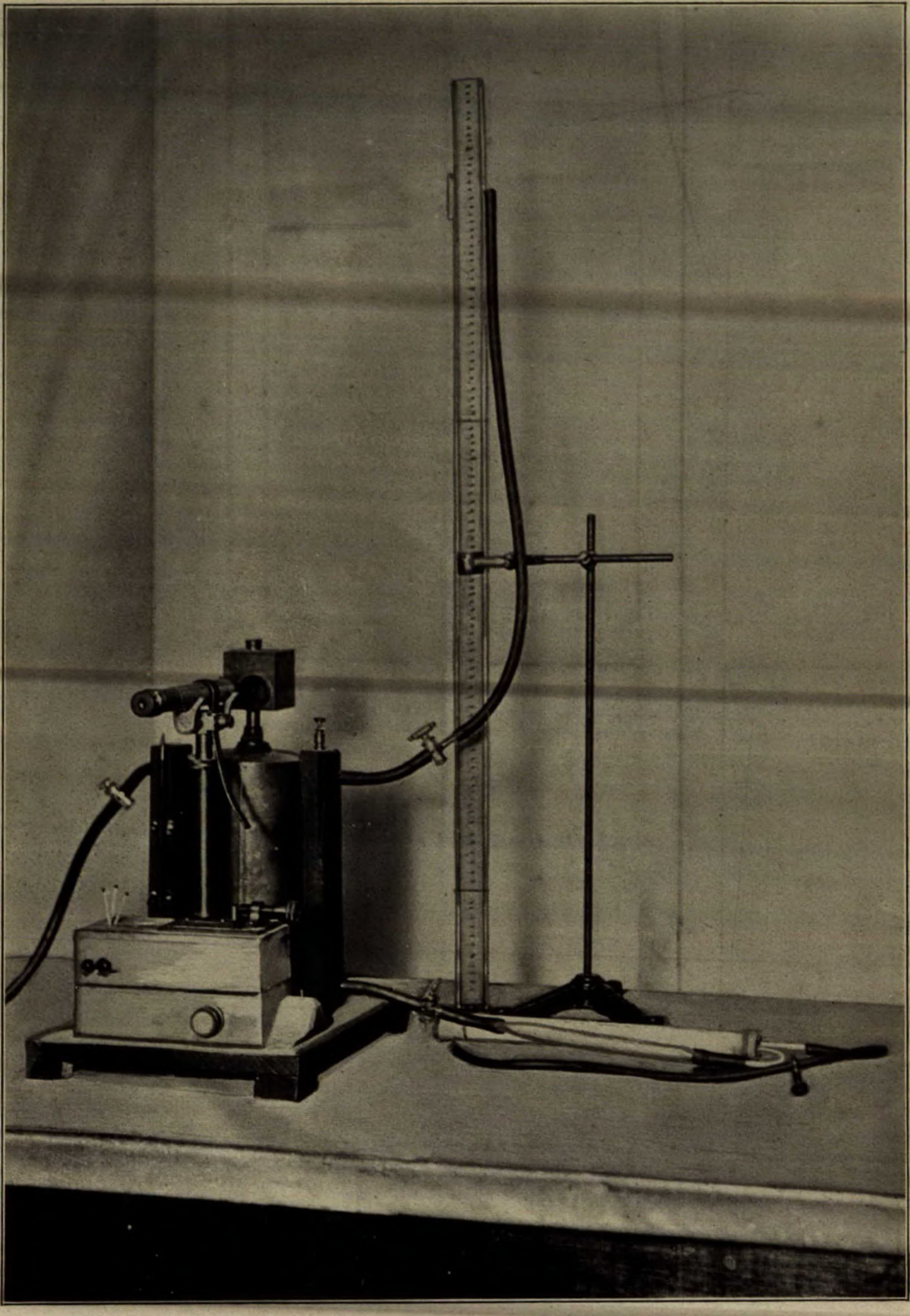

Ionisation vessel and electroscope.

CANADA

DEPARTMENT OF MINES

HON. ALBERT SÉVIGNY, ACTING MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR.

BULLETIN No. 16

Mineral Springs of Canada

IN TWO PARTS

Part I

The Radioactivity of some Canadian Mineral Springs

BY

John Satterly, M.A., D.Sc.

AND

R. T. Elworthy, B.Sc.

OTTAWA

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LETTER OF TRANSMITTAL.

DR. EUGENE HAANEL,
Director Mines Branch,
Department of Mines,
Ottawa.

Sir,—

I beg to submit, herewith, a report on the mineral springs of Canada, arranged in two parts: (I) The radioactivity of the waters; (II) Chemical composition and characteristics. The present issue embraces Part I only; Part II will be published later on. The report has been prepared in collaboration with Dr. John Satterly of the Department of Physics, University of Toronto, under whose direction the field work was carried out.

I have the honour to be,
Sir,
Your obedient servant,
(*Signed*) **R. T. Elworthy.**

Ottawa,
July 17, 1917.

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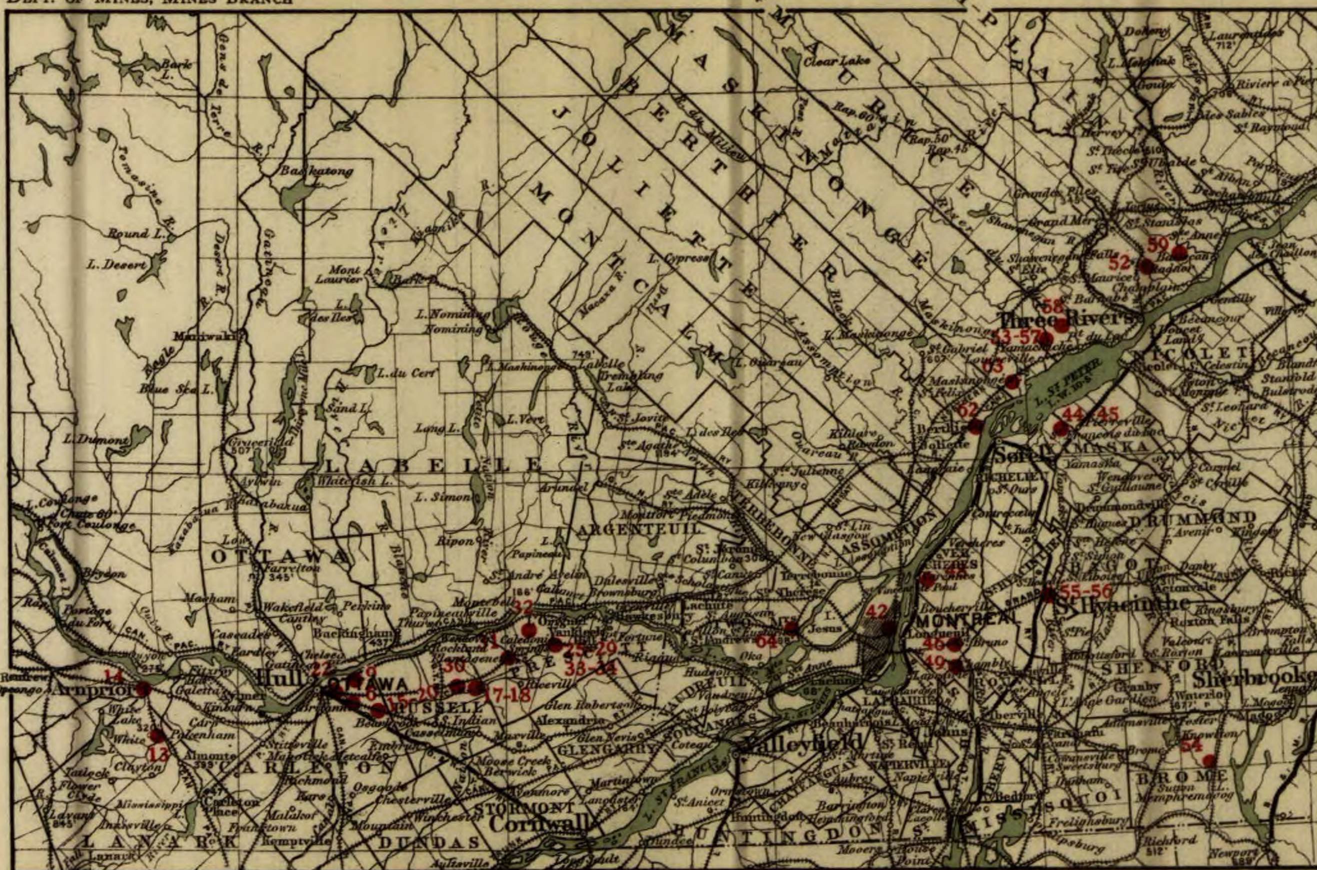

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MAP OF PORTIONS OF ONTARIO AND QUEBEC.
SHOWING LOCATION OF SPRINGS MENTIONED IN REPORT.

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THE RADIOACTIVITY OF SOME CANADIAN MINERAL SPRINGS.

INTRODUCTORY.

Since 1863, little attention, technically, has been given to the mineral springs of Canada. In that year, a report published by the Geological Survey, on the Geology of Canada, contained a chapter, by Dr. T. Sterry Hunt, on the analyses of many of the best known mineral springs in Ontario and Quebec. Very complete chemical analyses of the waters were given, but other properties which are considered of great importance to-day—especially from a therapeutic standpoint—were omitted. The chief of these omissions was the determination of the radioactivity of the spring waters: a subject of which there was no knowledge at that time.

Both in Europe and in the United States there has been considerable research work done on the radioactive content of springs, since it is believed that the therapeutic value of many spring waters may be mainly due to the possession of radioactive properties. Many of the earlier scientists stated that artificially prepared mineral waters, or salts obtained by evaporation from mineral spring waters were without the beneficial qualities possessed by the natural waters; and strange theories were put forward in explanation. It seemed possible that the radioactive properties of spring waters may account for this difference.

Moreover, many mineral waters—the use of which has, undoubtedly, beneficial effects in the treatment of various ailments—contain no uncommon chemical constituents which might account for the particular therapeutic value ascribed to them; in fact, in many cases, such waters are not different in composition from ordinary city supplies. This consideration again impels the suggestion that, the beneficial effects may be due to their radioactive properties.

When, therefore, in the summer of 1914, an investigation of the mineral springs of Canada, was commenced by the Mines Branch of the Department of Mines, Ottawa, it was decided to conduct the research along two lines:—

(I) An examination of the waters to determine the presence of radium and its radioactive products.

(II) A complete chemical examination of the waters.

The results of the first part of this investigation, obtained up to the end of 1916, are published in the following pages.

A report on the second part of the work, giving complete chemical analyses of the waters, will be issued at an early date.

SCOPE OF THE WORK.

Although a comparatively small number of springs have, as yet, been examined, a detailed record of the investigation of the majority of the more important Canadian mineral springs is included in this report.

In the summer of 1914, some fifty spring and deep well waters, situated in eastern Ontario, and western Quebec, were investigated.

Three centres were selected where suitable laboratory accommodation was available, and trips were made to springs in the vicinity of these centres, for the purpose of collecting water samples, and obtaining all necessary data.

The first centre was at the chemical laboratories of the Mines Branch, Ottawa, and measurements of the radioactivity of water samples from many of the deep civic and private wells in Ottawa were made; also of springs at Arnprior, Pakenham, Greens Creek, Carlsbad Springs, Hiawatha Park, and Hawthorne.

The second centre was at Caledonia Springs, Ontario, where, by the kind permission of the manager of the Caledonia Springs Mineral Water Co., facilities were obtained in the bottling plant building, for the setting-up of the necessary apparatus.

Seven springs exist within a very short distance of this centre, and springs at Alfred, Bourget, and Plantagenet, were easily accessible.

In the neighbourhood of Montreal, Que., many springs were visited and samples from them were taken to the third centre which was the physics laboratory of McGill University. Several of the deep well waters in Montreal and its neighbourhood were included in the work. The chief springs examined were at Chambly, Varennes, Ste. Hyacinthe, Abenakis, Radnor, Forges, St. Genevieve de Batiscan, Maskinonge, St. Severe, St. Leon, Berthier, St. Benoit, and Potton.

At the request of the Dominion Parks Commission an investigation of the hot springs at Banff, Alberta, was made in November and December, 1916. A laboratory was fitted up in the Government Fire Hall building at Banff, where every facility was given for the testing of the waters from the local springs. The Upper Hot Spring, Kidney Spring, Middle Spring, the Cave Spring, and the Basin Spring, were tested for their radioactivity, and samples were collected for chemical analysis. Two other springs were also examined at Banff.

RADIUM AND RADIOACTIVITY.

Before entering into a discussion of the methods employed in the measurement of radioactivity, and of the results obtained, a brief account of radium and its properties will be given.

RADIUM.

Radium is one of the rarest of the chemical elements. It is a metal, closely resembling barium in its properties, and if obtained in the pure, elementary condition, would appear white and silver-like. But in the laboratory it is usually obtained in the form of a salt, chiefly as radium chloride or bromide, and these, in the pure state, are white and crystalline. The usual appearance of "radium," however, is that of a few specks of a grey or brown substance, which are, for safety's sake, enclosed in a lead capsule. Viewed in the dark the "radium" glows with a faint phosphorescence.

Two reasons may be suggested to account for the interest in which radium is held by the non-scientific public: (1) its fabulous cost—the market price in 1914 being three million dollars per ounce; and (2) the wide-spread idea that it is efficacious in the treatment and cure of cancer.

The high price of radium is due chiefly to the rarity of pitchblende and high grade carnotite—the chief ores from which the metal is obtained; but this value is artificial, and bears no relation to the cost of extraction. Recently, the United States Government has taken steps to conserve and develop its supply of radium. The largest known deposit of radium bearing ore in the world is found in Colorado, as carnotite; and the United States Bureau of Mines has taken up the problem of the concentration and extraction of radium from this ore. Already suitable methods have been devised.[1] Up to August, 1915, 4,258 mgrs. of radium element had been produced at a cost of $155,322, which is equivalent to $37,600 per gram of radium, or just over a million dollars per ounce.

Radium-bearing minerals have not been found in economic quantities in Canada, although traces of such minerals have been discovered in some localities. The Prospector's Hand Book No. 1, "Notes on Radium-bearing Minerals," by Wyatt Malcolm, published by the Geological Survey, gives a list of these occurrences, and some tests for radioactive minerals are included in the book.

With regard to the second point, namely, the question of its efficacy in the treatment of cancer, medical opinion is still divided. The committee that reported to the United States Congress on the desirability of conserving and developing the radium resources of the country state that they are satisfied that certain forms of cancer are curable by radio-therapeutic treatment. Radium has, certainly, been used with success in dermatology, gynecology, and in the treatment of cancerous growths, hence an extensive literature in connexion with the medical use of radium has developed.

RADIOACTIVITY.

One of the most remarkable properties of radium is, that it is a constant source of invisible radiations. It is continually emitting a stream of charged electric particles or rays, which act on a photographic plate, and have the power of discharging electrified bodies. If the rays impinge on a prepared

[1]Bulletin No. 104, U.S. Bureau of Mines. The Extraction and Recovery of Radium, Uranium and Vanadium from Carnotite.

screen of phosphorescent zinc sulphide a constant succession of brilliant scintillations is observed when the screen is viewed through a lens in a dark room.

The luminous paint, so largely used lately in the making of luminous dials for watches, and aeroplane instruments, is a practical application of this phenomenon. The mixture consists, chiefly, of zinc sulphide, and a very small percentage of a radium compound. The constant succession of flashes caused by the α particles from the radium impinging on the zinc sulphide crystals, give rise to the green phosphorescence, easily visible in the dark.

Three kinds of rays are emitted by radium called respectively α, β, and γ rays.

The α rays consist of a stream of positively charged electric particles, which are very easily absorbed by thin sheets of metal foil, paper, and even by gases. Professor Rutherford showed, in 1909, that the α particle was a charged helium atom. This discovery explains the fact that helium is always found in radioactive minerals, and in the gases evolved from mineral springs. The β rays consist of a stream of negatively charged particles, (electrons as they are called) with far greater penetrating power than the α rays. They have strong photographic action, and are easily deflected out of their path by a magnet. The γ rays are the most penetrating of all, and will pass through a sheet of lead several centimetres thick. The β rays are akin in nature to X-rays.

Uranium and thorium have been found by Becquerel, in 1896, to possess radioactive properties, but the discovery by Professor and Mme. Curie, in 1898, of radium—a substance possessing an activity a million times greater than uranium—gave a great impetus to the study of radioactivity, and many facts and theories relating thereto have been established in recent years.

It is supposed that the radiations result from the breaking up of the radioactive substance. For example, radium is in a condition of constant decomposition or disintegration. The disintegration results in the emission of particles (which are shot off at great velocities), leaving a substance different in properties from the original body. This theory, to explain the phenomenon of radioactivity, was advanced by Rutherford and Soddy in 1903. It has been supported by every fresh discovery, and the theory may be considered to be completely justified.

Each of the radioactive substances uranium, radium, and thorium, has its series of decomposition products. It has been proved that radium is a disintegration product of uranium, although its immediate parent is ionium; similarly radium itself decomposes, giving off α and β rays and leaving radium emanation, or "niton" as it has been called by Sir William Ramsay. Radium emanation is a gas, all the physical properties of which have been ascertained, although the volumes with which experimenters have worked have been exceedingly small. Radium emanation, in its turn, disintegrates, giving rise to a series of solid substances named Radium A, Radium B, Radium C, Radium D, Radium E, and Radium F. This last product is thought to be lead. Each of these products during its existence sends out radiations of the above types having ranges and velocities peculiar to the product. In a similar way the decomposition of thorium results in the production of α and β rays and the formation of a series of substances; Meso-thorium, Radio-thorium, Thorium emanation, Thorium A, B, C, D, etc.

One important conception to be grasped is, that the decompositions take place at very different rates for different products; from a few seconds to thousands of years, and that the rate of disintegration follows the law of geometrical progression. For example, one ounce of radium will be half decomposed in approximately 2,000 years. In another 2,000 years half of the remaining half, namely a quarter, will have disappeared and consequently only a quarter remains. Yet another 2,000 years and only one-eighth is still in existence, and so on.

Radium emanation, the gas which is the product of the disintegration of radium, has a much shorter life. Half of any initial quantity of it will have disappeared in just under four days, *i.e.*, if we had one cubic inch of the gas to start with, only one-half of the cubic inch remains after four days. After another four days, only one-quarter is left, and so on.

Other radium disintegration products have only a few seconds of existence, as for example Radium A. The interval in which the half of any given quantity of a single radioactive substance disintegrates is called the "period of half life." Thus, 2,000 years—more closely 1,760 years, is the half life period of radium; that of radium emanation is 3·85 days. It should be remembered that the period of radium is very long compared to those of its immediate successors.

Consider one gram of radium bromide dissolved in one litre of water contained in a closed vessel. The radium will evolve radium emanation, and shoot out rays; the emanation will give off α rays, and form in succession the solid products Radium A, Radium B, and Radium C, etc. Presently, a time will arrive when practically just as much emanation is being produced from the radium as is decomposing into the solid products. Therefore, an equilibrium condition is obtained. This state is practically reached in a month, and is of importance in measuring the radium contents of waters or of radioactive solutions. If water, containing radium salts in solution, is bottled and closed up, radium emanation will be formed, and in about thirty days the maximum amount of emanation corresponding to the amount of radium will be present.

If there is no radium present in the water, but only dissolved radium emanation, the radioactive properties of the water will soon disappear, as there is nothing to generate new emanation as the old dies away.

THE RADIOACTIVITY OF NATURAL WATERS.

Natural waters may be either temporarily or permanently radioactive. In the former case, radium emanation will be found dissolved in the water picked up from the rocks and soils that the water has traversed, but as soon as the water is collected the emanation present starts to decay, and in several days will have almost all decomposed. The majority of waters are of this nature.

A permanently radioactive water will contain radium salts in solution, and this, necessarily, entails the presence of emanation, as the supply of emanation is being constantly renewed by the decomposition of the radium.

The results of the investigation show that most waters contain a little radium in solution, and considerably more emanation than would be the amount in equilibrium with the dissolved radium present.

If the radioactive water is used for medical purposes at its source the total activity is of importance, but if the water is bottled and kept, then on account of the decay of the radium emanation (unless there is a considerable amount of radium salts in solution) the total activity is of little value.

This point will be treated more extensively in the paragraph on the economic value of radioactive waters.

It is easy to explain the reason of the radioactivity of waters. Almost all rocks have been found to contain small amounts of radium;[1] igneous rocks, on the average, possess more than sedimentary rocks. The soil[2] also contains small amounts of radium.

The waters percolating through the ground will dissolve the emanation which is evolved from the rocks composing it, and they may also have a solvent action on any radium in the rock. They thus become radioactive. This is readily supported by the fact that, nearly all waters show a slight radioactive value, though few are permanently radioactive.

It has been stated that as a result of radioactive decomposition helium is produced from radiations. Helium has often been found in the gases that are evolved from springs. Shortly after the discovery of helium, Lord Rayleigh detected it in gases evolved from mineral springs of Bath (England), but not until Sir William Ramsay, and Professor Soddy, showed the connexion between radium and helium was its origin in natural waters well understood.

For example, the gases escaping from the King's Well at Bath, England,[3] contain 1·2 volumes of helium per 1,000 volumes of gas, the main constituents of the gas being nitrogen and carbon dioxide. Moureau and Lepape,[4] in their examination of certain French springs, have found from 1 to 10 parts per 1,000 in the gases evolved from the waters.

Strutt. Proc. Roy. Soc. A, 77, p. 472, 1906; 78, p. 150, 1907.
Eve and McIntosh, on Canadian rocks, Phil. Mag. 14, p. 231, 1907.
[2] R. B. Moore, J. Ind. Eng. Chem. Vol. 6, 1914, p. 370.
[3] Ramsay, Chem. News, 1912—105, p. 134.
[4] Moureau and Lepape, Comp. Rend. 1911—152, p. 546-51.

No work has been done on the gases given off from Canadian springs, except by Professor R. F. Ruttan[1] of McGill University, in his examination of the Caledonia Springs in 1903. He found that the gas evolved from the Duncan Spring contained a trace of helium.

[1]Page 24.

METHODS USED FOR THE DETERMINATION OF RADIOACTIVITY.

The examination of natural waters for radioactivity[1] entails two measurements: (1) of the total radium emanation present in the water at the time of collection of a sample; (2) the amount of radium salts held in solution.

As already explained, radium emanation soon decays, hence tests for the total emanation present in a water must be carried out as soon as possible after the collection of the sample; whereas the estimation of radium salts may be carried out at one's convenience.

On this account, the springs were visited at times which enabled samples to be conveyed with the least possible delay to a laboratory where the testing instruments were set up. The time elapsing between collection and testing was carefully noted, and the necessary corrections were applied to allow for the decay of the emanation during that period.

Observations of temperatures, rate of flow, depth of well or boring, and all particulars that could be ascertained, were made at the time when the samples were collected. If gases were evolved from the waters, samples were obtained both for chemical analysis and radioactive measurements. Samples of water both for the radioactive investigations and for chemical analysis were collected in five gallon glass demijohns, and such samples were immediately despatched to the testing laboratories.

PRINCIPLE OF THE METHOD EMPLOYED.

The principle employed in the measurement of radioactivity is, that radioactive substances cause the air surrounding them to become a conductor of electricity, and, therefore, an insulated electrically charged body placed therein is gradually discharged. The rate of discharge of the charged body is a measure of the conductivity or ionisation of the air, and hence of the strength of the radioactive substance responsible for the ionisation. The instrument usually employed for this purpose consists essentially of a metal vessel, through the top of which passes a metal rod insulated from the top of the vessel by a collar of amber, sulphur, sealing wax or some other non-conducting substance.

The rod bears at its upper extremity a narrow strip of gold leaf or aluminium foil hanging down like a streamer on a staff. When the rod is given a charge of electricity, the leaf is repelled from its vertical position to an inclined position. It then gradually collapses, as the charge on the rod leaks away. By a suitable arrangement the rate of fall of the leaf may be determined.

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[1] By this is meant activity due to radium, not to the other radioactive elements.

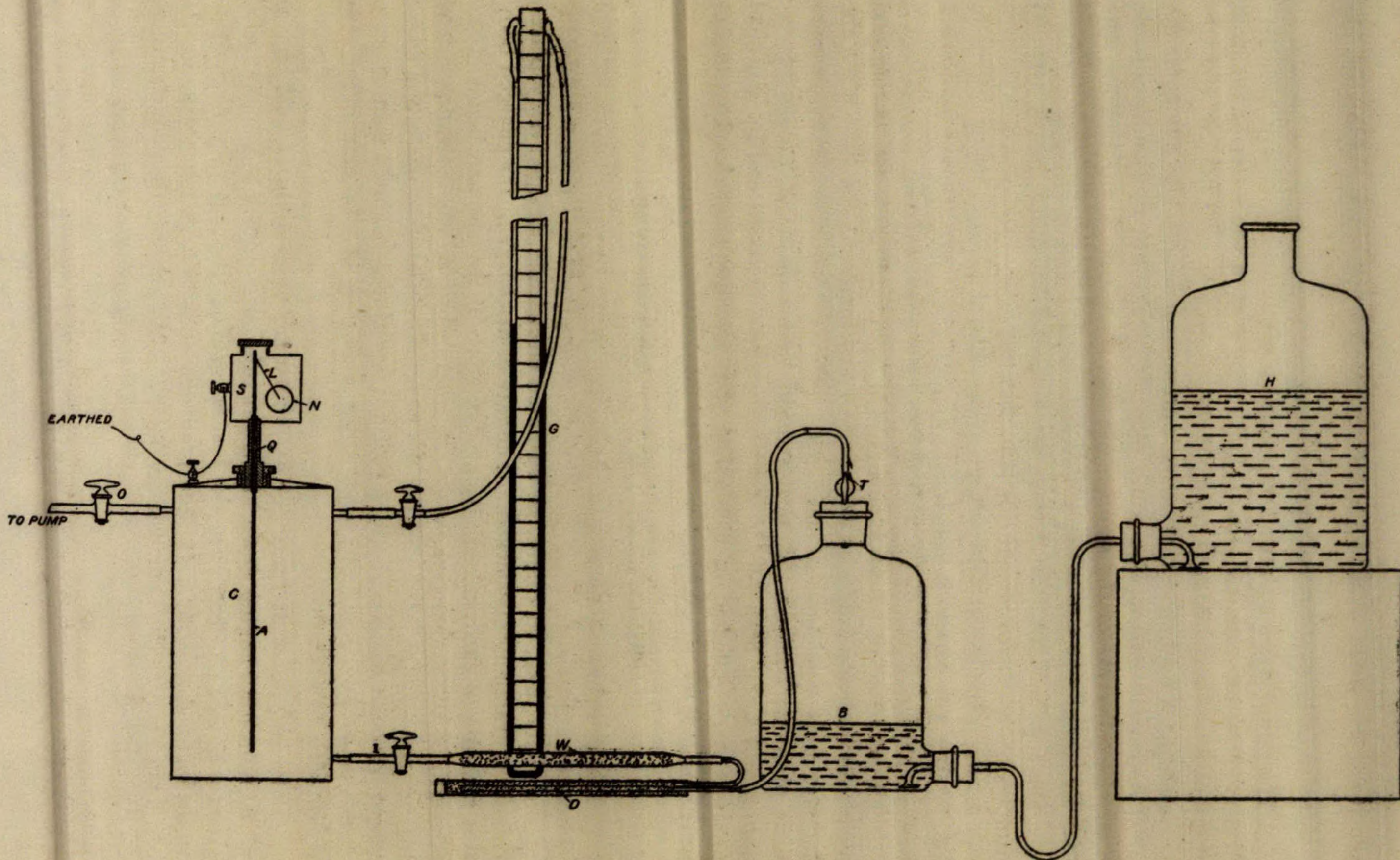


Fig. 1. Electroscope, drying tubes, and aspirators.

The metal vessel is usually called an *ionisation* or *testing vessel* while the upper portion of the rod, together with an enclosing chamber to prevent draughts acting on the gold leaf, is called an *electroscope.*

Due to the slight radioactivity of the earth and the air, there is always a slow rate of fall of the leaf. This is said to be due to the "normal leak," but even if only a small amount of a radioactive emanation—for example, radium emanation boiled out of a water sample—is mixed with the air, the rate of movement of the leaf is considerably accelerated.

DETAILED DESCRIPTION OF THE APPARATUS.

Fig. 1 and Plate I show the ionisation vessel, and the electroscope. The former consists of a stout brass cylinder **C**, 14 cms. diameter × $25\frac{1}{2}$ cms. high. Its volume is 3,930 cubic centimetres. The electrode **A**, is a brass rod 4 mms. diameter. This projects into the cylinder through an insulation consisting of a quartz tube **Q**, held in place by a hard rubber collar 1·4 cms. diameter. The joint is air tight. **A** reaches to within 2 cms. of the bottom of **C**. The gold leaf **L**—about 35 mms. long × $1\frac{1}{2}$ mms. wide—is attached to the upper end of the rod **A**. A cubical brass box **S**, of about 6 cms. side, surrounds the gold leaf. Two small windows **N**, in opposite sides of **S**, enable the leaf to be illuminated and observed. The rate of fall of the leaf is measured by means of a tele-microscope mounted horizontally in front of the windows. The microscope used, has a magnification of about 40. It is furnished with an eye piece scale, and all leaks are expressed in terms of the divisions of this scale. The vessel **C** is provided with three openings, to which are attached short pieces of thick rubber tubing. One of these is connected to a mercury manometer **G**, another **O**, to a pump by means of which **C** can be exhausted, while the third, **I**, serves to admit the gas after it has passed through suitable drying tubes, **W**, and **D**.

The vessel is firmly mounted on a wooden stand, with uprights from the stand gripping the vessel at the projecting tubes. The stand also carries the support of the tele-microscope.

The gold leaf is always charged to practically the same potential. The position given by the zero reading on the microscope scale corresponded to 350 volts, and the 100 reading on the scale to 200 volts. The rate of leak was observed over this interval. The voltage is always such as to ensure saturation for the small amounts of radioactive matter dealt with, and the movement of the leaf was found to be practically uniform over the range employed. The normal "air" leak, *i.e.*, the leak when the ionisation vessel was filled with dry air, was 0·02 to 0·05 scale divisions per minute. The normal air leak is usually subtracted from all other leaks, in order to determine the leak due to the radium emanation contained in the air.

MEASUREMENT OF THE RADIUM EMANATION DISSOLVED IN WATER.

In order to get the radium emanation out of a sample of water, nine litres of the water were placed in a tinned copper boiler **P** (Plate II), connected by a large rubber bung to the inner tube **M**—also of tin—of a condenser **C**, sloping upwards, as in the figure, so that the condensed steam, can run back into the boiler and thereby, keep the strength of the sample constant. An aspirator bottle **B** (Plate II and Fig. 1), filled with warm distilled water (50-60°C) was connected to the higher end of **M**. A tube **I** closed by a clip penetrated the bung and reached nearly to the bottom of **P**. When it was sure that all the joints were air tight, the sample was boiled. After half an hour's boiling, the tap **T** of vessel **B** and the clip **I** were opened, and as the water in **B** runs into the lower bottle **H** a vigorous stream of air was drawn through the boiling solution in **P**, and all the emanation expelled by the boiling was collected in the air, which now fills **B**. Two aspirator bottles, **B**, of volume about two litres, were filled with air in this manner. This ensures a complete sweeping out of the expelled emanation. Meanwhile, the insulated system of the electroscope was charged to the usual potential and observations of the normal rate of discharge or "air leak" made.[1]

The ionisation vessel is exhausted to a pressure of about one centimetre of mercury, and the air in the aspirators is allowed to pass in through a drying tube **D** containing calcium chloride. (See Fig. 1.).

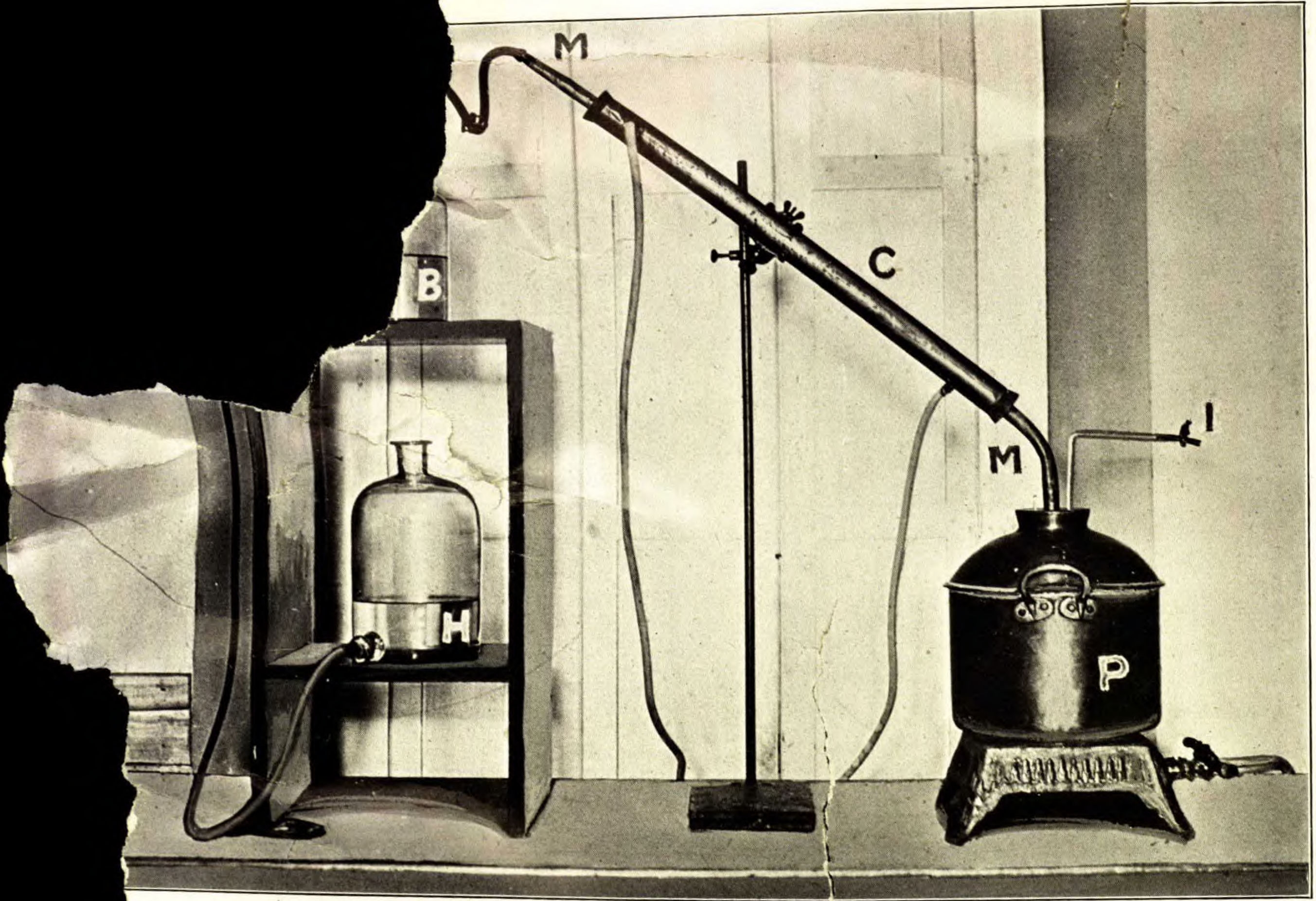
When the air has been in the vessel ten minutes, observations of the leak are taken.

Most experimenters in carrying out similar determinations allow the gas to stay in the ionisation vessel three hours before taking readings of the rate of leak of the charged gold leaf. It is known that the activity due to radium emanation and its products rises for the first ten minutes, remains constant for some time, and then rises until a maximum is reached three hours after the gas enters the ionisation vessel.

Steady readings can, therefore, be obtained from 10 to 20 minutes after the active air has been passed into the vessel. This procedure is much better than waiting for the three hour maximum. In 20 minutes only a small activity is deposited on the walls of the vessel, and if, after the leak has been taken, the vessel is exhausted, and air drawn through the apparatus, it is practically ready at once for a new test. Occasionally, samples of air to be tested were left in the ionisation vessel for three hours, and readings all along up to the maximum were taken to see whether it was really radium emanation that was being dealt with. In every case the 3 hour leak was found to be 50% greater than the ten minute leak, showing that the ionisation was due to radium emanation.[2]

[1] A delay of 10 minutes or so was always made after charging before measurements of the steady value of the "air leak" were taken. This is on account of absorption of the charge by the insulation.

[2] Satterly: Proc. Camb. Phil. Soc., Vol. XVI, Part 6, 1912, p. 514.



Apparatus for boiling water samples for the measurement of radium emanation.

The final readings will be expressed in this form: The emanation expelled from 9 litres of the sample water gives a leak of . . . divisions per minute. Of course, if the test is made some hours after the water is collected, a correction must be made for the decay of the emanation which has occurred in the interval.

STANDARD SOLUTIONS USED.

In order to find the radioactivity of a water, in terms of radium, a comparison is made between the rate of leak caused by emanation boiled out from a known volume of water, as described above, and the rate of leak caused by emanation boiled out from a solution containing a known amount of a radium salt.

Several such solutions were made up from standard radium solutions obtained from two sources:—

(1) 100 c.c. of a solution of radium barium bromide, in 50% hydrochloric acid, certified to contain $12\cdot2 \times 10^{-12}$ grms. of radium per c.c., obtained from the United States Bureau of Standards.

(2) 10 c.c. kindly presented by Professor Boltwood of Yale, containing $1\cdot5 \times 10^{-9}$ grms. radium.

Weaker solutions of various strength were made up from these by taking aliquot parts of them, and diluting with freshly distilled water and distilled hydrochloric acid solution. They were placed in 250 c.c. conical flasks, **F** (Fig. 2), and permanently connected up with condensers **C**, then boiled out at intervals during the course of the work.

The comparison experiments were conducted in much the same way as those for the water samples (page 12), the apparatus being arranged as in Fig. 2.

If a month is allowed to elapse between two boilings, the radium emanation will have grown to equilibrium amount. If a lesser period has elapsed, only a fraction of the equilibrium amount will have come into existence, but with the aid of tables drawn up by Kolowrat[1] and others, the necessary corrections can be made.

The mean result obtained from many tests on solutions of varying strength, and prepared from both standard solutions is, that a leak of one scale division per minute, ten minutes after the emanation has entered the electroscope, corresponds to 280×10^{-12} grm. of radium per litre; or, as it will always be expressed in this report, 280 units of radium per litre.

MEASUREMENT OF THE DISSOLVED RADIUM SALTS.

For the measurement of dissolved radium salts large quantities of each water (5 to [illegible] llons) [illegible]e sent to Ottawa, and there evaporated down to smaller bu[illegible] [illegible] reat precautions to keep every substance present in the wat[illegible] The following treatment ensured that all the mineral matt[illegible] s got into solution.

[1] Curie, ibid. Feb. 1910, [illegible] tivity. Kolowrat, LeRadium, July 1909.

A volume of water from 10 to 20 litres was evaporated down to 4 or 5 litres in large porcelain evaporating basins. The liquid remaining was filtered off, and the residue dissolved up as much as possible in hot dilute hydrochloric acid solution (distilled water and redistilled acid). The insoluble portion was transferred to the filter, and the whole well washed, dried, then heated in a platinum crucible until all the organic matter was thoroughly ignited. Hydrofluoric acid and redistilled hydrochloric acid were added to the residue, evaporated to dryness, and the contents of the

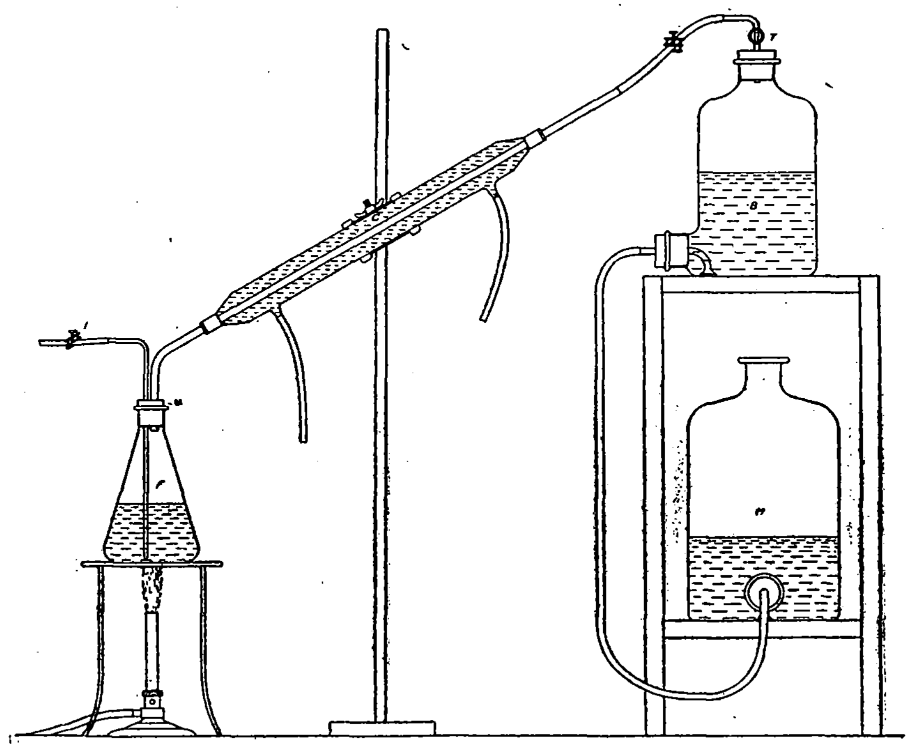


Fig. 2. Apparatus for boiling out standard radium solutions.

crucible again ignited. A treatment with hot dilute hydrochloric acid dissolved most of the residue; the solution was filtered off, and the residue treated in a similar manner. These operations were repeated until the last trace of residue was completely dissolved. All the filtrates were added to the original filtrate. The concentrates so obtained were bottled in large glass flasks (5 litre capacity), and sealed with well cleaned rubber stoppers.

After keeping for sufficient time to ensure an equilibrium condition between any radium salts and emanation, these were boiled out as described on page 12, passing air through the solutions, and then into the ionisation vessel. In testing for the dissolved emanation and for the dissolved radium, hydrochloric acid is added to the waters, so that all carbonates or bicarbonates present are converted to chlorides. This is to avoid the occurrence of any precipitation which would happen if temporarily hard waters—that is waters containing calcium or magnesium bicarbonates—were boiled. As the ordinary commercial hydrochloric acid usually is radioactive, and contains traces of sulphuric acid, both of which would cause errors, the hydrochloric acid used was always redistilled. The leak obtained on the second boiling gives, of course, the measure of amount of emanation in equilibrium with the dissolved radium. The leak obtained on the first boiling gives the measure of the amount of emanation in equilibrium with the dissolved radium plus the dissolved emanation which the water has picked up as gas in its passage through the ground. By difference, the seperate amounts can be deduced. The second item is usually much greater of the two, in fact one might say that for most of the waters tested they were only radioactive before their initial boiling.

THE RADIOACTIVITY OF GAS ESCAPING AT THE SPRING.

Gas was given off from many of the springs examined, especially from some of the Caledonia Springs and from the Banff waters. The chief constituents were usually methane or marsh gas, carbon dioxide, oxygen, and nitrogen. Analyses are given under the individual descriptions of the springs.

The gases evolved from most springs are radioactive. This property may be due to the presence of radium emanation, or to thorium emanation, or to both. Thus Schlundt and Moore in their examination of Hot Springs in Yellowstone Park[1] found thorium in 16 cases out of 82 gas samples examined, though in most instances the activity was solely due to radium emanation. On account of the rapid rate of decay of thorium emanation (its "half life period" is 54 seconds) tests have to be made at the time of collection of the sample. No attempts were made in this work to make examination for thorium emanation. Samples were always collected and tested quantitatively for the radium emanation, and positive results were obtained in every instance, though the values found are small compared to the Yellowstone Park Spring gases. The results are tabulated on page 41.

Helium is an essential constituent of a radioactive spring gas. (Page 6). Therefore, it would have been interesting to have made measurements of the amount of helium in the gases. However, in most cases the comparatively small volume of gas evolved would have made the collection of sufficient quantity for a quantitative examination of helium too lengthy an operation for the time at our disposal.

Schlundt and Moore, Bul. 395, U.S. Geol. Survey, 1909, p. 28.

For the collection of gases given off from waters, a funnel with a wide angled mouth was used. Gas was allowed to rise from this into a Winchester quart bottle, displacing the water with which the bottle had been previously filled. The bottle was then securely corked under water, and taken to the testing apparatus. A known volume of the gas was passed into the vessel, and the leak measured as described on page 12.

THE MODE OF EXPRESSING THE RESULTS OF RADIOACTIVE MEASUREMENTS.

The results of radioactive measurements are most conveniently expressed when the quantity of radium emanation is given in terms of the quantity of radium with which it is in equilibrium. For it is by a method of comparison that we quantitatively determine the amount of emanation. The amount of radium emanation in equilibrium with 1 gram of radium is called a "curie," after Professor and Madame Curie. This quantity is comparatively speaking a very large quantity, and for expressing the results of measurements on rocks, waters, and gases, a millionth of a millionth of a curie is a more convenient unit. This unit is written 10^{-12} curie. In stating the results in this report, however, the 10^{-12} curie will be omitted and the radium emanation content will be given in terms of this unit.

Thus in the example on page 17, it is shown that the Soda spring at Carlsbad Springs, Ontario, contained 81×10^{-12} curies per litre radium emanation. This will be written as 81 units per litre. Similarly 1×10^{-12} gm. radium per litre will be written 1 unit dissolved radium per litre.

The volume of a curie of emanation is about 0·6 cubic mm. or, approximately, 0·00004 cubic inch, so that some idea of the almost incredible powers by which we can note the presence of radium emanation may be learned when it is stated that the presence of a million of a millionth of this quantity can be detected. A gram of radium produces helium at the rate of 158 cubic millimetres a year. Helium is one of the "perfect" gases, and enters rarely into combination with any substance; so that whereas the radium emanation produced from radium decays, and its place is taken by freshly-grown emanation, the amount of helium produced goes on accumulating with time. The presence of helium in the issuing gases from many spring waters is explained by the fact that such waters are radioactive.

AN EXAMPLE OF THE METHOD OF MEASURING AND CALCULATING RADIOACTIVITY.

On July 22, springs at Carlsbad Springs, Ont., 8 miles from Ottawa, were visited. A 5-gallon sample of the water from the "Soda Spring" was collected at 9.30 a.m., and observations of temperature, flow, etc., made. The water was taken to Ottawa and 5 litres boiled out in the boiler **P** (Plate II). Air was bubbled through and the contents of the aspirators passed into the ionisation vessel at 3.40 p.m. At 3.50 p.m. readings of the leak were made during a ten minute period, and the leaf was found to fall at the rate of 1·44 divisions per minute. The normal rate was found to be 0·05 divisions per minute. Thus the net leak for 5 litres is 1·39. In six hours—the time that elapsed between the collection and the testing of the sample—the emanation had decayed 4·4% of its initial amount, hence at the time of collection the leak would have been 0·06 more, viz., 1·45 divisions per minute, or 0·29 divisions per litre, per minute.

As a leak of 1 division per minute is caused by the emanation in equilibrium with 280×10^{-12} grms. radium, there must be an amount of emanation in equilibrium with 81×10^{-12} grms. of radium, or, as we express it, 81 units of emanation per litre of water.

For the estimation of dissolved radium in the water 12 litres of the water were evaporated and bottled. After the water had stood for a month, equilibrium was obtained. It was then tested, and the leak was found to be 0·05 divisions per minute, or 0·004 divisions per litre, per minute.

Thus the Soda Spring water contains the dissolved radium to the extent of 0·004 × 280 units radium per litre, *i.e.*, 1·1 units per litre.

Thus 1 litre of the water fresh from the spring may be said to contain 1 unit radium and its equilibrium amount of emanation, and 80 units of dissolved emanation.

PROCEDURE AT THE SPRINGS.

At the wells and springs the bottles were washed out with the issuing water, and then filled up with as little agitation as possible, since any splashing would cause the loss of dissolved emanation. Measurements of temperatures were made with standardized thermometers: a minimum and maximum temperature thermometer being used for deep wells and cavities. The specific gravity of the water was also taken, and any colour or smell noted.

The flow was usually estimated by observing the time taken to fill a receptacle of known volume. Several chemical tests were made for hydrogen sulphide, and for free carbon dioxide in the water.

Any gas issuing was noted, its supply roughly gauged, and if coming off in appreciable amount, two samples were taken—one for radioactive, the other for chemical tests.

The general surroundings of the springs were observed, such as the nature of the soil, the proximity of a river, etc. A few samples of mud and deposit were often collected, though these specimens have not as yet been examined.

DESCRIPTIONS OF WELLS AND SPRINGS.

Although the work was started with the intention of examining mineral springs, several deep well waters in Ottawa and Montreal have been investigated for their radioactivity. The waters in Ottawa were examined while the apparatus was in an experimental condition.

The wells of Montreal have been the subject of two reports by the Geological Survey—"The Artesian and other deep wells on the Island of Montreal," by F. D. Adams and O. E. LeRoy, issued in 1904, and "The Artesian Wells of Montreal," by C. L. Cumming, Memoir 72, published in 1915. In consequence, much data has been accumulated, and it seemed of interest to include waters from some of the deeper wells which are mentioned in these reports.

In the following pages brief descriptions of the wells and springs are given, together with the various observations and results detailed at some length. The map opposite page 1, shows the locations of most of the mineral springs examined.

The results are tabulated on page 43, so that comparison may conveniently be made.

All temperatures are given in Centigrade degrees. A table showing the equivalent Fahrenheit temperature is given on page 55. The method of expressing the radioactivity of the waters has already been explained on page 16.

OTTAWA DISTRICT.

1. Y.M.C.A. well, Metcalfe Street, Ottawa.

The well is sunk to a depth of 1,100 feet. The water is alkaline, and has a slight taste of hydrogen sulphide. Temperature 10·5°C. Mineral contents 540 parts per million. The emanation content was found to be 73 units per litre.

No test for the presence of dissolved radium was carried out.

2. Capital Brewery well, Wellington St., Ottawa.

This well is 709 feet deep. The water rises to within 70 feet of the surface, and is pumped by means of compressed air. On this account measurements of radioactivity of the water are uncertain because much of any emanation present will be blown out by the air. Temperature 10·5°C, flow 3,800 gallons per hour. Activity equivalent to 2·8 units, per litre.

For dissolved radium, no test was made.

Civic Wells in Ottawa.

Name	Depth.	Temp.	Flow gals. per hour.	Activity per litre.
No. *3 Dundonald Park*	1,380 ft.	10·5°C.	265	22 units.
„ *5 Cor. Elgin and Lewis*	900 „	9·5°	300	50
„ *7 Cor. Lloyd and Queen*	265 „	9·5°		11
„ *8 Rosemount Ave.*	203 „	9·8°	2,400	11
„ *12 Cor. Hopewell and Bank* ...	398 „	11·0°	1,440	70

Tests for dissolved radium were carried out on samples 3 and 8 but no trace was found.

4. Ottawa Dairy Well, Somerset St., Ottawa.

The well is 812 feet deep and the log of the drilling was obtained. The first 78 feet consisted of clay and shale. From 78 to 113 feet the drill penetrated a black limestone rock. The remaining 692 feet were bored in a dark grey limestone rock.

The water issues from the Trenton (limestone) formation. The flow is 2,000–3,000 gallons per hour. The mineral content is 228 parts per million. Compressed air is used to lift the water and a low result was therefore obtained for the emanation present. The water contained 1·4 units of emanation per litre.

9. Hiawatha Park well, Besserer's Wharf, Gloucester tp., Carleton co.

This is a bored well 150 feet deep with a natural flow of 250 gallons per hour. Temperature 9·5°C. The water contains a little hydrogen sulphide, giving it a slight sulphur taste. Radioactivity, 90 units per litre.

No dissolved radium was found in solution.

10. Hopper's Well, 15 Linden Terrace, Ottawa.

This well is 385 feet deep; the first 80 feet is clay, then 10 feet gravel, and the remaining 295 feet is in the black Trenton limestone. Temperature 9°C. The flow is small and the well can easily be pumped dry. It contains 2,400 parts per million of mineral matter, though when the well was first drilled water of a more saline nature was obtained.

Radioactivity, 109 units per litre.

It contains no dissolved radium salts.

11. Tally Ho Water, Ottawa Hunt Club well.

The water from this well has a large sale in Ottawa as Tally Ho water. The well is 265 feet deep. The water had a temperature of 11°C. It is pumped some distance from the well to the bottling plant. The activity was found to be equivalent to 81 units per litre.

21. Westman's Well, Britannia Heights, Ottawa.

This well is 63 feet deep, 57 feet in gravel and 6 feet in rock. The water is clear and has a sp. gr. of 1·0005 at 15°C.

Temperature 8·3°C. (47°F).

Radioactivity, 123 units of emanation per litre.

No dissolved radium was found.

23. Well at the Cedars, Aylmer, property of F. G. Wait.

Activity 162 units per litre.

No dissolved radium was found.

6. Borthwick Mineral Spring.

This spring is situated in the south half of lot 20, concession IV, Ottawa Front, Gloucester township, Carleton county. The spring has been bricked up, and is enclosed in a wooden house. It lies in low lying marshy ground between two ridges. The flow is moderate and the well can easily be pumped dry. The capacity of the well is 3,000 gallons and it refills in about twelve hours. The water probably rises from the lower Silurian limestone. Temperature 10·5°C. It is mentioned by Sterry Hunt in Geology of Canada. (p. 537).

Total initial activity 140 units per litre. Dissolved radium 8·4 units per litre. From this we see that of the initial 140 units only 8 were due to dissolved radium; the 132 is just dissolved emanation.

13. Dominion Spring. Fitzroy township, Carleton county.

The spring is situated on the farm of W. Gillan. The spring has been known for many years and is mentioned by Sterry Hunt in Geology of Canada. It is stated that the water rises from the Chazy or Calciferous formation.

The well is 14 ft. deep and the flow is small. There is much hydrogen sulphide given off from the water and a turbidity due to precipitated sulphur soon arises when the water stands for a short time.

An analysis of the water has been made which shows that the principal constituent is sodium chloride. Temperature 10°C.

The initial activity is equivalent to 22 units per litre, and the radium in solution 0·8 units of radium per litre.

14. Diamond Park spring. Sanitaris Water.

Lot 26, concession XII, Pakenham township, Lanark Co.

This spring lies at the foot of a hill about 50 yards from the Madawaska river. It rises in a cemented and covered well, and flows at a rate of about 250 gallons per hour. The water has a pleasant salt taste and is sold as 'Sanitaris' water, by the Sanitaris Mineral Water Co., Arnprior, Ont. An analysis of this water has been made which shows the principal constituents to be sodium chloride, magnesium and calcium bicarbonates.

The initial activity is equivalent to 226 units per litre, and radium was found in solution to the extent of 1·7 units per litre.

This is one of the most radioactive springs that was found during the work, but on account of the small dissolved radium content the water, when bottled, will not retain its activity for many days.

15–20. Carlsbad Springs, Russell county, Ont.

Carlsbad mineral springs are about eight miles from Ottawa, on the Russell road. There are four springs of very different character in a very small area here. In this respect the group resembles the group at Caledonia Springs. The springs are owned by Mr. T. Boyd, who has erected a commodious sanitarium which is open during the summer months, and at which suitable provision is made for visitors to obtain hot sulphur baths and to drink the mineral waters.

Three of the springs, the White Sulphur, the Gas, and the Soda Water rise in wooden cased wells, the overflow running into a creek near by. The Magic Carlsbad water is pumped and comes from a depth of 240 feet. The Lithia water flows up around the pump casing from a vein 60 feet deep.

Particulars of the Carlsbad Springs are as follows:—

Name of Spring.	*Temp.*	*Flow.* gals. per hour.	*Emanation.* units per litre.	*Radium.* units per litre.
Soda Water....................	9°C	120	81	1·1
Magic..........................	9° „		87	25
Lithia..........................	8·9° „	400	70	3·1
Gas............................	12° „	50	not tested	
White Sulphur.................	8·9° „	400	90	0·8

It is of interest to note that the water from the greatest depth contains the largest amount of radium.

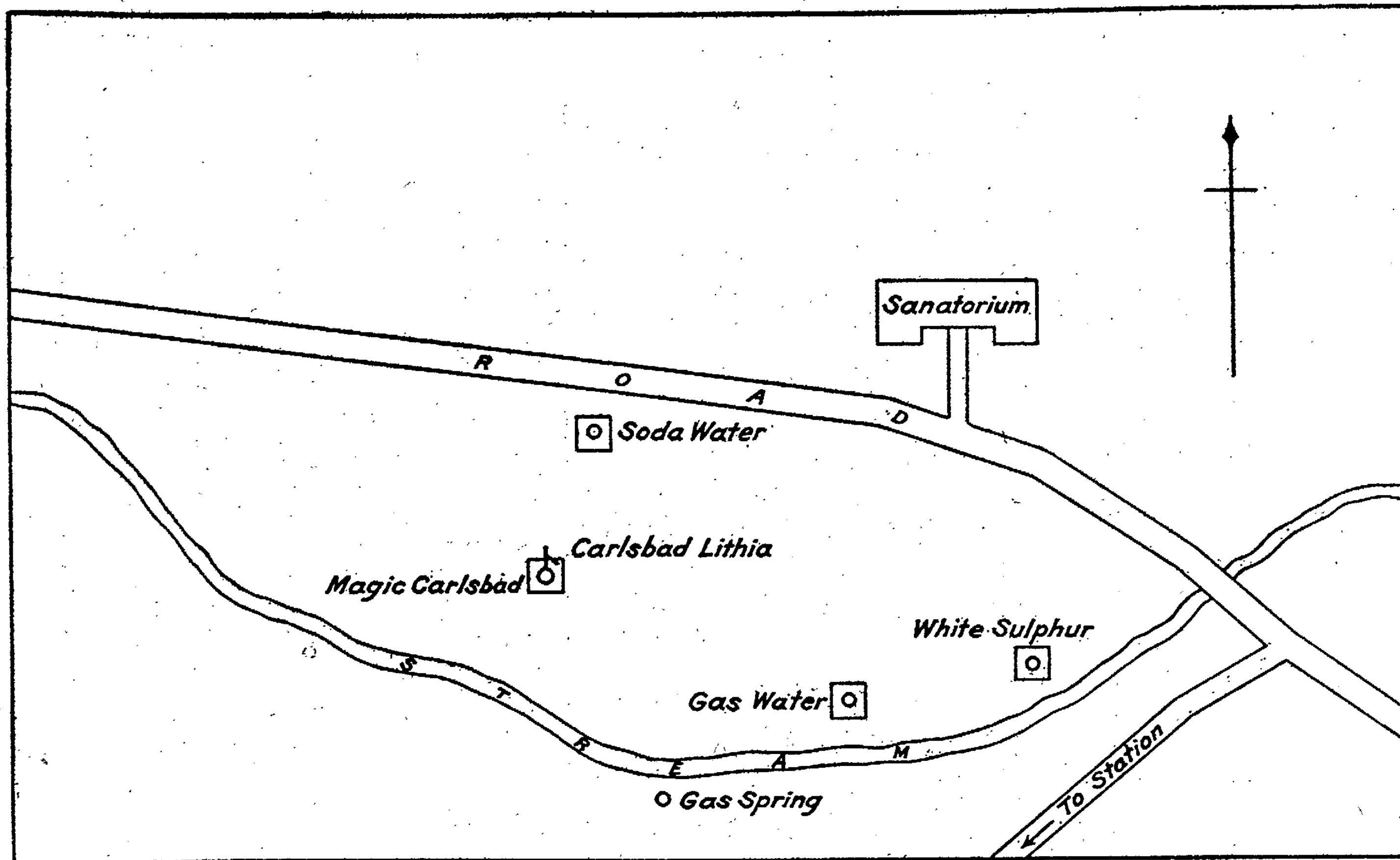
Gas is evolved from the springs in fairly large quantity.

Analysis showed it to be 91·7% Methane.
0·6 „ Carbon dioxide.
0·8 „ Oxygen.
6·9 „ Nitrogen.

The nitrogen probably contains traces of helium but no examination for it has been made. The activity of the gas was found to be equivalent to 230 units per litre.

17 and 18. Springs at Bourget, Clarence township, Russell county.

The Russell Lithia Co. own two springs on lot 20, concession II. Both were drilled, and one has a considerable flow, about 800 gallons per hour. This spring which issues from a one inch stand pipe, has a temperature of 8·6°C. It is fairly strongly mineralized, having a specific gravity of



Sketch plan of Carlsbad Springs

Fig. 3.

1·0065 at 15°C. and is saline to the taste. Much gas issues with the water and also from pools in the swamp around the spring. This gas consists chiefly of methane and possesses an activity of 540 units per litre. The initial activity of the water is equivalent to 56 units per litre, and the radium content 5·9 units per litre.

The second spring is some 200 yards away and is the source of the Russell Lithia Water. The water is pumped to a tank in the bottling house near by. It has a saline taste and its specific gravity is 1·0038. It was found to possess an activity equivalent to 10·9 units per litre. Several other springs are found in the neighbourhood of very similar character to the two investigated. Two were inspected on the farm of A. Martel, about 2 miles away from the Russell Lithia Springs. One was 96 feet and the other 136 feet deep. Both were bored wells with a natural flow. The water had a pleasant saline taste.

No radioactive examination has been made of these.

Natural gas has been found in the vicinity.

30. Adanac Spring, Bourget.

This is a fresh water spring owned by the Caledonia Springs Mineral Water Co. It was discovered during the construction of a cutting on the neighbouring railway. A substantial house has been built, and the spring enclosed in a large white tiled well. The water has a flow of about 50-60 gallons per hour, and is almost a pure water. It contains no traces of hydrogen sulphide and no gases are evolved from it. Its temperature is 10·3°C. Most of the high land in the neighbourhood is of a sandy nature and probably the water is a surface water perfectly filtered by the sandy soil.

Its radioactivity was 202 units per litre, which is large in comparison with other springs in the neighbourhood. The radium content of the water was found to be 0·3 unit per litre.

22. Victoria Sulphur Spring, Carleton county, Ont.

This is a disused spring on Green's creek, two miles from Ottawa near the Montreal road. It is situated on the bank of the creek and flows at the rate of 250 gallons per hour. A considerable quantity of hydrogen sulphide is contained in the gas given off from the water, accounting for the sulphur deposit around the spring. Temperature 9·2°C. Specific Gravity 1·004 at 15°C. The initial activity of the water was 112 units per litre.

Only a trace of radium was found in solution.

The gas evolved is principally methane and was found to have an activity equivalent to 800 units per litre. Water from this spring was once in great demand, and a sanitarium built on the site had some repute, but it is now in ruins and the spring is disused.

25–29. The Caledonia Springs, Prescott county, Ontario.

These springs are probably the best known in Canada, and with the exception of the work of R. W. Boyle and D. McIntosh on the springs at Banff and Fairmont, are the only ones that have been the subject of any radioactive examination previous to this investigation, Professor A. S. Eve of McGill University having made measurements of their radioactivity in 1907.

Chemical analyses have been made of these waters on at least three occasions, previously, in 1843 by Dr. James Williamson, in 1863 by Dr. Sterry Hunt of the Geological Survey, and in 1903-1907 by Professor R. F. Ruttan, of McGill University, who made an exhaustive report on the springs for the Caledonia Springs Mineral Water Co. We are indebted to the Company for the assistance they have given in providing laboratory accommodation at the bottling plant at Caledonia Springs, and in putting Professor Ruttan's report at our disposal. An excellent hotel, managed by the Canadian Pacific Railway, is situated close to the springs, and usually many guests are to be found taking a 'cure'. The springs enjoy a wide reputation for their beneficial effects.

According to Sterry Hunt the waters issue from the Trenton limestone formation.

Five springs belonging to the Caledonia Springs Mineral Water Co. were investigated: the *Duncan spring*, situated about two miles from the hotel; the *Gas spring* and the *Saline spring*, situated near the hotel, and some 50 yards apart; the *White Sulphur spring* which issues only a few feet from the Saline water; and the *Artesian Sulphur* water which rises from a bored well at some distance from the hotel, across the railway track.

The Duncan spring has a flow of about 180 gallons per hour and a temperature of 9°C. The water is less pleasant to the taste than the other Caledonia waters, due to the relative preponderance of magnesium salts and it has a distinctly purgative effect. The radioactivity was found to be equivalent to 53 units per litre, on August 2, 1914, and radium content 5·6 units per litre.

A considerable amount of gas issues with the water from the pipe. Analysis of this in 1903 by Professor Ruttan gave:—

Methane	86·00%
Ethane and heavy hydrocarbons	0·77 „
Carbon monoxide	1·05 „
Carbon dioxide	0·69 „
Nitrogen	11·46 „
Rare gases, argon with traces of helium	0·02 „

The value for the radioactivity of the gas was found to be 204 units per litre.

The Saline spring and the *White Sulphur spring* issue only a few feet apart. The sulphur water comes from a fissure in the rock and the saline from the junction of the clay and rock. A natural fault of 2 feet rises between these two springs at the junction of the clay and rock. Since the radioactivity measurements were made in 1914 the outlet of the two waters has been completely altered. White tiled partitions have now been built and the two waters are entirely separated.

The Saline water is bottled, and has an extensive sale under the name of 'Magi' Caledonia Water. The temperature of both Saline and Sulphur springs was found to be 8·3°C., the flow of the Saline about 160 gallons per hour, and of the White Sulphur 250 gallons per hour. The radioactivity of the saline was found to be equivalent to 70 units per litre, while that of the Sulphur was 73 units per litre. Both were found to contain, at the time of collection of a sample, 5·6 units of dissolved radium per litre.

The Gas spring water, some 50 yards away, resembles the Saline water in chemical composition, though the flow is slightly less, being about 150 gallons per hour in August, 1914. The temperature was 7·9°C.

The radioactivity is slightly higher than the two previous waters, the result being equivalent to 90 units per litre.

Gas evolved from the Gas spring had an activity due to 306 units per litre.

Analysis of the gas by Ruttan gave:—

Methane	63·10%
Ethane	0·74 „
Carbon monoxide	1·00 „
Carbon dioxide	0·80 „
Nitrogen	33·60 „

The water level had to be lowered by pumping off water before much gas was evolved.

The Artesian Sulphur water is rather different to any of the previous waters. The well is bored to a depth of 168 feet—the first 68 feet being in clay. No water was found at the junction of the rock and clay. The water carries less mineral matter in solution than any of the others, and the alkalinity is high.

There is a considerable amount of hydrogen sulphide in the water, much more than in any of the others. This water is pumped across to the hotel and used for the sulphur baths.

The radioactivity was found to be equivalent to 56 units per litre, and the radium in solution 1·7 units per litre.

Marsh Gas at Caledonia Springs.

For the sake of comparison a sample of marsh gas was collected from the bed of the creek flowing near the bottling plant and tested for its radioactivity which was found to be 1,130 units per litre.

It is interesting to compare the results obtained for the radioactivity of the waters and gases with those obtained by Prof. Eve in 1907. (Transactions Roy. Soc. Can. 1910, sec. iii-53).

Radioactivity of Caledonia Springs, Ontario.

	Radioactivity of				Dissolved radium in water, units.	
	Water, units.		Gas, units.			
	1907	*1914*	*1907*	*1914*	*1907*	*1914*
Duncan spring....	—	53	420	204	18	5·6
Saline spring.....	—	70	210	—	14	5·6
Gas spring.......	—	90	620	306	15	8·4
White Sulphur spring.........	—	73	—	—	15	5·6
Artesian Sulphur spring.........	—	56	—	—	10	1·7

The waters contain very little radium in solution.

Their radioactive properties therefore will soon disappear after bottling. The small amounts of radium present will of course generate some emanation, which may not be too small to have beneficial results if sufficient water is taken.

33 and 34. Gurd's Saline Wells, Caledonia Springs.

Two wells owned by Charles Gurd and Co., of Montreal, were investigated. These wells are situated some 250 yards from the main group of the Caledonia Springs and the water from them is more saline.

The two wells, 20 feet apart, are both 68 feet deep, sunk through clay to the rock. The temperature of each is 8·8°C.

No hydrogen sulphide is present in the waters. Barrel loads are taken to the bottling plant in Montreal each week, from the less saline well. The activity of the less saline water was found to be 50 units per litre, and radium in solution 0·8 unit per litre, while initial activity of the strong saline was also 50 units per litre. Both these springs probably rise from the same formation as the other Caledonia Springs.

31. Plantagenet Mineral Spring, Prescott county, Ont.

This is an old spring mentioned by Sterry Hunt in Geology of Canada, p. 541. He supposes it to come from the Lower Silurian formation. The spring is close to Plantagenet Station. The water is strongly saline and is little used at present. The flow is small, about 10 gallons per hour. The temperature is 8·5°C. The well is sunk 14 feet down to rock. The initial emanation content was 104 units per litre.

32. Spring at Alfred, Alfred township, Prescott county.

This is a fresh water, probably the result of surface filtration through local sandy soil. The well is on the sloping side of a large plateau. It was opened up by the Caledonia Springs Mineral Water Co. in 1913. The flow varies considerably with the season of the year. Temperature 6·5°C. Emanation content 185 units per litre.

MONTREAL WELL WATERS.

35. Guaranteed Pure Milk Company's Well, St. Catherine st., West.

The well is 151 feet deep, and the water flows naturally with a head of 15 feet. It is pumped, however, and has a flow of about 3,500 gallons per hour. The temperature is 10·5°C.

The water contains a high proportion of calcium bicarbonate, resembling several other waters in this part of the city. An analysis has been made. The water contains 429 parts per million of mineral matter. The radioactivity was found to be 176 units per litre. No radium was found in solution.

36. Laurentian Spring Water.

Messrs. Robert White and Company, 208 Craig street.

The well is 457 feet deep. Water was struck at 250 feet and again at 450 feet, and the combined capacity is 20,000 gallons per hour when pumped by an air lift pump with air at a pressure of 100 pounds per square inch.

The temperature was found to be 12°C. Analysis of the Laurentian water shows it to contain very small amounts of calcium and magnesium, bicarbonates, and large proportions of sodium salts, which make it a very suitable drinking water. The water probably rises from the Trenton limestone, though a well near by on the same property seems to obtain its water from a shale bed which occurs interstratified with the Trenton limestone. The initial radioactivity was found to be 5·6 units per litre. Probably this is low on account of the method of pumping. No examination for radium in solution has been made.

37. Well at 112 Beaudry street, Montreal, the property of Charles Gurd, Esq.

The well is 318 feet deep. Water was struck at the bottom and rises to 50 feet from the surface. The well had stood idle for some months, but previous to the collection of a sample, the pump had been working for four hours, ensuring a fresh sample. The flow was found to be 400 gallons per hour.

An analysis has been made and shows the water to contain almost equal amounts of sodium chloride, calcium and magnesium bicarbonates. The radioactivity was found to be equivalent to 62 units per litre. No radium in solution was found.

38 and 39. Two springs flowing in the C.N.R. tunnel under Mount Royal, Montreal.

An opportunity was taken to collect samples from two of the most strongly flowing springs that had been opened up during the boring of the C.N.R. tunnel.

The first of these was 1,300 feet west of Maplewood Avenue shaft, 225 feet below the surface. The water issues from a crevice about 2 feet from the floor of the tunnel, and flowed at a rate of 120 gallons per hour. The rock here was almost pure limestone. No analysis has been made of the water, though water from a well near by contained much calcium carbonate and sulphate. Temperature, 8·5°C. The activity was found to be equivalent to 300 units per litre.

The second spring is 3,100 feet southeast of the Maplewood Avenue shaft, and dripped from a crack in the roof at a rate of about 25 gallons an hour. The temperature was 9·7°C. The rock was essexite, a plutonic rock, composed essentially of plagioclase, feldspar, augite, and hornblende. The activity was found to be 126 units per litre.

No tests for dissolved radium were made on these two samples.

40. Brandram-Henderson Co. well, Mile End.

All the water was struck at 500 feet, and the well is 510 feet deep. The supply is about 5,000 gallons an hour. The natural level of the water is 18 feet below the surface, but on heavy pumping it is lowered to 26 feet. The water contains chiefly calcium carbonate and sodium sulphate, and is rather hard. It contains some hydrogen sulphide. The initial radioactivity was 154 units per litre, but it contains no radium in solution.

41. Canada Bread Company's well, 611 Rivard Street.

The well is 508 feet deep, and will supply 3,000 gallons of water per hour. The chief constituents of the water are sodium chloride, sodium sulphate, and calcium carbonate.

The initial emanation content was 75 units per litre.

No radium in solution was detected.

43. Watson Foster Company's well, Maisonneuve.

The well is 750 feet deep, and is pumped into a large storage tank. No estimate of the flow was obtained. An analysis of the water has been made, and it shows the chief constituents to be alkaline bicarbonates, and that it possesses a mineral content of 1,500 parts per million. The initial radioactivity was found to be 42 units per litre. No radium in solution was detected.

46. Mount Bruno Floral Company's well.

This well is situated at St. Bruno, Chambly county, Que. It was drilled by Wallace Bell, who gives the log of the well as follows: 22 feet to bed-rock, then 384 feet in hard rock, probably Hudson River or Utica shale.

The water is unsuitable for watering purposes. It has a slightly flat taste due to its high magnesium content.

The flow is not known, but there is a plentiful supply. An analysis has been made of the water showing that it contains predominant quantities of sodium chloride and bicarbonate. Temperature 8·9°C. No radium in solution was indicated. Activity 100 units of emanation per litre of water.

47. Mount Royal Cemetery well.

This well, 354 feet deep, is drilled in the igneous mass of the mountain.

The water rises to the surface in wet weather and the flow varies much. The temperature was 11·6°C., when the sample was collected on August 27, 1914. The activity was 66 units per litre. No test has been made for dissolved radium.

50. Bluebonnets Race Course well, Montreal Jockey Club.

The well examined is 203 feet deep and yields water at the rate of 132,000 gallons a day. The temperature was 8·3°C.

The well penetrates the solid rock for a few feet. An analysis has been made which shows the water to contain almost equal amounts of alkali chlorides and bicarbonates, and alkaline earth bicarbonates. The activity was found to be 25 units per litre. It contains no radium in solution.

51. College St. Laurent, St. Laurent.

The well is 487 feet deep. In boring, the drill first passed through 31 feet of hard-pan, and then through 465 feet of limestone. The normal level of the water is 13 feet below the surface. The capacity of the well is not known, but it easily yields 10,000 gallons a day. No analysis has been made, though the water is said to contain small amounts of lime and magnesia.

Temperature 9·5°C. Activity 140 units per litre. No radium in solution was detected.

Montreal City water and Ottawa River water.

During the work a sample of water was taken from the supply pipe in one of the laboratories in the Macdonald Physics Building, McGill University.

The emanation content was found to be 2·5 units per litre. No estimation of radium in solution has been made, though a test by Professor Eve[1] in 1909 gave $0{\cdot}25 \times 10^{-12}$ grams of radium per litre. At the same time he obtained an average result of 0·9 unit of radium per litre of sea water, as a result of testing six samples of water taken from the Atlantic ocean.

Dr. J. Satterly working on samples of water obtained from various points on the sea coast of England found 1 unit radium per litre for the content of sea water, a result closely agreeing with Professor Eve's. Prof.

[1]A. S. Eve, Phil. Mag., July, 1909, p. 102.

Joly, of Dublin, has obtained similar results. A test on a sample of water taken on July 28, 1914, from the Ottawa river above the Chaudiere falls, gave 14 units per litre for the initial emanation content, but no trace of radium in solution could be detected.

42. Viauville Mineral Spring, Maisonneuve.

The water from this spring is bottled and sold under the name of Radium Water.

The boring was made in the hope of striking natural gas.

Good water was met with at 450 feet, which rose to within 10 feet of the surface. Drilling was continued to 1,190 feet when water containing much hydrogen sulphide gas was struck, which rose to the surface and flowed at a rate of 5,000 gallons in 24 hours. The final depth reached was 1,500 feet and the only rock met with was Trenton limestone.

The bottled water has a salt taste due to the comparatively large amount of sodium chloride present, but when tasted at the spring the odour and flavor of hydrogen sulphide, giving the peculiar "rotten egg" taste, are predominant. No other spring water was found which contained as much as this, 460 parts of hydrogen sulphide per million by weight or 30·5 c.c. per litre (8·5 cu. ins. per gallon) being found.

An analysis of the water shows that it is strongly mineralized and contains principally sodium chloride and sodium sulphate.

The temperature was 12·5°C. when the spring was visited on August 21, 1914. The radioactivity was found to be equivalent to 11·0 units per litre. No radium in solution was detected. These results agree with those of Dr. McIntosh of McGill University, who found about as much radium emanation present as is found in ordinary St. Lawrence water.

44 and 45. Abenakis Springs, St. François du Lac, Yamaska co., Que.

A first class health resort has been established at Abenakis Springs under the management of Mr. W. E. Watt. There are three springs rising from drill holes in a flat marshy plain a little distance from the steeply sloping side of higher ground running parallel to the St. Francis river.

There are two summer houses about 100 yards apart. In the West House one pipe goes down for 12 feet from which water is pumped. Another boring three feet away is sunk 60 feet and flows naturally, at a rate of 60 gallons an hour. When the well was first drilled the pressure was sufficient to raise the water 20 feet from the ground.

In the East House another spring 12 feet deep has a flow of 1 gallon per minute.

The temperatures of all three were found to be 9°C. when inspection was made on August 24, 1914.

The West House running spring gave a value for its total activity equivalent to 134 units per litre; while the one in the East House, only one-fifth as deep, gave 62 units per litre. The dissolved radium content of each was found to be 0·5 unit radium per litre. The waters are saline in character containing approximately 10,000 parts per million of sodium chloride, and one-tenth as much magnesium chloride.

48. Varennes Springs, Varennes township, Vercheres co., Quebec.

There are two springs situated about 1 mile north of the village of Varennes, and about 500 yards from the right bank of the St. Lawrence river. They were examined by Sterry Hunt in 1863, who stated that the water comes from the Utica or Hudson River formation.

They are the property of Messrs. Charles Gurd and Co., of Montreal, but at the time of visiting the water was seldom bottled. The spring investigated rises in a 30-inch earthenware pipe and the well so made is about 10 or 12 feet deep. The flow was found to be 180 gallons per hour on August 28, 1914. There is a considerable evolution of gas, chiefly methane, from the spring. The radium emanation content of it was found to be 810 units per litre.

The temperature of the water was 8·6°C., and the measurement of the radioactivity gave a value equivalent to 224 units per litre. Radium in solution was found to the amount of 9·2 units radium per litre.

This is one of the richest springs investigated during the work, as regards its total emanation content. The chief chemical constituents of the water are a considerable amount of alkaline chlorides, and a less amount of calcium and magnesium bicarbonates.

49. Richelieu Spring, Grand Coteau, Chambly Basin, Que.

This spring, owned by Mr. George Tetreau of Montreal, had been newly cleaned up, and a cement pit 5 feet diameter × 15 feet deep, constructed. A pump, with a silver-lined block tin pipe, had been fitted up. The water was 8 feet deep at the time of our examination on August 29, 1914, and, therefore, the volume of the water was about 3,000 gallons. After being pumped nearly dry the well takes 2 days to refill.

The spring is situated about 100 yards in front of a ridge 40-50 feet high, and the ground gradually slopes to the Richelieu river. Below the spring house the ground is marshy. Sterry Hunt states that the water rises from the Hudson River formation.

The temperature was 9·4°C. The emanation content is 104 units per litre. No radium in solution was found. An analysis has been made and shows the water to be a saline water of pleasant taste containing chiefly sodium chloride and bicarbonate, together with some magnesium bicarbonate.

52. Spring at Radnor Forges, Champlain co., Que.

The water from this spring is bottled by the Radnor Water Co., as "Radnor" mineral water. It is situated close to the Radnor Forges iron works. The water rises in a pipe 6 inches diameter, which is sunk 12 feet in the rock, and is piped across a creek to the bottling works. There is a steady flow of 1,500 gallons per hour. The temperature was 7·5°C. This is one of the most active waters found during the work, giving a value for the total emanation equal to 345 units per litre. Radium in solution is present to an extent of 0·3 unit radium per litre.

The water has a pleasant, slightly saline taste, and is a very satisfactory mineral water for bottling purposes, though the small dissolved radium content would not give the water any value from a therapeutic point of view.

53. Spring at St. Leon, Maskinonge county, Que.

This spring belongs to the St. Leon Mineral Water Co. of Toronto, but of late years no water has been bottled. The water rises in a well about eight feet square, near the ruins of a once flourishing sanitarium. It is about 20 feet from the Rivière-du-Loup, into which the overflow of 100 gallons an hour empties.

Much gas is evolved from the water, and its activity was found to be equivalent to 140 units per litre. Sterry Hunt gives the formation from which the water issues to be Hudson River or Lower Silurian.

The emanation content of the water was 39 units per litre at the time of collection—(Sept. 9, 1914)—and the radium in solution in the sample collected was 2·2 units radium per litre. Analysis shows that the water is strongly mineralized, and that the chief constituents are chlorides and bicarbonates of sodium, calcium, and magnesium.

54. Potton Spring, Potton township, Brome co., Que.

The spring flows from a crevice in the rock of the hillside. A sanitarium has been built near the spring, and numerous visitors go to take the cure. The spring and hotel are the property of Mr. J. A. Wright. An analysis has been made of the water, showing it to be slightly mineralized, containing only 135 parts per million of mineral matter. Calcium, magnesium, and sodium bicarbonates may be considered the chief constituents. Some hydrogen sulphide is present, giving the water a very noticeable taste. The activity was found to be 280 units per litre, for a sample collected on Sept. 8, 1914. No trace of radium in solution was detected.

55 and 56. Springs at St. Hyacinthe, St. Hyacinthe county, Que.

Two springs in the neighbourhood of St. Hyacinthe were investigated, one on the farm of Napoleon Solis, in the parish of St. Hyacinthe le Confesseur, the water of which is bottled by the St. Hyacinthe Mineral Water

Co., under the name "Philudor" water, and the second at the village of La Providence, on the farm of the Sisters of La Metairie. The water from this second spring is not used.

'Philudor' Spring.

This spring lies close to a creek at the foot of a steep slope. A pipe goes down 28 feet in a boring drilled 20 years ago. There is a slight natural flow into a wooden trough at the rate of 35 gallons per hour. At the time of inspection—September 9, 1914—the water had a temperature of 8·3°C., and was slightly salt to the taste, and contained a little hydrogen sulphide gas in solution. There was another spring about 50 yards away, drilled to a similar depth, having a slightly greater flow. No measurements were made. The radioactivity of the Philudor water was due to 106 units of emanation per litre, and the radium in solution amounted to 46 units radium per litre. The chemical analysis shows the water to be a saline water, containing chiefly sodium chloride and sodium bicarbonate.

The other spring, at the village of La Providence, is in a very similar situation, at the foot of a slope. It is enclosed in a wooden casing, and the water is 10 feet deep. The flow is not great, only about 10 gallons an hour. A small amount of gas is given off, the emanation content of which was 540 units per litre. The temperature registered was 9·4°C. The initial radioactivity of the water was equivalent to 112 units per litre. An analysis has been made of the water collected, and the results show that it is an alkaline-saline water, containing, chiefly, sodium bicarbonate and sodium chloride.

57. St. Leon, Maskinonge county, Que.

This spring is on the farm of Mr. B. Lupien, and water from it was bottled at the time of inspection by Mr. J. C. Rousseau of Three Rivers, as St. Leon Mineral Water. It is one mile farther up the Rivière-du-Loup than the old St. Leon spring. The water rises from the Hudson River or Lower Silurian formations. There are two springs, 15 feet apart, and close to the river bank. The larger one has a wooden tub 3 feet diameter, surrounding it, and a pump is fitted. The well is 12 feet deep, and water from it is shipped away. The natural flow is small, about 30 gallons an hour. The temperature was 8·4°C. It was found to contain emanation equivalent to 148 units per litre, and radium in solution to the extent of 0·8 unit radium per litre. Chemical analysis shows the water to be strongly mineralized, with sodium chloride as the predominating constituent.

Gas is given off, consisting chiefly of methane, the emanation content per litre of which was 460 units.

58. Spring at St. Severe, St. Severe township, St. Maurice co., Quebec.

This is the "Aetna" spring giving "Divina" mineral water, owned by Mr. J. I. Lemyre of Three Rivers. The spring, which is enclosed by a cement well 4 feet diameter x 24 feet deep, was in a hollow close to the Rivière-du-Loup, on the farm of Mr. A. LaCerte.

The water is very saline to the taste, and seems to have a small flow. The temperature was 8·3°C., and the activity at the time of inspection was equivalent to 87 units per litre. Radium in solution was found to an extent of 2·8 units radium per litre. An analysis has been made showing sodium chloride to be the chief constituent, together with magnesium chloride and bicarbonate.

59. Spring at Ste. Genevieve de Batiscan, Que.

This spring of strongly saline water was struck at a depth of 200 feet when drilling for fresh water. It is situated on the right bank of the Batiscan river, just above the bridge leading across to the village. The water is bottled by D. Veillet and Co. under the name of "Star" mineral water. Salt is also obtained by evaporation of the water, 8 gallons of which give 1 pound of salt.

Much gas is given off, collected in a tank over the well, and used to run a gas engine in the bottling works. Analysis of the gas showed it to be chiefly methane. Sterry Hunt states that the water comes from the Lower Silurian formation.

The flow from the well was 500 gallons an hour, and the temperature 8·3°C., when the spring was visited on September 12, 1914.

Its activity was found to be equivalent to 145 units per litre, and the radium in solution was 0·8 unit radium per litre. The water contains 29,000 parts of mineral matter per million parts of water, over 23,000 of which consist of sodium chloride.

60 and 61. Springs at Ste. Agathe, Que.

Two springs at Ste. Agathe were next investigated; the first rising at the side of the road near Lake Castor. This water had a temperature of 11°C., and was just a surface water with a flow of some 20 gallons an hour. Emanation found was equal to 193 units per litre. The second spring was also a surface spring a mile farther along the road, and gave a result of 25 units per litre for its total activity.

No measurements of dissolved radium nor analyses have been made of these waters.

62. Spring at Berthier, Berthier co., Quebec.

This was one of the most interesting springs visited, from the point of view of its situation. It is at Fernierville and rises in the middle of the River Bayonne. A wooden tub surrounds it, and there is a considerable evolution of gas with the water, which appears to be entirely free from admixture with the river water. The water had a saline taste and showed a temperature of 8°C., the temperature of the river flowing around it being 16°C.

Gas analysis showed the gas to be chiefly methane. It contained emanation to the extent of 450 units per litre. The flow of the spring is 250 gallons per hour, and the water contained emanation corresponding to 112 units per litre. A trace of radium in solution was found. The spring is mentioned by Sterry Hunt, who made analysis in 1863. He states that the water comes from the Lower Silurian formation.

The strange situation of the spring is the result of a landslide in 1904 when the course of the river was changed. In spring and winter, the spring is covered up by the depth of river water. Only in summer is the source apparent. Analysis showed the water to contain chiefly sodium chloride and bicarbonate, together with some magnesium bicarbonate.

63. Spring near Maskinonge, Maskinonge co., Quebec.

This spring is in a natural state, and was discovered by Mr. J. I. Lemyre of Three Rivers in 1912. The spring is at the foot of a steep slope, and about 40 yards from the right bank of the River Maskinonge. The pool was about 5 feet diameter, and there was a considerable evolution of gas when it was visited on September 16, 1914. The water had a pleasantly saline taste, resembling the "Magi" Caledonia water.

The temperature was found to be 8°C., while that of the river, near by, was 15°C.

An analysis of the water showed that it contains alkaline chloride in large amounts, also bicarbonates of sodium, magnesium, and calcium. The total emanation was found to be equivalent to 79 units per litre, while radium to an extent of 0·5 unit per litre was found in solution.

64. Spring at St. Benoit, Two Mountains county, Quebec.

The water rises in a large well in a small wooden house, and flows into a creek about 200 yards away. The surrounding country is flat. The well contains 8–9 feet of water, and is 6 feet square. No gas is given off.

The water has a pleasant, slightly saline taste, with a sweetish after-taste; and analysis shows that the water contains sodium chloride as the primary constituent together with magnesium chloride and calcium chloride. The temperature was found to be 10·6°C. when the well was visited on September 18, 1914.

The activity was low, only 25 units per litre.

No trace of dissolved radium was found.

The water is owned by Alfred Ferland, and is bottled by the Canadian Aerated Co., of Montreal. According to Sterry Hunt, the origin of the water is the Potsdam formation, (Geology of Canada 1863, p. 542), which is chiefly sand and gravel.

THE BANFF HOT SPRINGS, BANFF, ALBERTA.

At the request of the Dominion Parks Branch of the Department of the Interior, an investigation was made of the hot springs at Banff, in November and December, 1916. The examination was carried out in a similar manner to that of the springs investigated during 1914 in Ontario and Quebec, with some improvements due to the experience gained in the previous work.

A laboratory was temporarily fitted up in a room in the fire hall at Banff, where every convenience was found, and which possessed the great advantage of being in close proximity to the springs under examination. The usual measurements of total radioactivity were made, together with all necessary observations of temperature, rate of flow, etc. Samples of the gas evolved from the springs were collected both for analysis and for the estimation of their radioactive value. Water for chemical analysis, and for further examination for its dissolved radium content, was sent to Ottawa.

The hot springs at Banff are probably the best known springs in Canada.

Since their discovery in 1880, the Dominion Government, Dr. R. G. Brett, and the Canadian Pacific Railway, have each done much to develop them. Their medicinal value has been recognized, and a sanitarium, hospital, and swimming baths have been built in recent years.

Banff is situated in the chief national park in Canada—the Rocky Mountains Park—and is eighty miles from Calgary on the Canadian Pacific Railway. It is the chief tourist centre for the Rocky Mountains, and is the home of the Alpine Club of Canada. The celebrated Banff Springs Hotel is close to the town. Being on the main line of the C.P.R., from Vancouver to Montreal, and in the midst of the mountains, Banff is a favourite place for a break in the journey across Canada. Travellers from China, India, and Australia, are frequent visitors, besides the many American and Canadian tourists who make Banff their headquarters for excursions in the mountains. The hot swimming baths and natural basins, supplied with water from the springs, form one of the chief attractions. In winter the experience of swimming in pools of hot water surrounded by snow and ice and in view of the snow covered mountains is unique.

The accessibility of Banff, the beauty and grandeur of its surroundings, its exhilarating and healthful climate, the character and value of the hot springs, undoubtedly justify all expectations that Banff will eventually be the chief health and pleasure resort of Canada.

There are five principal springs at Banff. They are all situated on the northeastern slope of Sulphur mountain, and are situated on a line nearly parallel to the ridge. It is very probable that they rise through a fault in the limestone formation of the mountain.

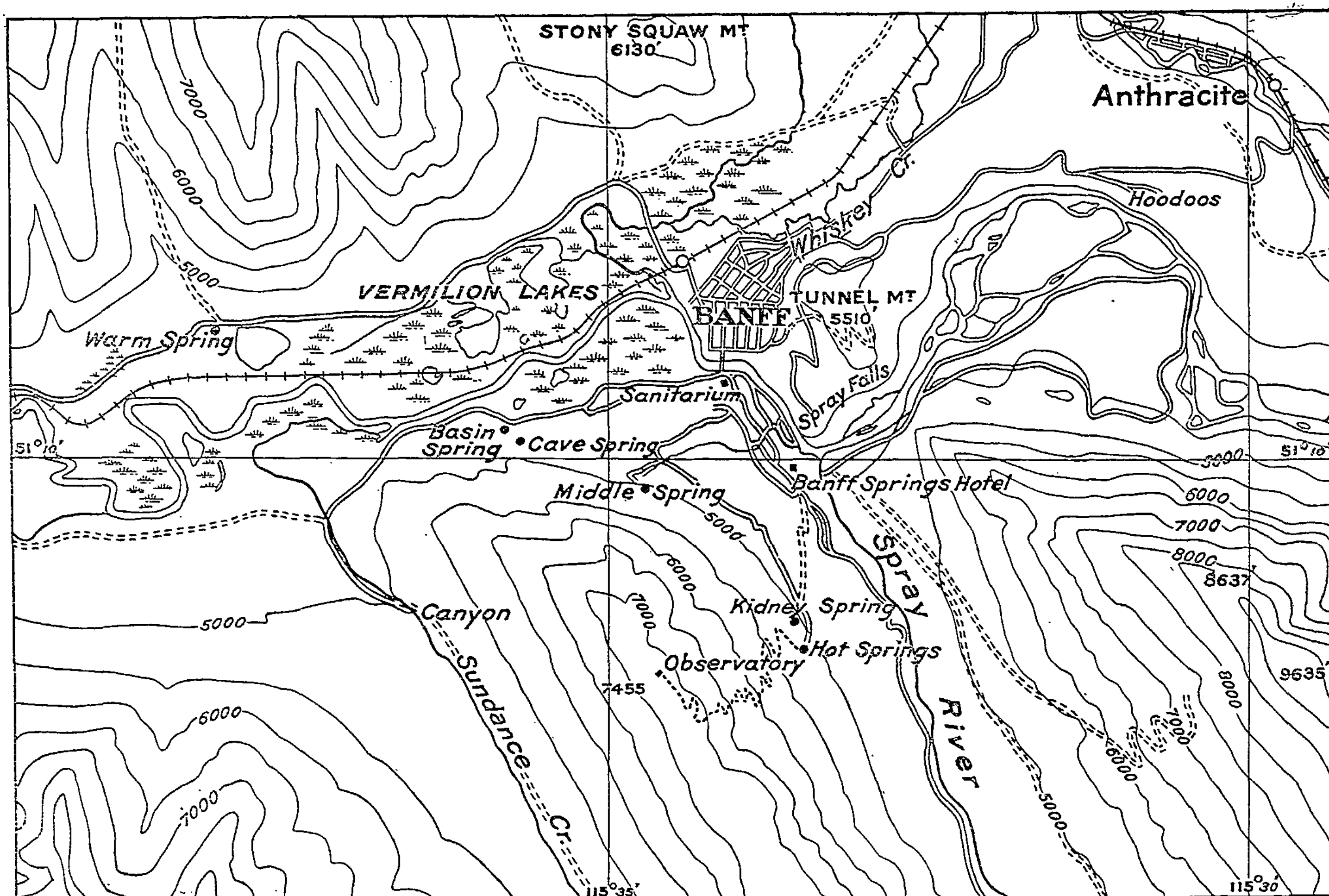


Fig. 4. Map of Banff, Alberta, showing location of hot springs. (Scale: 1 mile to 1 inch.)

The Upper Hot Spring is at the greatest altitude, being 5,000 feet above sea-level, and 500 feet above the valley. It is reached by a well constructed road winding up the pine-covered mountain side—a pleasant three-mile walk or drive from the town. There are private baths, and an open swimming pool supplied directly with hot water from the spring. A pipe three quarters of a mile in length conveys the water to the Banff Springs Hotel swimming bath, and to the Brett Hospital. The temperature of the water (114°F.), is a few degrees above that of the other springs, and the flow, though somewhat variable, is large, and always sufficient to supply the baths and swimming pools.

The Kidney Spring rises about 200 yards below the Hot Spring, and a little from the road up the mountain side. Its flow is comparatively small and no use is made of the water. It is at a slightly lower temperature than the Hot Spring.

The Middle Springs are situated a mile and a half northwest and lower down the mountain. They are reached by a road branching off from the Hot Springs road. These springs are still in their natural state; one rises in a pool inside a small cave, another, of greater volume, issues from under a rock at the mouth of the cave. The overflow after spreading into several pools runs into the Bow river. The waters of these springs are similar in properties to those of the Kidney and Upper Hot Springs.

The Cave and Basin Springs are the best known, as they are closer to the town, and have been developed to a greater extent. They are situated on the lower slope of Sulphur mountain and are a mile from Banff.

The Cave Spring is said to have been discovered by Canadian Pacific Railway surveyors in 1880. Noticing a cloud ascending from the hillside they made their way to the place and found steam issuing in large volume from a hole in the ground. Making a rough ladder of trees they descended through the hole and found themselves in a cave, the floor of which was a large pool of steaming hot water. This cave has been preserved, and a tunnel entrance has been constructed to give easier access. The pool has the form of a horse shoe and is about 30 feet across at its widest diameter, and four to five feet deep. The water can be seen bubbling up with great force through the sandy bottom in three or four places, and the overflow from the pool runs into the new swimming bath outside. The walls of the cave are thickly encrusted with crystals of gypsum.

The Basin Spring is at the other end of the swimming bath. It rises in a pool of elliptical shape approximately 40 feet long and 25 feet wide. The depth is from four to eight feet.

The influx of hot water through the floor of black sand is very distinct. One overflow enters the swimming bath, while another runs off at the opposite end of the pool.

The recently completed swimming bath is one of the finest open air baths in America. It is 200 feet long x 100 feet wide, with a depth varying from 4 to 8 feet. Certainly, no bath could have more magnificent surroundings. The walls on the two sides are of plate glass, allowing full view of the mountains and the Bow valley. The dressing rooms contain the latest conveniences and sanitary arrangements. The water, continually renewed by the overflow from the two springs, is at a temperature of about 75°F. Its colour, from a milky blue to a clear green, is very variable owing to the sulphur in suspension in the water.

Besides the five principal springs investigated, measurements of the radioactivity of two other springs in the neighbourhood were made.

One of these is a warm spring, three miles out of Banff, on the automobile road by the shore of Vermilion lake. It had a temperature of 19·4°C. when visited on December 13, 1916, and remains open all through the winter, affording an attractive watering place for the mountain sheep in the vicinity. It has a slight taste of hydrogen sulphide.

The second spring was a fresh-water spring, fifty yards behind the Alpine Club on the side of Sulphur mountain.

The flow was about 3,000 gallons per hour, and the temperature, 6·6°C., when it was examined in December, 1916. (The air temperature at the time was about −10°C.). The radioactivity is high like most fresh water springs of a similar nature.

The following data was obtained for the seven springs investigated at Banff:—

Spring.	Temp. Degrees C.	Temp. Degrees F.	Rate of flow gal. per hr.	Emanation in units per litre.	Dissolved Radium in units per l.	Activity of gas evolved units per l.
Upper Hot.......	46·0	115	8,000	221	8·6	
Kidney...........	39·0	101·5	1,200	392	8·5	
Middle...........	33·5	92	6,000	294	8·6	1,910
Cave.............	29·5	85	15,000	470	8·5	3,340
Basin............	34·5	94	10,000	232	8·5	2,370
Auto Road.......	19·4	67	6,000	640	23·5	
Alpine Club......	6·6	44	3,000	475	—	

The figures given for the rate of flow of the various springs are the results of rough measurements, and are only approximate. Little data has been collected with regard to variations, though, as might be expected, the flow usually seems smaller in the early part of the year.

The Gases Evolved from the Springs.

Considerable quantities of gas are given off from the Cave, Basin, and Middle Springs. The values of the radioactivity of the samples collected are given in the table. They show the gases to be the most radioactive of any yet examined in Canada. Analyses of the samples from each of the three springs are given, together with an analysis of the gas which is evolved from the King's Spring at Bath, England, which resembles the Banff gases. The gases contain an exceedingly high percentage of nitrogen. Ordinary air contains about 79%, whereas 98% of the Banff gases consists of nitrogen. The origin of the gases is probably air dissolved in the rain-water, which after penetrating thousands of feet of limestone rises to supply the springs. The oxygen of this air in its underground passage will be used up in oxidizing sulphides to sulphates, leaving the nitrogen, which is very inactive. The high percentage of nitrogen, and the comparatively high radioactivity, made it interesting to endeavour to determine the amount of the rare gases of the atmosphere present in the Banff gas. As a result of several experiments[1] it was found that there was 1·2% of argon, together with a trace of helium.

Analyses of the Banff Gases.

Constituent.	Cave Spring.	Middle Spring.	Basin Spring.	King's Spring, Bath, England.
Methane	0·11	0·15	0·19	—
Hydrogen	0·09	0·07	0·04	—
Oxygen	0·45	0·81	0·50	—
Carbon dioxide	1·11	1·18	1·34	3·60
Nitrogen } Argon and helium }	98·24	97·79		
Nitrogen			96·68	95·45
Argon and helium			1·25	0·95

Banff Springs are among the few springs that have been the subject of radioactive examination before this work of the Mines Branch was undertaken. In 1913, R. W. Boyle and D. McIntosh[2] carried out some work on springs at Banff, Fairmont, and Sinclair.

Their results are published as follows:—

	Total Emanation.	Radium.
	units	units
Fairmont	3,500	100
Sinclair	4,000	trace
Banff	?	trace

There is nothing to show which spring at Banff was investigated. The agreement between these results and those obtained in this work is not very close.

It is interesting to compare the results obtained by Schlundt and Moore[3] working on hot springs in the Yellowstone Park in 1905, with those of the Banff waters.

[1] Elworthy, R. T. Trans. Roy. Soc. Can. 11. Sec. iii., 1917.
[2] Trans. Roy. Soc. Can. 7, Sec. iii, 1913, p. 163.
[3] H. Schlundt and R. Moore, Bul. 395, U.S. Geol. Sur

The waters of the Yellowstone Park springs, U.S.A., have been divided into three classes:—

(1) Calcareous waters, carrying relatively large quantities of calcium carbonate in solution.

(2) Siliceous acid waters, which usually carry free acid in solution, and possess an astrigent taste.

(3) Siliceous alkaline waters.

Of these three classes, the Banff waters most nearly correspond to the first, though they differ to the extent that, the chief acid ion is the sulphate ion, instead of the carbonate ion; that is, the Banff waters contain principally calcium sulphate. They also carry less mineral matter in solution. The chief calcareous waters in the Yellowstone Park are the Mammoth Hot Springs. Comparing the values obtained for springs of this group, it is seen that much lower results were obtained for the radioactivity of gases evolved than were found in the case of the Banff springs. The total radioactivity of the springs varied considerably from 1,600 $\times$ 10^{-12} curies per litre to negative results, though several of them—Dedolph Spring, Cold Spring, and Soda Spring—agree very closely with the values obtained for the Banff springs.

The temperatures of the Yellowstone Park springs are in most cases considerably higher. The Mammoth Hot Springs are considered to pass through Jurassic and Cretaceous limestone while the Banff waters rise[1] in an earlier formation, the Intermediate limestone of the Devonian period.

Yellowstone and Banff Springs: Some Comparative Results.

Name.	Temp. °C.	Activities of gas curies $\times 10^{-12}$ per litre.	Total emanation curies $\times 10^{-12}$ per litre.
Mammoth Hot Springs, U.S.A.			
Hot River (1a)	51	——	1,610
Cleopatra	71	none	none
Hymen	71	none	trace
Squirrel	32	2,850	70
Soda	15·5	570	122
Banff Springs, Alberta.			
Upper Hot	46	——	221
Cave	29·5	3,340	470
Basin	34·5	2,370	232
Middle	33·5	1,910	294

[1] C. Camsell, Guide to the Geology of the Canadian National Parks, Department of Interior, 1914, p. 50.

Radioactivity of Well Waters Investigated.

No.	Well.	Temp. °C.	Depth in ft.	Flow gal. per hr.	Emanation units per litre.	Dissolved radium units per litre.	Dissolved solids parts per million.
1.	Y.M.C.A., Ottawa...	10·5	1,100	——	73	—	—
2.	Capital Brewery, Ottawa............	10·5	709	3,800	2·8	—	—
3.	City well, Dundonald Park..............	10·5	1,380	265	22	—	—
5.	City well, Elgin and Lewis Sts...........	9·5	900	300	50	—	450
7.	City well, Lloyd and Queen Sts..........	9·5	265	——	11	—	528
8.	City well, Rosemount Ave...............	9·8	203	2,400	11	0	890
12.	City well, Hopewell and Bank..........	11·0	398	1,440	70	—	—
4.	City well, Ottawa Dairy.............	15·0	812	2,500	1·4	0	—
10.	Hopper's well, Ottawa	9·0	385	small	109	0	—
11.	Tally Ho well........	11·0	265	——	81	0	—
21.	Westman's well, Britannia...........	8·2	57	——	123	0	—
23.	Mr. Wait's well, Aylmer...............	....	....	....	162	0	—
35.	Guaranteed Milk Co., Montreal...........	10·5	150	3,500	176	0	429
36.	Laurentian Spg. well, Montreal...........	12·0	450	4,500	5·6	—	—
37.	Gurd's well, Beaudry St., Montreal.......	10·5	390	360	62	0	1,202
40.	Brandram-Henderson, Montreal.......	9·6	510	2,000	154	0	550
41.	Canada Bread Co., Montreal...........	12·5	400	3,000	75	—	628
43.	Watson-Foster Co...	12·0	750	——	42	0	1,525
46.	Mount Bruno Floral Co................	8·9	406	——	100	0	1,976
47.	Mount Royal Cemetery..............	11·6		900	66	—	—
50.	Bluebonnets well....	8·3	108	80	25	0	432
51.	College St. Laurent, Montreal..........	9·2	487	400	140	0	—
24.	Ottawa river...... .	22·0	——	——	14	0	—
	Montreal tap water..	——	——	——	2·5	—	—

Radioactivity of the Springs Investigated in Canada.

No.	Location of Spring.	Temp. in degrees Centigrade.	Rate of flow gal. per hour.	Total mineral matter in solution. Parts per million.	Radium emanation in units of 10^{-12} curie per litre water	gas	Dissolved radium in units of 10^{-12} gm. per. litre.	Geological formation.
6	Borthwick, near Ottawa........	10·5	200	11,200	140	—	8·4	Lower Silurian
9	Hiawatha Park, near Ottawa.....	9·5	250	—	90	—		Calciferous
13	Gillans, Pakenham, Ont.........	10·0	—	9,272	22	—	0·8	Chazy or Calciferous
14	Sanitaris, Arnprior, Ont.........	9·0	260	4,814	226	—	1·7	Limestone
15	Carlsbad White Sulphur.........	8·9	300	3,210	90	—	0·8	Hudson River
16	„ Magic.................	9·1	—	20,618	87	—	25·0	„ „
19	„ Soda.................	8·9	120	1,394	81	230	1·1	„ „
20	„ Lithia................	9·0	400	4,886	70	—	3·1	„ „
17	Russell Lithia, Bourget, Ont.....	10·0	—	7,918	109	—	2·5	Utica Shale
18	„ „ „ „	8·6	700	—	56	—	5·9	„ „
22	Victoria Sulphur, Ottawa........	9·2	250	—	112	800	trace	Trenton limestone
25	Caledonia Saline...............	8·5	165	8,118	70	—	5·6	„ „
26	„ Sulphur..............	8·3	250	6,231	73	—	5·6	„ „
27	„ Gas..................	7·9	150	8,457	90	306	8·4	„ „
28	„ Duncan..............	9·0	180	10,009	53	204	5·6	„ „
29	„ Artesian Sulphur......	9·4	—	3,386	56	—	1·7	„ „
30	Adanac, Bourget, Ont...........	11·0	60	120	202	—	0·3	Surface
31	Plantagenet, Ont..............	8·5	10	—	104	—	—	Trenton limestone
32	Alfred, Ont....................	6·5	900	—	185	—	—	Surface
33	Caledonia Gurd's strong saline...	8·8	—	9,842	50	—	1·7	Trenton limestone
34	Caledonia Gurd's less saline......	8·7	—	5,384	50	—	0·8	„ „
38	C.N.R. Tunnel, Montreal Essexite	9·7	25	—	126	—	—	Essexite
39	C.N.R. Tunnel, Montreal Limestone.....................	8·5	12	—	300	—	—	Limestone
42	Viauville, Montreal............	12·5	1,500	10,111	11·2	—	—	„
44	Abenakis, East House, Que......	9·0	60	13,749	62	—	0·5	Hudson River
45	„ West House, Que......	9·0	80	14,116	134	—	0·5	„ „
48	Varennes, Quebec..............	8·6	180	11,634	224	810	9·2	Utica or Hudson R.
49	Chambly, Quebec..............	9·4	—	2,567	104	—	0·0	Utica
52	Radnor Forges, Quebec..........	9·5	1,500	1,888	345	—	0·3	Trenton limestone
53	St. Leon (old), Quebec..........	7·5	90	13,958	39	140	2·2	Hudson River or Utica
54	Potton, Brome co., Quebec.......	10·0	60	200	280	—	0·0	
55	St. Hyacinthe (Philudor)........	8·3	35	4,789	106	—	46	Hudson River
56	St. Hyacinthe (La Metairie) Que.	9·4	10	2,986	112	540	0·5	„ „
57	St. Leon (Lupien) Quebec........	8·3	30	13,746	148	460	0·8	„ „
58	St. Severe, Quebec..............	8·3	80	17,945	87	—	2·8	Utica Shale
59	St. Genevieve, Quebec...........	8·3	500	28,680	145	—	0·8	„ „
60	Ste. Agathe (Lake Castor), Quebec	11·0	20	—	193	—	—	
62	Berthier, Quebec...............	8·0	60	6,868	112	450	trace	Trenton limestone
63	Maskinonge, Quebec............	8·0	—	6,184	79	250	0·5	„ „
64	St. Benoit, Quebec..............	10·6	10	5,263	28	—	0·0	Potsdam
65	Upper Hot Spring, Banff.........	46·0	8,000	1,098	221	—	8·6	
66	Kidney spring, „	39·0	1,200	1,064	392	—	8·5	
67	Middle spring, „	33·5	6,000	1,059	294	1910	8·6	
68	Cave spring, „	29·5	15,000	1,017	470	3340	8·5	Intermediate
69	Basin spring, „	34·5	10,000	1,905	232	2370	8·5	Limestone
70	Auto Road spring, „	19·4	6,000	427	640	—	23·5	Devonian period
71	Alpine Club spring, „	6·6	3,000	441	475	—	—	

THE RADIOACTIVITY OF SPRINGS IN EUROPE AND AMERICA.

A considerable amount of research work has been done in Europe upon the radioactivity of mineral springs. The results obtained by the various observers are mostly expressed in uncertain units, particularly the mache unit, which depends in some measure on the instrument used, and, therefore, it is difficult to get such results into a suitable form for comparison. In this bulletin no attempt has been made to detail the numerous researches that have been carried out on many individual springs. Reference will only be made to a few groups of waters that have been investigated. A brief bibliography is given in Appendix I. Sir William Ramsay's report[1] on the radioactivity of the Bath Springs, England, undoubtedly gave much publicity to the fact that spring waters contained radioactive substances—although a considerable amount of work along similar lines had been done previously. Professor Schlundt and R. B. Moore measured the activity of many springs in Yellowstone National Park in 1906, publishing their results in Bulletin No. 395, U.S. Geol. Survey.

Dr. J. Satterly, in 1910 and 1911, did some work on river and well water at Cambridge, England.[2]

An investigation of the same nature as is outlined in this report was carried out on the Saratoga Springs, New York state, in 1914, by R. B. Moore and Whittemore.[3]

Only the Caledonia Springs, and three springs in the west, have been previously investigated in Canada: the Caledonia Springs by Prof. A. S. Eve,[4] in 1910, and springs at Banff, Fairmont, and Sinclair, by R. W. Boyle[5] and D. McIntosh, in 1913.

In all these cases, higher values were obtained than have been found in the course of this work.

In this investigation, some attempt has been made to correlate the radioactivity with the geological formation from which the spring rises. A recent Swedish paper[6] has taken up this question in a very complete manner and contains the following conclusions:—

A marked difference in the radioactive value was obtained between springs which issued from sedimentary formations and those from primary rocks, the latter being on an average five times as active.

Springs from sedimentary rocks gave an average value of 710 units per litre; those from shales 1,000 units per litre; while waters from sandstones gave values in the neighbourhood of 2,650 units per litre.

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[1] Chem. News, Mar. 22, 1912, p. 133.
[2] Satterly, Proc. Cam. Phil. Soc., Vol. XV, p. 542, Vol. XVI, Pt. IV.
[3] Jour. Ind. and Eng. Chem., July 1914, p. 552.
[4] A. S. Eve, Trans. Roy. Soc., Can. Sec. iii, 1910, p. 53.
[5] R. W. Boyle and D. McIntosh, Trans. Roy. Soc. Can. Sec. iii, 1913, p. 163.
[6] Sahlbohm Arkiv Kem. Min. Geol., 1916—6 Nos. 3-1-51. or J. C. S. Abs. ii 208, 1916.

The chemical composition of the rocks through which the water flowed had an effect, in that rocks with a normal lime and silica content have the greatest radioactivity, whereas a too high content of either lime or silica diminishes the radioactivity.

The Swedish spring waters were found to be more radioactive than other waters, indicating a relatively high radium content of the rocks and mountains.

A considerable amount of work has been carried out by D. Isitani, on Japanese mineral springs,[1] and the results have shown that they are very active, many of them giving values similar to springs at Joachimsthal in Austria, the most active known.

Variations found in the values of the radioactivity of springs at different times.

Some recent work by R. Ramsay[2] on two springs at Bloomington, Indiana, has shown a close agreement between flow and radioactivity. In the case of the Illinois Central Spring, which issues from coarse gravel, the flow ranged from 13,000 to 250,000 gallons a day, while the radioactivity varied from 20 to 800 units per litre. The activity was found to vary directly as the flow: the one rising and falling with the other almost identically. This is further proof that radioactivity of waters is due to the solution of radium emanation from the soil and rocks through which the water percolates. Water from springs of deep seated origin, however, which have a more or less constant flow, would be expected to give a more constant value for radioactivity. It is unfortunate that time has not permitted any work to be done on this question, especially as such good opportunity presents itself in the close proximity to Ottawa of some typical mineral springs.

The following list shows the values obtained for the radioactivity of various springs in different parts of the world. In most cases, only the emanation content, or total initial activity, has been measured. The Saratoga Springs group forms the most suitable standard to compare with the values found in this investigation.

[1] Proc. Tokyo Math. Physics. Soc. (2) 6,1912, (2) 7,1913, Jour. Ind. Eng. Chem., 1915, p. 1081.

[2] Phil. Mag. 30, p. 815, 1915. Phys. Rev. (2) 7284, 1916.

The Radioactivity of Springs in Europe and America.

Location of Spring.	Observer and Reference.	Radioactivity. Gas. Units per litre.	Radioactivity. Water. Units per litre.	Radium in water. Units per litre.
England.—				
Nine wells, Cambridge	Satterly		130	
Well at Dale's brewery, Cambridge	Proc. Camb. Phil. Soc.,		196	0·9
Water from the River Cam.	XV, Pt.VI, 542, 1910 and XVI, Pt. IV, P. 360, 1911		7	3·09
Kings Well, Bath	Ramsay	33,650	1,730	138·7
Cross spring „	Chem. News, 105-134, 1912		1,190	
Hetling spring „			1,700	
Hospital Natural Baths, Buxton	Makower	7,700	830	
Gentlemen's Natural Baths „	Chem. News, 105-135, 1912.		1,100	
Europe.—				
Quelle Am. Schweitzergang				
Joachimsthal, Austria			70,000	
Choussy spring, La Bourhoule, France	Laborde and Lepape		22,900	
Celestins spring, Vichy, France	Compt. Rend.,		653	
Chomel spring, „ „	155-1202, 1912.		653	
Hôpital spring „ „			22	
Vauquelin spring, Plombieres	Brochet		4,800	
Dames „ „	Compt. Rend.,		10,700	
Lambinet „ „	150-423, 1910.		15,900	
United States.—				
Hot River, Mammoth Hot Sp., Yellowstone Pk.	Schlundt and Moore		1,440	
Apollinaris Spring „ „ „	Bul. 395, U.S. Geol.		1,210	
Five Hole Lake, Lower Geyser Basin „	Sur.	329,000	320	
Nymph spg., Yellowstone River locality		7,300	263	
Imperial spg., Hot Spgs. Arkansas	Boltwood		10,100	
Twin spring „ „ „	Am. Jour. Sci.,		2,480	
Arsenic spring „ „ „	4th ser. 20-128,		874	
Liver spring „ „ „	1905.		662	
Cave spring „ „ „			140	
Emperor spring, Saratoga Springs, N.Y. state		221	70	68
Hawthorne No. 1, „ „ „ „	R. B. Moore and Whittemore,	213	142	42
Hawthorne No. 2, „ „ „ „	Jour. Ind. and Eng. Chem.,	51	161	99
Geyser „ „ „ „	6-552-1914	34	39	—
Pump Well No. 4 „ „ „ „		678	231	21
Crystal Rock „ „ „ „		847	880	9
Canada.—				
Gas spring, Caledonia Springs, Ont.	Eve, A. S.	620		15
Saline „ „ „ „	Trans. Roy. Soc. Can.,	210		14
Duncan „ „ „ „	4, sec. iii, 1910, 55.	420		18
Artesian Sulphur „ „ „				10
Sulphur „ „ „				15
Fairmont Springs, B.C.	Boyle and McIntosh		3,500	100
Sinclair „ „	Trans. Roy. Soc. Can.,		4,000	trace
Banff „ Alberta	7, sec. iii, 1913, 163.		?	trace
Sea water from the Atlantic				0·9
Water from the St. Lawrence	Eve, A.S., Phil. Mag. July, 1909, P. 102.		25	
Water from the Ottawa	This report.		14	

CONSIDERATION OF THE RESULTS.

It is interesting to compare the results obtained in this work with the radioactivity of some of the chief European and American springs.

One of the most radioactive waters known in the world is the Quelle am Schweitzergang at Joachimsthal, Bohemia; in the neighbourhood of which the pitchblende, that has constituted the chief European source of radium, is mined. The value found for the radium emanation content of the water of this spring is approximately 70,000 units per litre, while the radioactivity of most Canadian waters is only about one seven-hundredth of this amount. On comparing them with the values obtained by Sir William Ramsay for the Bath Springs in England, the difference is not quite so great, except as regards the amount of radium salts in the waters. The King's Well at Bath gave the relatively high value of 138·7 units radium per litre, while the highest value found for any of the Canadian waters was 46 units (Philudor spring, St. Hyacinthe).

This high value found for the Philudor spring, is an exception, the average amount being about 3 units, a value only slightly greater than has been found for sea water, e.g., 1 unit radium per litre.

In the United States no group of springs has been more fully examined than that at Saratoga, New York state, and complete results of the radioactivity of the waters and gases evolved from the springs have been published. Some of the results are included in the tabulated list of results on page 46, from which it will be seen that the Canadian waters give figures of the same order as the American, especially with regard to the radium emanation content. Thus, Sanitaris, Adanac, Varennes, Radnor Forges, Potton, and the Banff Springs, all show a slightly higher content than the Emperor, the Hawthorne, or the Geyser Springs at Saratoga, though not as high as the Crystal Rock spring. While the Canadian waters give lower figures for the radium salts in solution, the gases evolved possess a higher radioactive content in most instances.

In regard to the individual springs, Radnor Forges spring was found to be the most active of any measured in Ontario or Quebec, but the radium it carries in solution is low.

Potton, Varennes, Adanac, Sanitaris, follow it in descending order, each one possessing an activity of over 200 units per litre; yet, of these only the Varennes water contains radium salts in much more than a measureable amount. The Philudor water is the most permanently radioactive. The Banff waters give the highest results of any springs as yet examined, though they are not as active as the Bath waters in England. However, in other respects there is a great similarity between the Banff and the Bath springs, especially in regard to the mineral constituents of the waters and to the gases which are evolved from the springs. The similarity in the composition of the gas has already been referred to (page 40).

RELATION BETWEEN RADIOACTIVITY AND OTHER PROPERTIES.

As far as possible, information has been collected as to the geological formations from which the springs issued, with the hope that there might be a relation between the radioactive value of the waters and the geological formation through which the water had passed. No such relation, however, is apparent. Engler and Sieveking, as a result of testing several hundred springs in southwest Germany, Austria, and Italy,[1] stated that springs arising from granite rocks are generally more active than those from sedimentary formations. More recent work on Swedish springs by N. Sahlbohm has confirmed this.[2] This generalization would be expected from the work of Hon. R. J. Strutt[3] on the radium content of rocks. Examining specimens from most parts of the world, he found granites to be considerably more radioactive than sedimentary rocks.

However, nearly all the springs investigated in this work rise from sedimentary formations, and even though these are the most ancient deposits known their radioactive content is small. Most of the springs issue either from the Trenton limestone or from the Utica or Hudson River formation. Professor Eve[4] found the radium content of a sample of Trenton limestone from the neighbourhood of Montreal to be 0·92 unit radium per gram of rock. Utica shale contains a similar amount.

As would be anticipated, no difference is apparent between the radioactivity of springs from these two formations.

Another observation has been, that thermal are usually more active than cold springs. The only thermal waters investigated in Canada are the Banff waters, and they are more radioactive than the cold springs in the east. Fresh water springs are, nearly always, more temporarily radioactive than mineralized waters, and no exceptions were found among the seventy Canadian springs examined. Waters from Adanac, Alfred, Potton, Lake Castor (Ste. Agathe) springs, also the springs in the Canadian Northern tunnel at Montreal, all have relatively high radioactivity and low mineral content. In such waters however, dissolved radium is usually absent. Attempts have been made to find a relation between the total mineral matter in the water and its radioactivity. Fig. 5 shows the results of plotting both the radium emanation and dissolved radium content against the mineral matter in the water. Beyond illustrating the statement just made, namely, that fresh waters usually possess a relatively high activity, it gives no indication of any relation in the case of the more mineralized waters.

Between the radium and the calcium content of the waters, no connexion can be observed. A tentative relation was found in the Saratoga Springs,

[1] Engler and Sieveking, Zeit Anorg. chem., 1907, 53, 1-25.
[2] Sahlbohm Arkiv. Kem. Min. Geol., 1916, 6.
[3] Strutt, Proc. Roy. Soc. 77A; 472 and 7A, 150.
[4] Eve, Phil. Mag., August 1907, p. 231.

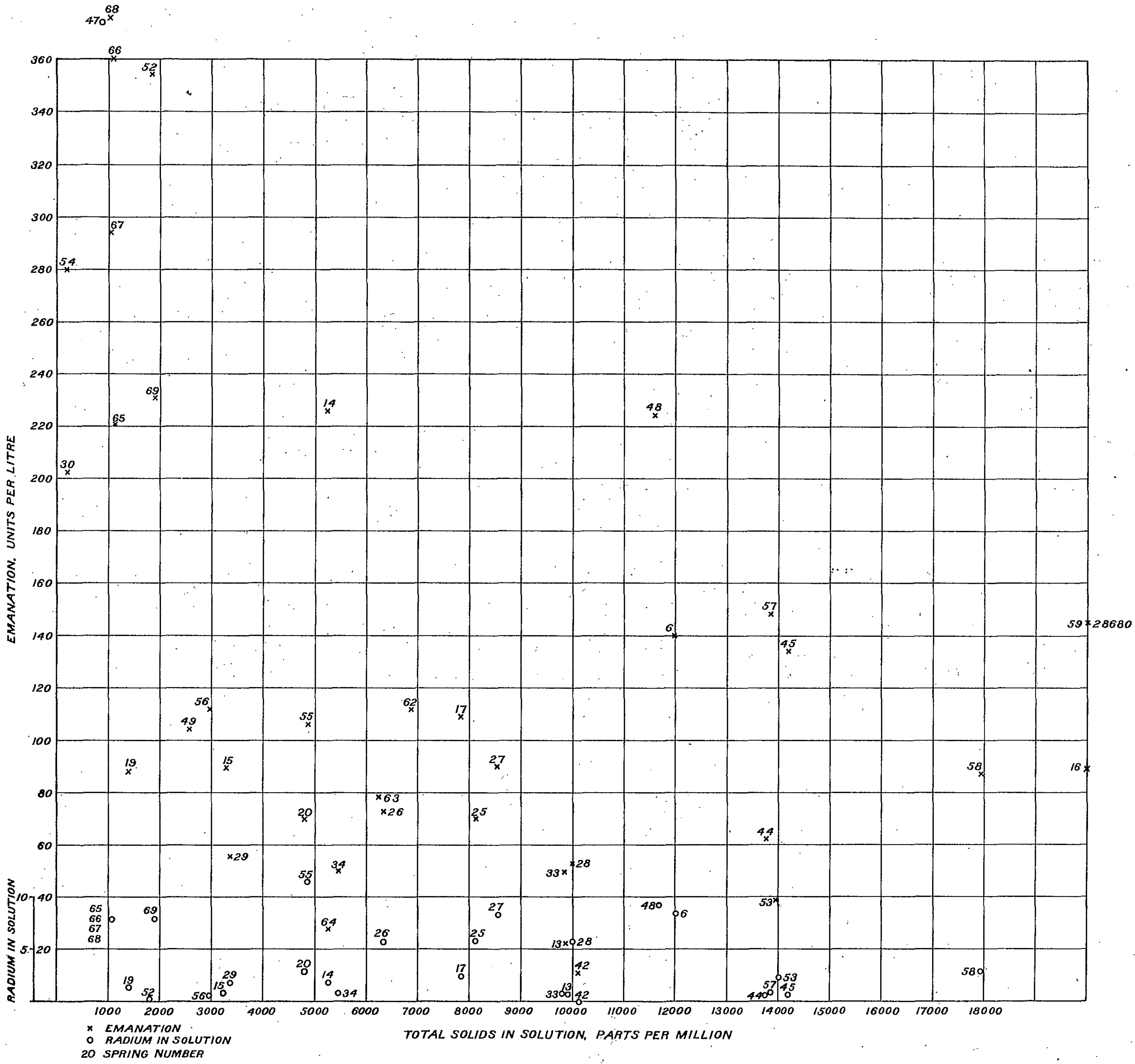

Fig. 5. Showing relation between radioactivity and total solids in solution.

where the more active springs possessed a slightly higher barium content. As barium has seldom been detected in any of the Canadian water this could not be confirmed. Mention has already been made of a relation between the flow and the radioactivity of springs. Unfortunately, there has been no opportunity to conduct throughout a long period, a series of determinations on any Canadian spring.

ECONOMIC VALUE OF THE RADIOACTIVITY OF MINERAL SPRINGS.

THE THERAPEUTICS OF RADIOACTIVE WATERS.

It has been stated previously that the discovery of the radioactivity of mineral waters confirmed the belief that the beneficial effects of many spring waters were due in many cases to some other factor than the known mineral constituents. It may be interesting to outline the main results of investigations concerning the therapeutic value of radioactive waters, although the greater part of such work has been done using artificially prepared radioactive solution, usually many times more active than naturally found solutions.

In the first place an increased activity of all the processes of nutrition and metabolism occurs. Increased oxidation is evidenced by a rise in the percentage of all urinary solids other than the chlorides, and a considerable multiplication of the red blood cells has been often observed. Difference of opinion exists as to the question of the bactericidal effects of radium and its derivatives. Some authorities have denied any such effects, yet treatment at Bath has shown an antibacterial effect in the case of gonococci. Radium emanation certainly has power to stimulate the elimination of toxins.

Under the influence of radium emanation the insoluble sodium mono-urate can be changed into a soluble mono-urate, which subsequently decomposes into ammonia and carbon dioxide. Work upon patients whose blood contained uric acid has shown that a similar process takes place in the human body when treatment in an "emanatorium" is given.

The chief agent in the therapeutic use of waters is radium emanation. There are five ways of absorbing emanation:—

1. Through the lungs.
2. Through the digestive organs.
3. Through the skin.
4. Through the medium of different forms of injection.
5. Through the employment of local applications externally.

In the first case the chief source of the emanation would be the gases which are so often evolved from springs. These gases, passed into the air of a suitable room, constitute it an "inhalatorium."

The lung is the quickest medium of absorption and discharge, and the radium emanation dissolves in the blood to a certain extent. From the blood it can enter the organs and tissue cells. The most satisfactory condition will arrive when the blood is saturated with emanation.

The second method of absorption will be adopted when waters containing radium or emanation are drunk. In this way the emanation penetrates the stomach and intestines, and diffuses into the capillaries of the lymph and portal vein, and much of the emanation imbibed reaches the arterial blood. In the case of inhalation the emanation is much more rapidly absorbed, but it is retained only as long as it is breathed, while in the drink cure emanation is introduced into the system, and solid decomposition products are deposited, which will continue to send out the radiations which are the valuable agents.

In many cases, relatively strong radium solutions are injected into patients, though such treatment hardly comes within the province of natural water therapy.

Besides inhaling radioactive air, and drinking radioactive water, a variety of baths using radioactive water have been devised, though the question of absorption by the skin is a much discussed one. The majority of authors agree that emanation does not get into the organism through the skin, but it exclusively gets into the blood through the lungs.

However, others arguing on the grounds of their experience state that if baths are taken for sufficiently long time, considerable emanation is absorbed.

THE USE OF THE RADIOACTIVE WATERS AT BATH, ENGLAND.[1]

It may be of interest to outline the various ways in which the spring waters at Bath are utilized for therapeutic treatment. Bath is the oldest and most famous health resort in the British Isles. The city was founded by the Romans in the first century, though legend attributes the discovery of the hot springs in 800 B.C. to Prince Bladud, son of the ancient British King, Lud Hudibras, and father of Shakespeare's King Lear. Culverts and baths built by the Romans still remain, together with many other antiquities. Bath, however, was most famous in the eighteenth century, when Queen Charlotte resided there, and the town was the most fashionable resort of society in England.

There are three hot springs at Bath:—

(1) The King's Spring rises in the King's Bath, which is surrounded by buildings of great historic interest. Radioactive waters are served from a fountain in the famous pump room which is supplied direct from the King's Spring; (2) The Hetling spring which supplies both drinking water and swimming baths in the old Royal or Hetling baths; and (3) the Cross spring which was the fashionable bath of the seventeenth century, when Pepys bathed there.

Since Sir William Ramsay's report on the radioactivity of the Bath waters, showing that they were the most active in Great Britain, the latest methods have been employed to utilize this property.

It has been stated that radioactive waters may be used in three ways:—by inhaling the gases given off from the hot waters; by drinking the water; and by external application in the form of baths. Each one of these methods is employed at Bath.

[1] "Notes on the Therapeutics of Radium in the Bath Waters." Compiled by John Hatton, Director of the Baths.

A Radium Inhalatorium has been opened in which apparatus is installed whereby the radioactive waters of the Hot Springs may be inhaled or used for special sprays in a finely atomized form. The gases from the springs are also supplied in conjunction with the waters. The waters are atomized by steam, air, or by the gases containing considerable amounts of emanation evolved from the springs.

Nasal sprays and douches, and ear and eye sprays are also given.

The radioactive waters are served for drinking in the grand pump room, and during the summer season at the Colonade fountain in the Institute gardens. The cost of a single glass of water is 2d, while a book of 14 tickets may be obtained for 1/6. An inhalation of radioactive water in the Inhalatorium costs 1/6, while the various sprays are obtainable for 1/6 or 2/0.

The Queens baths adjoining the grand pump room and the New Royal Baths, afford every convenience for all kinds of baths in the radioactive waters. The high temperature at which the water issues from the springs—49° C. or 120°F. enables baths and douches to be given without any necessity for artificial heating.

There are deep baths with arrangements for lowering helpless patients into the waters, all kinds of reclining baths, douches, and douche-massage baths, such as are employed at Aix-les-Bains, Plombieres, and other famous European spas.

Besides these, there are large and well appointed swimming baths.

THE ECONOMIC IMPORTANCE OF THE RADIOACTIVE PROPERTIES OF SPRINGS.

The first point that is usually raised when it is stated that a spring is radioactive is, to inquire whether the fact shows that there may be deposits of radioactive minerals in the neighbourhood.

Insufficient data has been collected, as yet, to definitely state that a deposit of pitchblende, carnotite, or other radioactive mineral would so strongly activate springs rising in the neighbourhood as to indicate the presence of such a deposit; though it is probable that it would. For instance, one of the most active waters is found at Joachimsthal, Austria, which is also the district of the earliest and chief supply of European pitchblende. Springs in Japan have been found to be nearly as active as the spring at Joachimsthal, and therefore Dr. Ishizu, who carried out the investigation, states that Japan probably possesses large deposits of radioactive ones.[1]

Yet the difference between the radioactivity of the rich Austrian water and that of the Caledonia springs, for example—Joachimsthal is only several hundred times as active as the waters from Caledonia Springs—seems hardly as great as might be expected considering the presence of pitchblende in the first case and its probable absence in the second.

[1] Jour. Ind. Eng. Chem., 1915, p. 1081.
Mineral Springs of Japan, Dr. R. Ishizu, Tokyo.

No Canadian water, however, gave results which would indicate the possibility of the presence of radioactive minerals in its neighbourhood.

The chief value of a strongly radioactive spring lies in the possible use of this property for therapeutic treatment. The methods of utilization of the radioactive waters and gases of the Bath springs have been outlined in a previous paragraph. Similar therapeutic treatment is provided at most of the principal spas in Europe. At four of the springs in Canada visited in 1914, health resorts were established, Caledonia Springs, Carlsbad Springs, Potton Sulphur Spring, and Abenakis Springs, but these at present are not developed to the same extent as European spas. The radioactivity of all the Canadian springs so far examined is lower on the average than that of the majority of European springs which are celebrated for their curative properties.

Until considerable experimental work is done on the therapeutic value of waters of low radioactivity, it is difficult to estimate the precise value of most Canadian springs from a radio-therapeutic standpoint. Many are undoubtedly valuable on account of their mineral constituents however.

The Banff springs might be utilized in a similar manner to the Bath springs, as considerable quantities of gas of comparatively high radioactive value are evolved. At present the radioactive water is used in baths which are continuously renewed from the springs. The air of the immediate neighbourhood must also contain radium emanation.

In the third place, would any of the waters be of use to bottle and sell as radioactive waters? The answer is in the negative. As previously explained, it is only when a water contains a considerable amount of radium in solution that it is of much value for bottling as a radioactive water, few Canadian waters contain more than comparative traces of dissolved radium. The water holding the most radium in solution—Philudor water from St. Hyacinthe—is only about one hundred-thousandth times as strong as the artificially prepared radioactive water used for medical purposes.

APPENDIX I.

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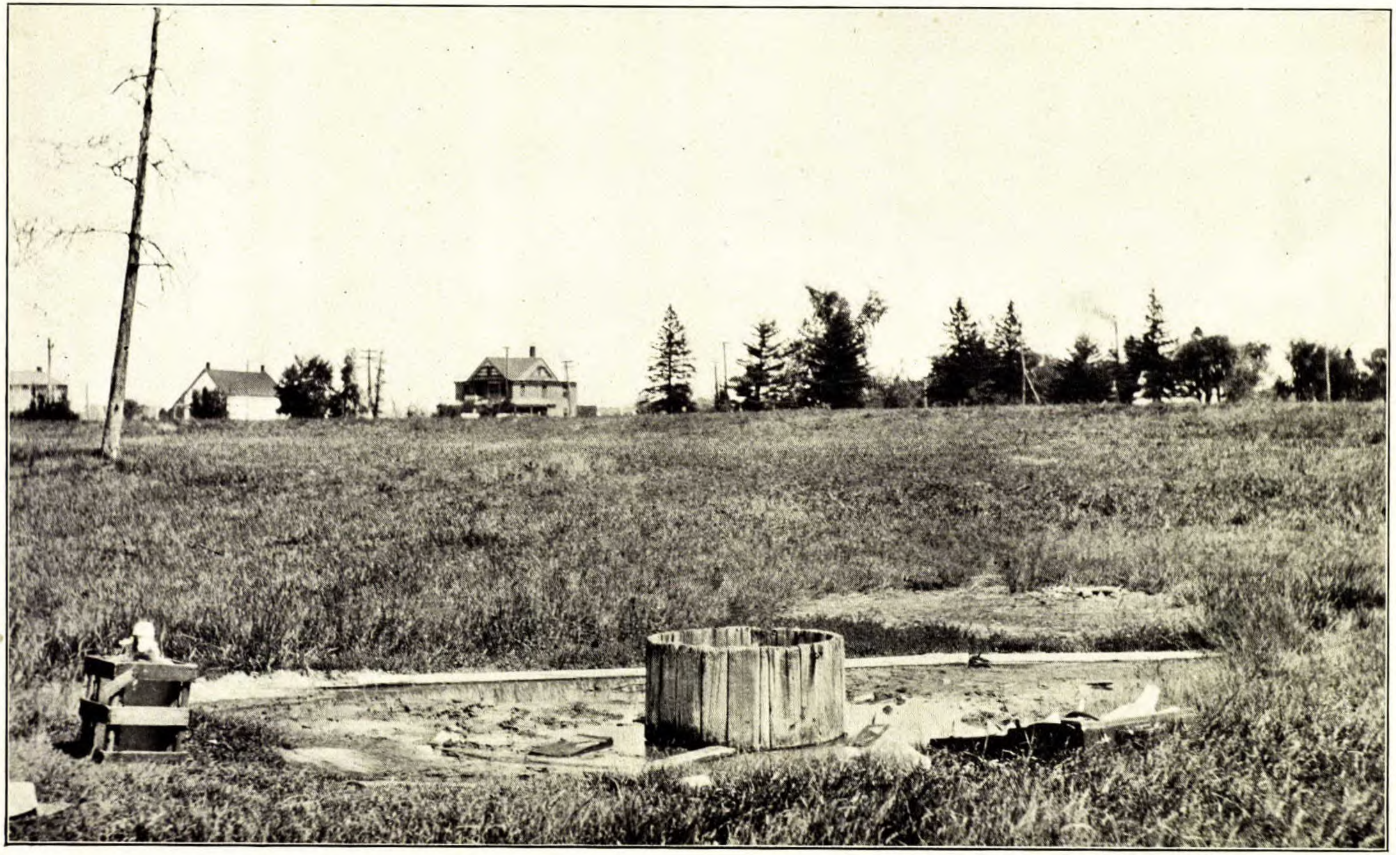
APPENDIX II.

Table of Equivalent Centigrade and Fahrenheit Temperatures.

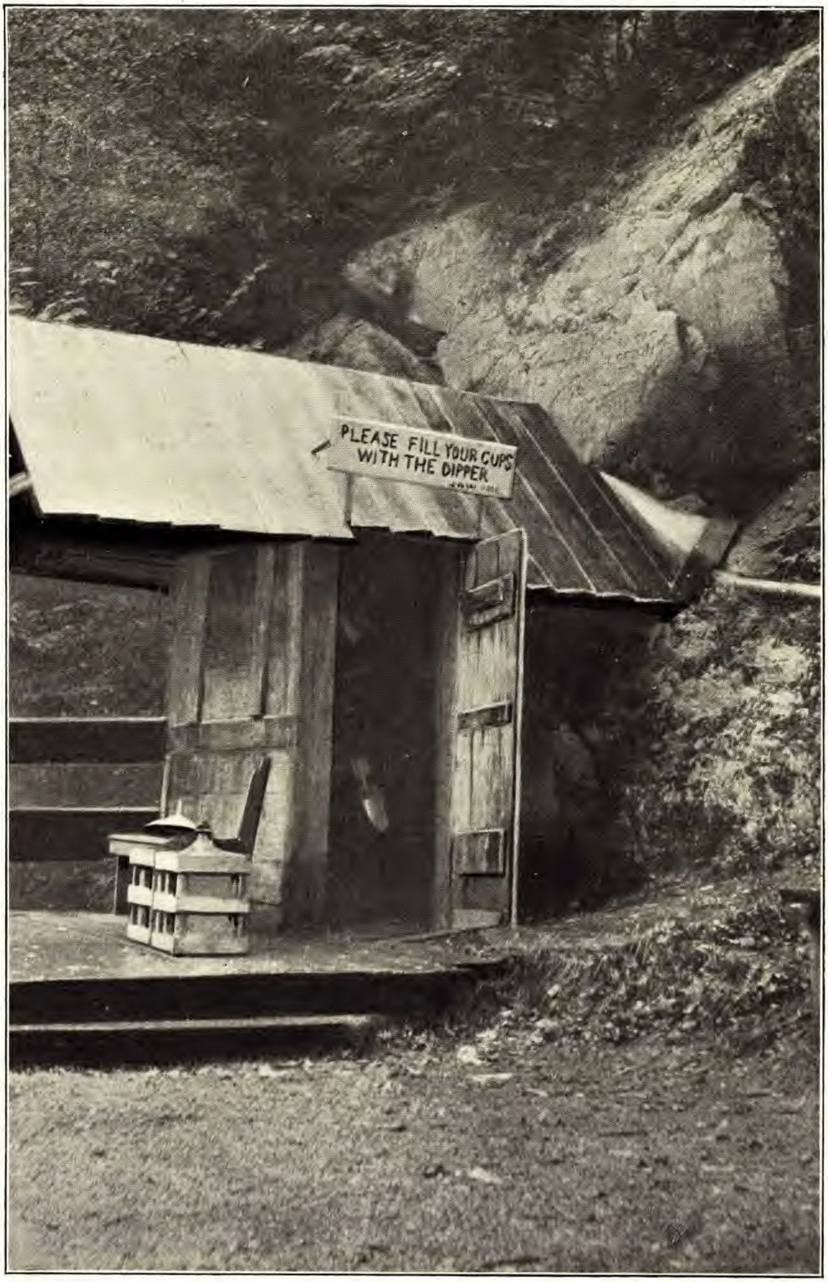
Degrees Centigrade.	Degrees Fahrenheit.	Degrees Centigrade.	Degrees Fahrenheit.
0	32	22·0	71·6
5·0	41	23·0	73·4
6·0	42·8	24·0	75·2
6·5	43·7	25·0	77·0
7·0	44·6	26·0	78·8
7·5	45·5	27·0	80·6
8·0	46·4	28·0	82·4
8·5	47·3	29·0	84·2
9·0	48·2	30·0	86·0
9·5	49·1	31·0	87·8
10·0	50·0	32·0	89·6
10·5	50·9	33·0	91·4
11·0	51·8	34·0	93·2
11·5	52·7	35·0	95·0
12·0	53·6	36·0	96·8
12·5	54·5	37·0	98·6
13·0	55·4	38·0	100·4
13·5	56·3	39·0	102·2
14·0	57·2	40·0	104
14·5	58·1	41·0	105·8
15·0	59·0	42·0	107·6
16·0	60·8	43·0	109·4
17·0	62·6	44·0	111·2
18·0	64·4	45·0	113·0
19·0	66·2	46·0	114·8
20·0	68·0	47·0	116·6
21·0	69·9	48·0	118·4
		49·0	120·2
		50·0	122

Carlsbad Springs, Ont.

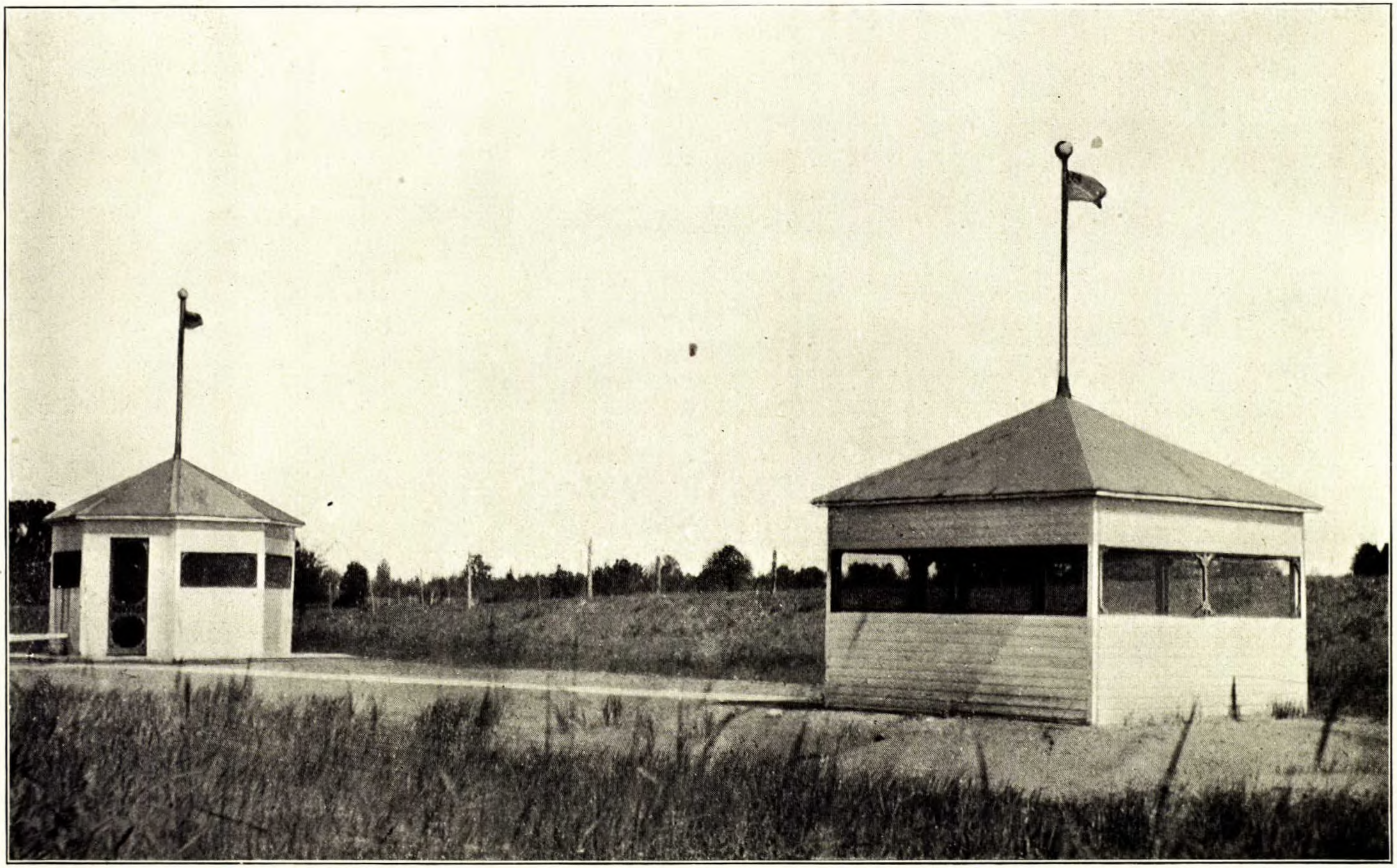


Plantagenet Spring, Ont.

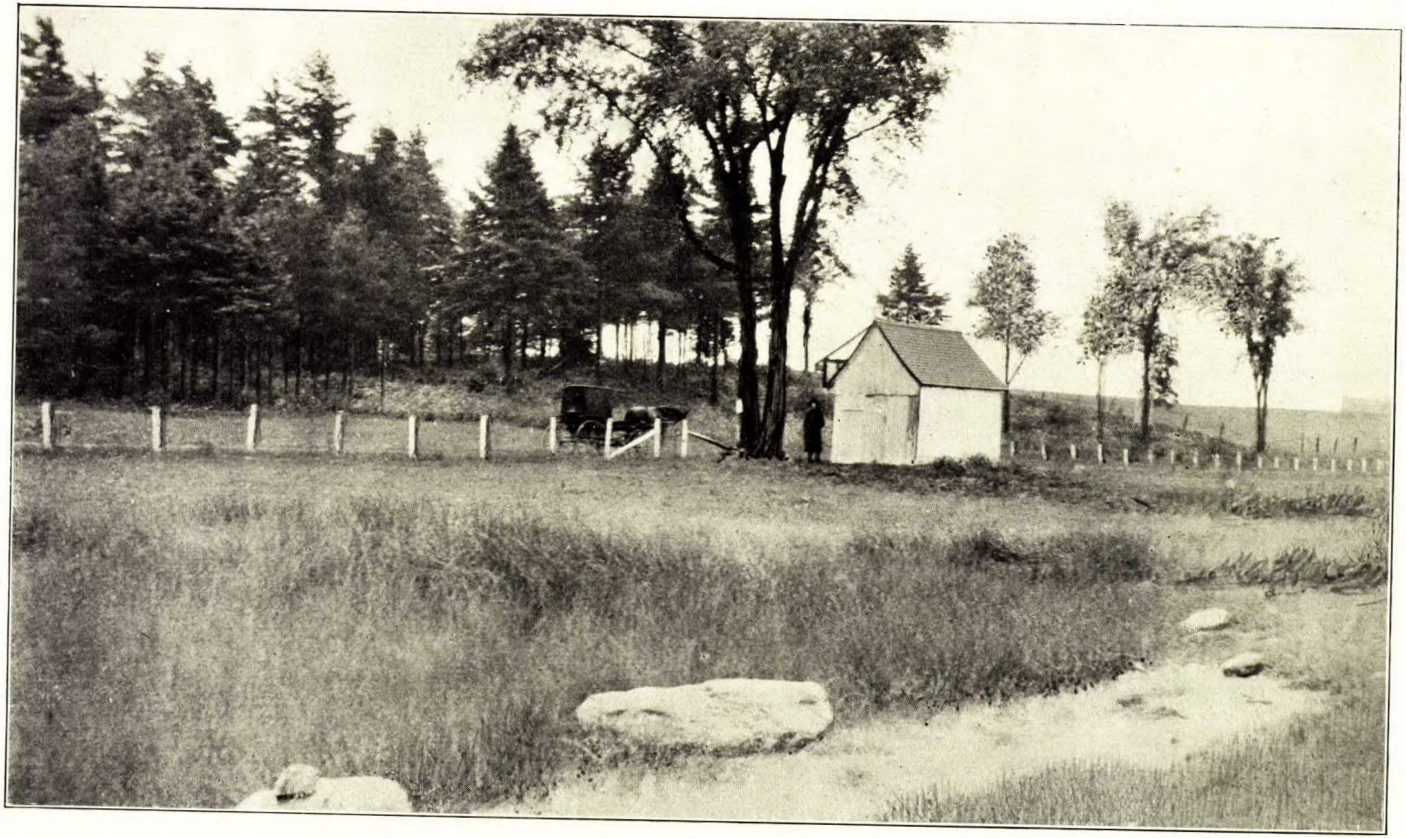
Russell Lithia Spring, Bourget, Ont.



Potton Spring, Brome Co., Que.



Abenakis Springs, Que.



Richelieu Spring, Chambly basin, Que.

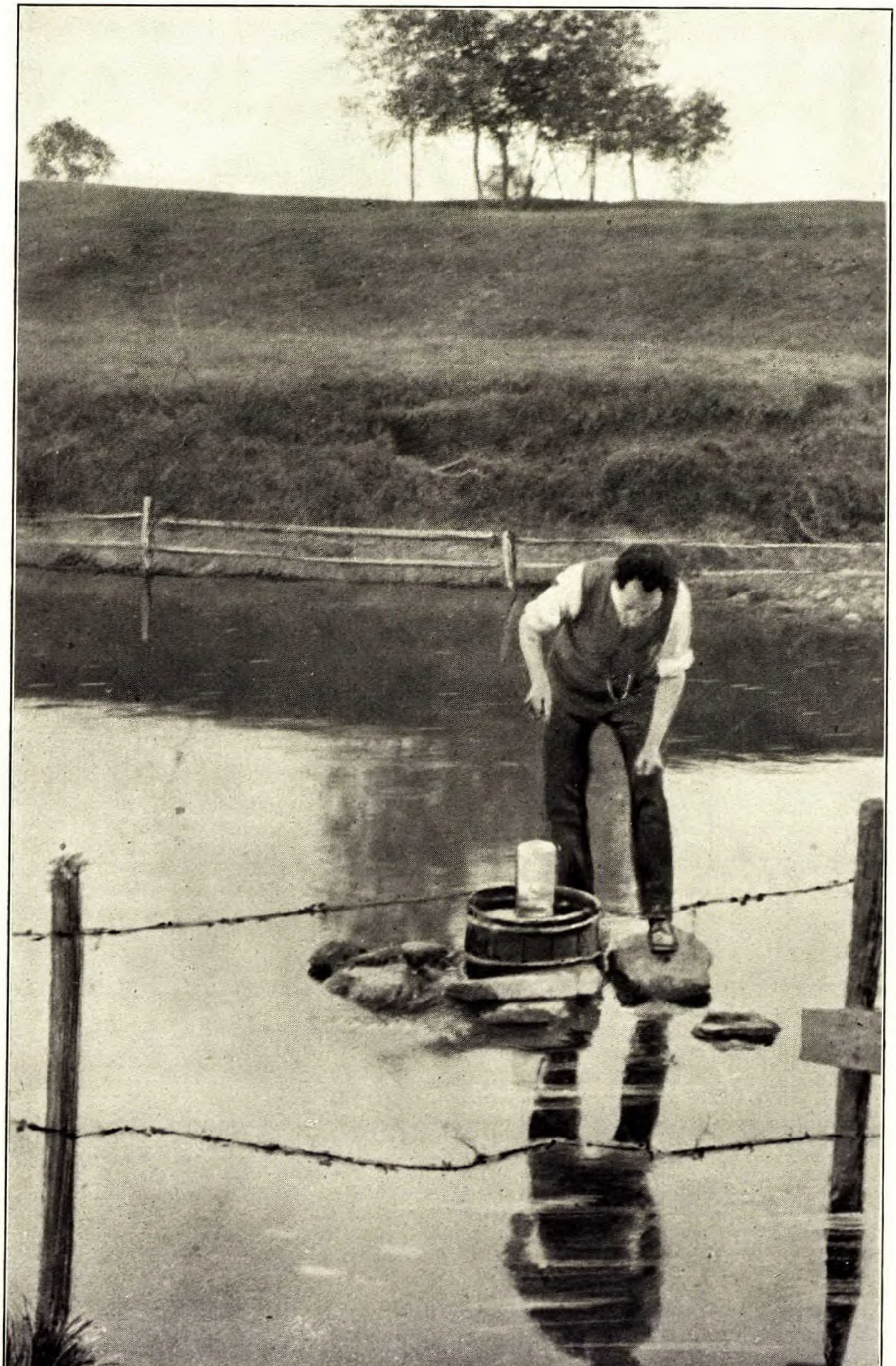
St. Leon old spring, Que.—casing of well.

St. Leon old spring, Que.—overflow to river.

Philudor Spring, St. Hyacinthe, Que. (Typical location of many springs.)

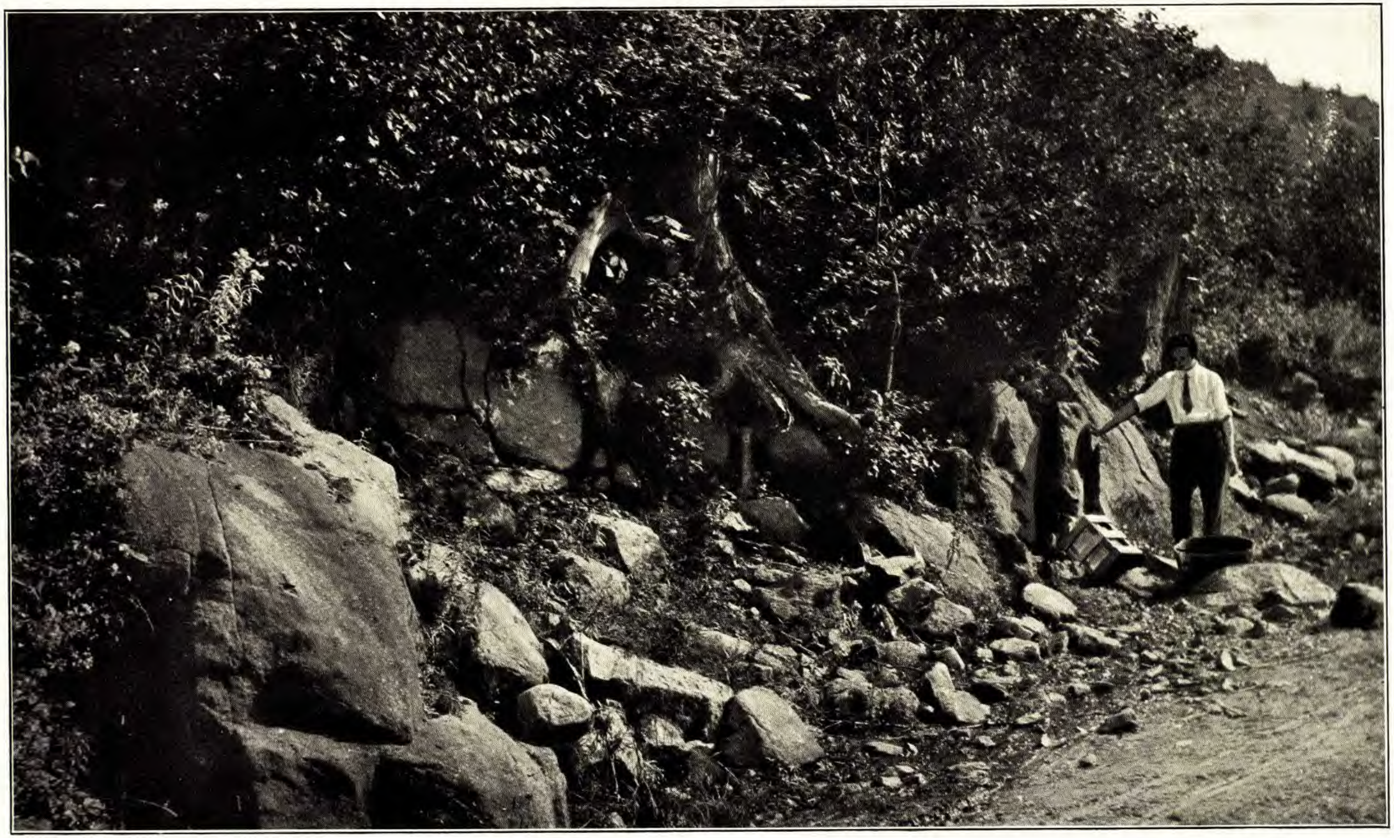
La Providence Spring, St. Hyacinthe, Que. (Typical location of many springs.)

St. Leon (Lupien) Spring, Que.



Spring in Bayonne river, Berthier, Que.

Lake Castor, Ste. Agathe, Que.



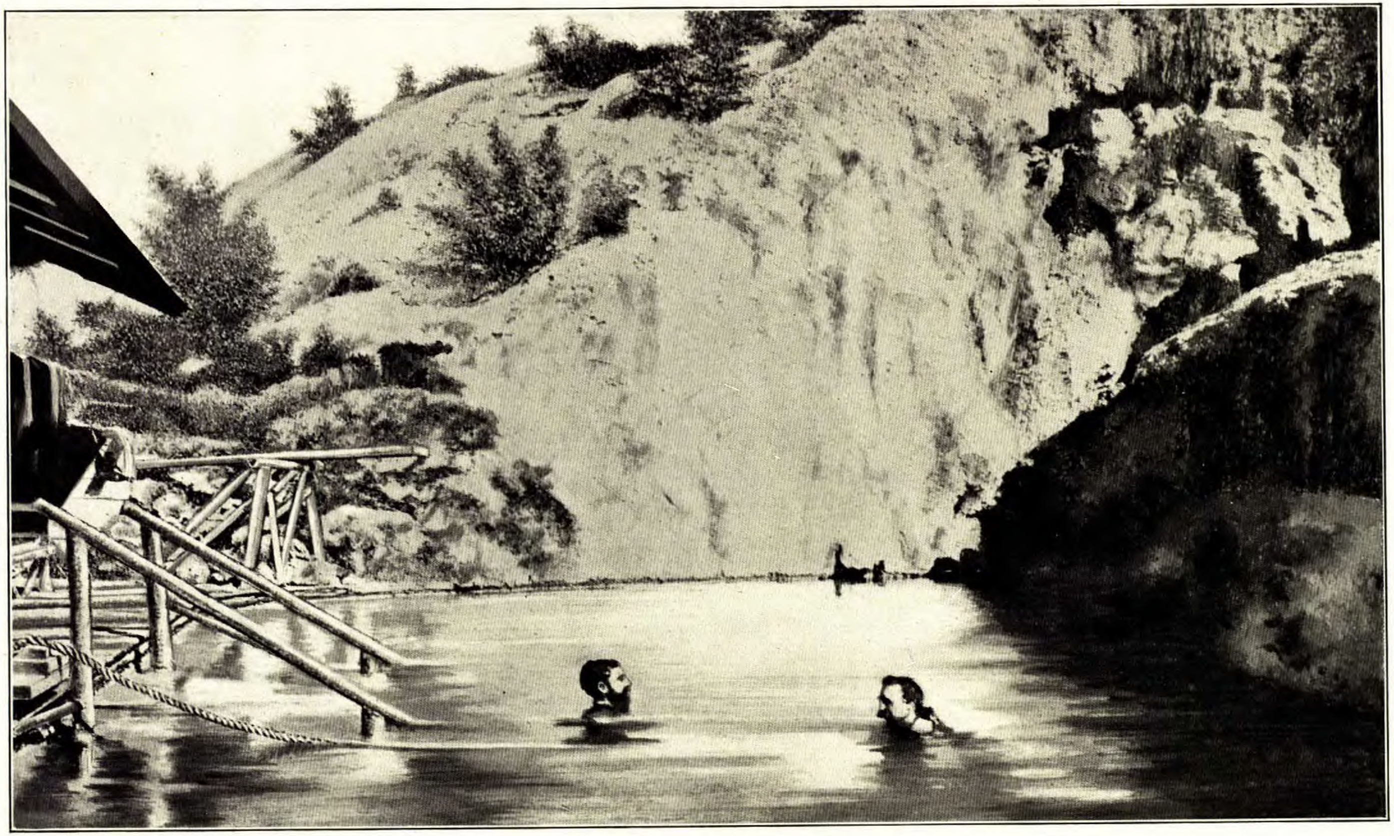
Roadside Spring, Ste. Agathe, Que.

Spring at Maskinonge, Que.

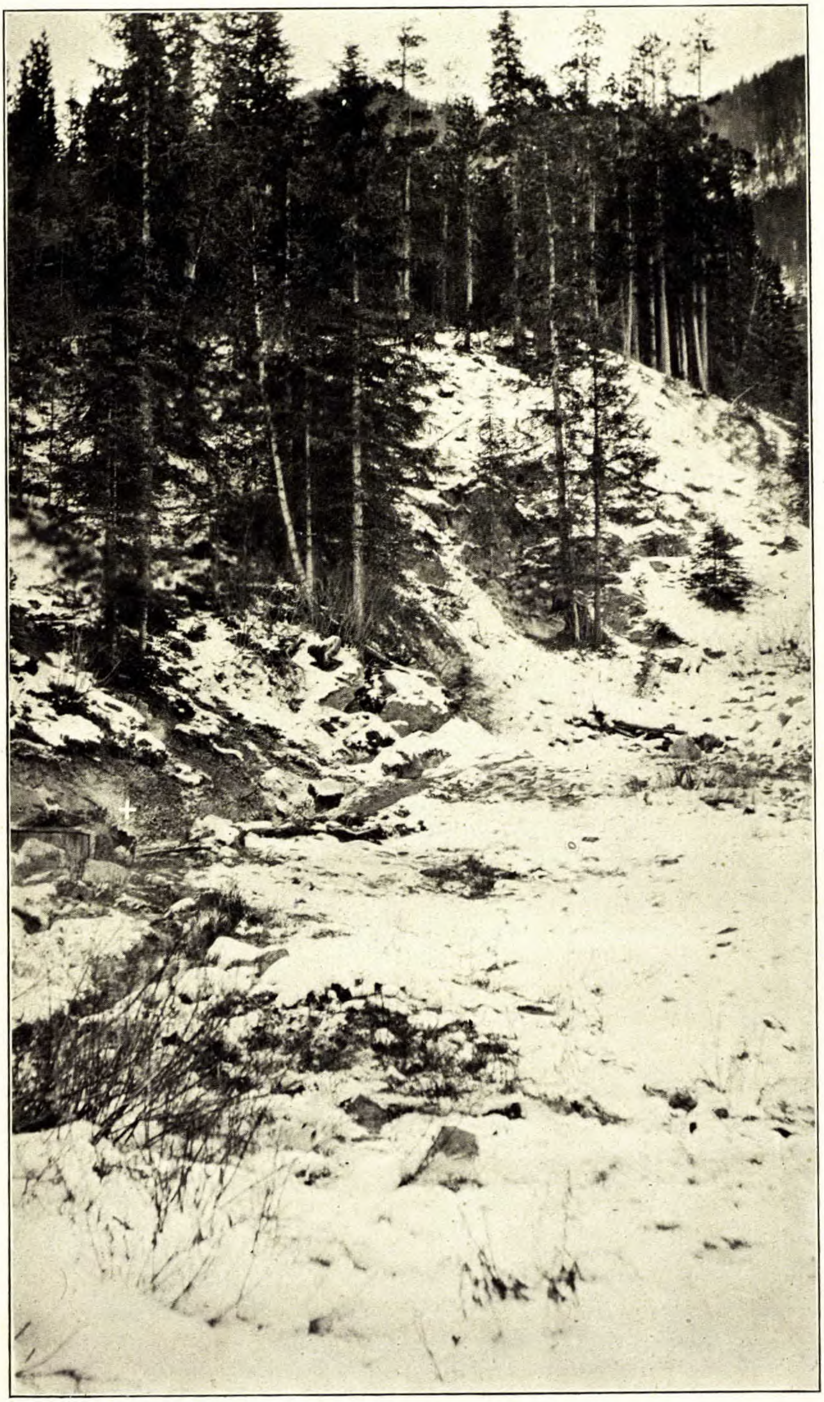
Spring at St. Severe, Que.

Photo by Byron Harmon, Banff.

Cave Spring, Banff, Alberta.



Basin Spring, Banff, Alberta.



+ Kidney Spring, Banff, Alberta.

Middle Spring and Cave, Banff, Alberta.

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