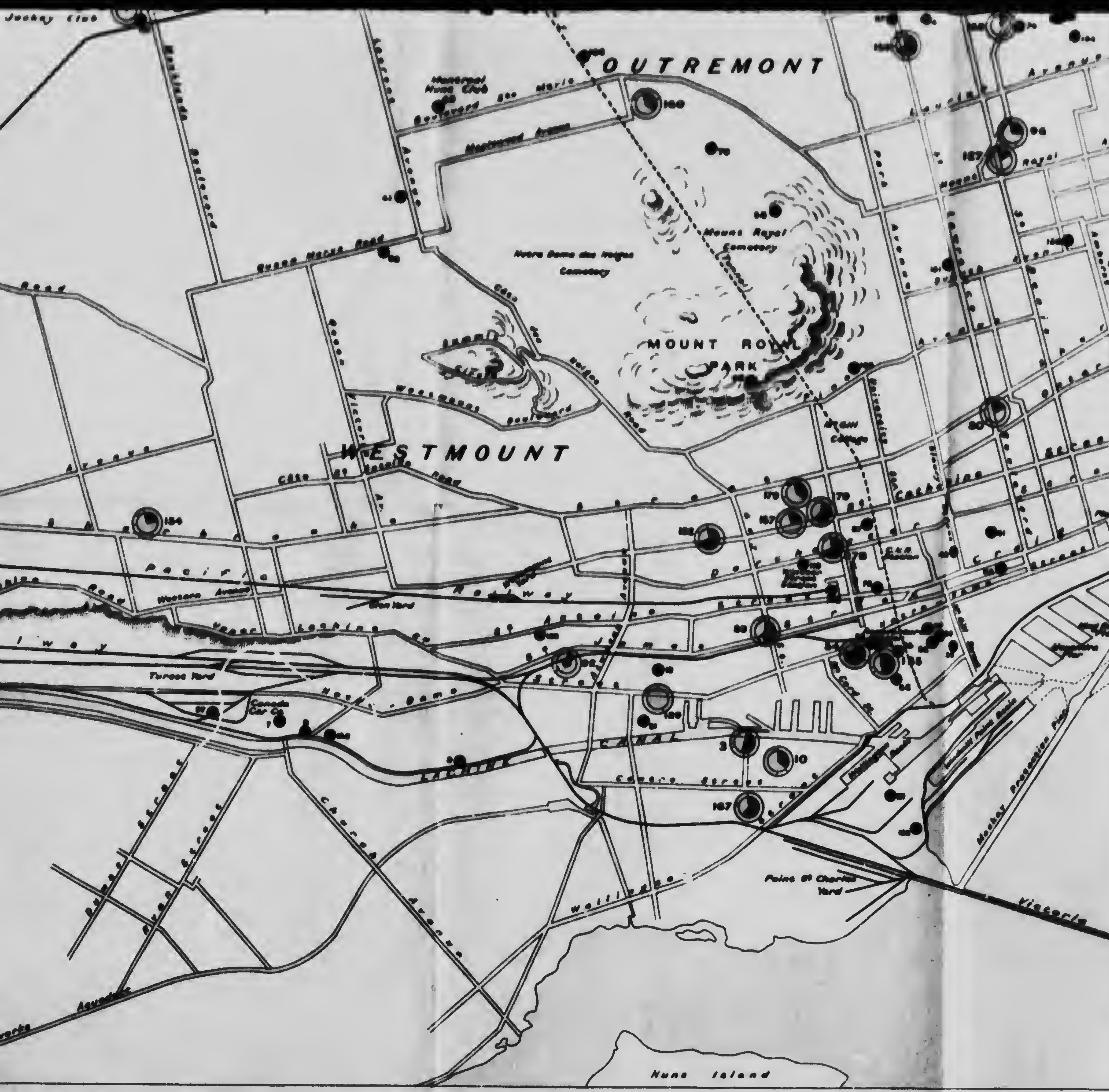


Diagram of the City of Montreal and Vicinity, showing loc

Scale of Feet

and Vicinity, showing location of **Artesian Wells**

Scale of Feet


LONGUE-POINTE
Dominion Park
RIVER
Ile Charron
Ile Verte
BOUCHERVILLE
ontreal and Southern Railway
True North
Legend
CHLORIDE
CARBONATE
SULPHATE
Artesian Well. Sectors show relative proportions of chemical constituents of salts in water, stated in terms of chemical weights
Sulphurous Well
Non Sulphurous Well
Dry Well
Well numbers referred to in memoir
1490