CANADA
DEPARTMENT OF MINES
HON. R. B. BENNETT, ACTING MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
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MINES BRANCH INVESTIGATIONS OF

MINERAL RESOURCES AND THE MINING INDUSTRY, 1925

I

HOT SPRINGS IN WESTERN CANADA THEIR RADIOACTIVE AND CHEMICAL PROPERTIES

R. T. Elworthy

INTRODUCTORY

In 1914 the Mines Branch of the Department of Mines began an investigation of the mineral springs of Canada, and during the summer of that year many of the better known springs in Ontario and Quebec were examined. Two years later, a survey was made of the radioactivity and chemical properties of the hot springs at Banff, Alberta. The results of these investigations were published in two reports.[1]

In 1923 the Dominion Parks Branch of the Department of Interior asked that measurements be made of the radioactivity of a hot spring situated close to the Kootenay Park entrance to the Banff-Windermere highway. In order to have reliable comparative values and to complete the knowledge of the properties of the chief mineral springs in British Columbia, the investigation of several other hot springs in the province was carried out at the same time.

The greater number of mineral springs in Canada have, therefore, been examined and their properties measured and recorded.

SCOPE OF PRESENT REPORT

Complete field tests at the springs and subsequent analyses and determinations in the laboratories of the Mines Branch in Ottawa were carried out on waters from four springs, viz., Radium Hot Springs in Kootenay Park, Fairmont Hot Springs in the Columbia valley, Halcyon Hot Springs on the Upper Arrow lake, and Harrison Hot Springs on Harrison lake, near Vancouver. As the hot springs at Banff were the subject of a thorough investigation in 1916, field tests only were made on the waters at Banff, chiefly with a view to ascertaining whether any change of concentration of mineral constituents in the waters had taken place in the last eight years and if the temperature of the springs had altered.

To make the report more complete additional information on other springs in British Columbia has been added. Particulars of hot springs near Jasper Park, in the Lillooet River area, and on the coast of British

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[1] Elworthy, R. T.: "The Radioactivity of Some Canadian Mineral Springs," Mines Branch, Dept. of Mines, Canada, Rept. 435 (1917);
"The Chemical Character of Some Canadian Mineral Springs," Mines Branch, Dept. of Mines, Canada, Rept. 472 (1918).

Columbia are thus included. Most of these springs have been reported on by officers of the Geological Survey, and analyses of the waters have been made in the Mines Branch laboratories. No field tests or determinations of radioactivity have been carried out, however.

EXTENT OF INVESTIGATION

The thorough investigation of a mineral spring involves a number of tests both in the field and in the laboratory. It includes the measurement of the radioactivity of the waters and of any gases evolved, the examination of spring deposits, the determination of temperature of the waters and other physical properties such as specific gravity, conductivity, colour, and taste, observations of the flow and the physical conditions of the surroundings of the spring, together with detailed quantitative chemical analysis of the water and of the gases given off.

Data bearing on the economic value of the springs and the possibilities of their utilization are also desirable. The investigation of the better known springs treated in this report has been along these lines.

RADIOACTIVITY OF MINERAL SPRINGS

It has been known for the last twenty years that most waters from springs and deep wells hold in solution varying amounts of niton or radium emanation, the gas that is given off during the disintegration of the element radium. Occasionally minute amounts of radium salts may be found in such waters. The presence of these elements has been suggested by some authorities to account for the undoubted therapeutic effects of many mineral waters and frequent investigations of the radioactivity of springs in all parts of the world have been reported from time to time in scientific literature.

The source of this emanation is the radium which is known to be present in extremely minute amounts in many rocks, sands, and soils which the water traverses in its underground path. It may also come from the disintegration of radium salts dissolved in the water, which have been taken up underground. If radium emanation alone is present the water is said to possess temporary radioactivity. The majority of spring and well waters are of this nature. If radium is present the water is permanently radioactive.

Radium emanation breaks down or disintegrates just as radium does, but its half life period is far shorter, being only 3·75 days. The radioactivity of a sample of water, taken from a spring, quickly disappears, except in those very rare cases when radium itself exists in solution in small amount.

In approximately 4 days a water sample having temporary radioactivity will lose one-half of its initial radioactivity, in 8 days three-quarters will have disappeared and in 2 weeks it will have practically vanished. Because of this few, if any, spring waters have any value for bottling on account of their radioactive properties.

Therefore it is desirable that the measurement of temporary radioactivity should be made at the spring immediately the sample is taken or within a few hours of collection. The time that has elapsed since the collection of the sample must be exactly known.

Methods Employed for the Determination of Radioactivity

The examination of spring waters for radioactivity entails the measurement of the total radium emanation present in the sample at the time it is collected, and the determination of radium present either as a radium salt in solution or suspension.

The methods employed for these measurements have been fully described in the earlier report[1]. On account of the greater radioactivity of most of the waters in British Columbia that were examined, a much smaller quantity of water was used for the determinations in the later work. Amounts varying from 250 c.c. to 1,000 c.c. instead of several litres as in the previous work, were boiled out in pyrex glass flasks. The tests were usually made within a few minutes of the collection of the samples. The same ionization vessel with electroscope was used as in the former investigations.

One improvement in the electroscope was the addition of a stop, fitted so that the gold leaf could be clamped when the instrument was packed for transportation. This proved most successful for protecting the leaf. The same strip of leaf was in use throughout the investigation, surviving without injury or damage over three thousand miles of transportation by rail and by road.

Standard Solutions Used

Standard radium solutions were used, and were obtained by diluting suitable aliquot parts of 100 c.c. of a solution of radium barium bromide, in 50 per cent hydrochloric acid, certified to contain $12 \cdot 2 \times 10^{-12}$ grammes of radium per c.c. purchased from the United States Bureau of Standards.

These dilute solutions were contained in 250 c.c. Erlenmeyer flasks, closed with rubber stoppers which were fitted with suitable inlet and outlet glass tubes for attaching to the condenser and for bubbling air through the solutions in the flasks. These tubes were closed by short pieces of rubber tubing and clamps. The flasks fitted into a case and were carried without any loss or damage. At each place where tests were made, the electroscope was graduated by means of these standard solutions in the usual way.

The following results show what concordant results were obtained, especially considering the rough field conditions under which the work was carried out and the rough handling that the apparatus perforce received.

Amount of Radium Giving a Leak of 1 Division per Minute
(Units 1 x 10^{-12} grm. radium)

	July 7	Aug. 7	Aug. 9	Aug. 15	Aug. 20	Aug. 25	Dec. 20	Mean
Solution W 6 C, containing 610 x 10^{-12} grm. radium...	....	....	296	....	338	320	305	311
Solution W. B. containing 244 x 10^{-12} grm. radium...	268	305	....	300	....	311	....	295
Average............	....	....	....	....	....	....	....	303

This value has been used in calculating the results of the tests made.

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[1] Mines Branch, Dept of Mines, Canada, Rept. 435, pp. 9-17 (1917).

Expression of Results of Radioactive Measurements

The quantity of radium emanation found in the waters and gases is most conveniently expressed by giving the amount of radium with which the emanation would be in equilibrium. The amount of radium emanation in equilibrium with one gramme of radium is called a "curie", after Professor and Madame Curie. This quantity is a very large amount and for expressing the results of measurements on rocks, waters, and gases, one millionth of a millionth of a curie is a more convenient unit. To avoid the printing of twelve zeros the practice is to express this unit algebraically as 1×10^{-12} curie.

However, in this report, 1×10^{-12} will usually be omitted and the results will be written as 100 units or 2,500 units or whatever the figure may be.

CHEMICAL CHARACTER OF THE WATERS

Field Tests

The field tests comprised measurements of hydrogen sulphide and carbon dioxide, when present, of temperature, and rate of flow. An approximate determination of the concentration of the water by the measurement of its conductivity was also carried out.

The method primarily developed for the determination of the character of waters leaking into oil and gas wells in western Canada[1], proved most useful as a rapid means of ascertaining the concentration of the waters, and the results obtained agreed well with the more accurately determined figures obtained by evaporation and weighing in the laboratory.

Chemical Analysis

Five-gallon samples of water from the springs were collected and sent back to the Chemical Division of the Mines Branch for analysis. The determinations of the principal elements and radicles were made according to the usual standard methods.[2]

The analyses are reported in the usual ionic form, with the hypothetical combinations calculated. Chase Palmer's classification has been applied to the waters, following its use in the previous work.[3]

Gases Evolved

Gases bubble up with the water in most of the springs. Samples of these gases were collected and returned to the Chemical Division for analysis; J. Moran, Associate Chemist, carried out the analyses of these samples.

Helium is undoubtedly present in these gases but quantitative determinations of this element were not possible at the time. The whole subject of gases from mineral springs has been most fully reviewed by the eminent French authority, Professor Moureu.[4]

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[1] Mines Branch, Dept. of Mines, Canada, Sum. Rept. 1922, pp. 58-70.

[2] Mines Branch, Dept. of Mines, Canada, Rept. 472, pp. 16-21 (1918).
"Standard Methods of Water Analysis," American Public Health Association.
U.S. Dept. of Agriculture, Bureau of Chemistry, Bull. No. 91.

[3] Mines Branch, Dept. of Mines, Canada, Rept. 472, pp. 11-15 (1918).

[4] Moureu: Jour. Chem. Soc. Trans., vol. 124, p. 1905 (1923).

ORIGIN OF HOT SPRINGS

The term "hot spring" if strictly applied, relates only to those waters which issue from the ground at a temperature of 90°F. or more the year round, whereas those possessing a temperature of 70°F. and above are termed "thermal" springs. All the springs examined fall into the former category, since they have temperatures above 90°F.

Opinions differ concerning the origin of thermal waters, although satisfactory explanations can be advanced in many particular cases. The fundamental difference in the various theories lies in the determination of the source of the water, whether it be of meteoric or magmatic origin.

In the case of the springs under discussion the water is undoubtedly surface water which has percolated through the earth's crust and obtained its heat from the rocks through which it has traversed. The water from the surface may penetrate to a sufficient depth to come in contact with masses of volcanic origin which still retain residual heat and afterwards appear elsewhere at the surface as a hot spring. More probably underground temperatures in the localities where these springs occur are above the average surface temperature, on account of the great heat generated during the great earth movements that have taken place in the past during the formation of the mountains, and that are probably still in progress. It is known as a result of observations in deep mines and well borings that the temperature of the earth's crust in regions of comparatively uniform and undisturbed formations increases at the rate of 1°F. for each fifty or sixty feet in depth in undisturbed areas. An estimate can thus be made of the depth from which a spring has risen when its temperature has been ascertained. In regions of great stress and pressure such as the Rocky Mountain area, a much greater temperature gradient would be found. Water circulating in regions of heated rocks will be heated to the temperature of these rocks and owing to the relatively poor conductivity of the formations it traverses on its way to the surface it will still retain much of this heat when it ultimately issues at the surface as a hot spring. This is the most probable explanation of the origin of the hot springs in British Columbia.

A contributory cause may be the heat derived by oxidation of pyrite which is disseminated through the limestone formations which the water traverses.

The amount of heat brought to the surface by hot springs is great. For example the daily flow from all the springs in Banff is about 1,000,000 gallons and the average temperature is approximately 100°F. About one thousand million British Thermal Units daily is, therefore, the amount of heat brought to the surface.

DESCRIPTION OF SPRINGS

The Banff Hot Springs

The Banff hot springs, close to Banff, in the Rocky Mountain National Park, are widely known on the North American continent, mainly because of their picturesque situation in the heart of the Rocky mountains, beside one of the main routes across the continent.

The springs were the subject of a thorough investigation in 1916, the results of which are given in detail in Mines Branch report No. 472, pp. 126-151.

There are five hot springs at Banff: the Upper Hot Spring and the Kidney Spring in the northeast side of Sulphur mountain, 3 miles from the town; the Middle Spring, situated at the foot of the upper slope of Sulphur mountain, 2 miles from the town; and the Cave and the Basin springs nearer the town, on the lower slope of Sulphur mountain overlooking the Bow valley and Vermilion lake. The Upper Hot Spring and the Cave and Basin springs supply water for the Upper Hot Spring bathing pool and the Cave and Basin swimming bath respectively. The Kidney and Middle springs are not yet utilized.

In the spring of 1923, the Upper Hot Spring ceased to flow for a few weeks. It was therefore of importance to determine if the concentration of the mineral constituents of the spring water has been altered. Measurements with the conductivity bridge showed practically no change in composition, a result afterwards confirmed by the analyses which are reported later.

RADIOACTIVITY

No measurements of radioactivity were made on this occasion. The results obtained in 1916 were:—

Spring	Temperature	Rate of flow, gal. per hour	Radioactivity Units per litre-water		Gas evolved Units per litre
			Emanation	Dissolved radium	
Upper Hot	115	8,000	221	8·6	....
Kidney	101·5	1,200	392	8·5	....
Middle	92	6,000	294	8·6	1,910
Cave	85	15,000	470	8·5	3,340
Basin	94	10,000	232	8·5	2,370
Auto Road	67	6,000	640	23·5	....
Alpine Club	44	2,000	475	....	....

CHEMICAL CHARACTER

The waters of all the Banff springs are alike in character and composition and fall into the calcic, sulphated, saline class of mineral waters.

The chief constituents are calcium and magnesium sulphates, and calcium bicarbonate.

Measurements made with the conductivity bridge, as reported below, show that little variation in composition has taken place in the last eight years and the temperature has likewise changed little.

Mineral Matter in Solution[1]

(Parts per million)

Spring	By conductivity bridge 1923	Analysis, 1916	Temperature 1923	Temperature 1916
			°F.	°F.
Upper Hot	1120	1098	118	115
Middle	1047	1059	89	92
Cave	1109	1017	87	85
Basin	1660	1905	95	94

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[1] Complete analyses of these waters are given on pp. 128-148, Mines Branch Rept. 472.

The Upper Hot Spring water was the only one of which an analysis was made on this occasion. The report follows, together with the results of the 1916 work for comparison.

Banff, Upper Hot Spring

	1923	1916
Sample collected	August	Dec. 1916 and Jan. 1917
Temperature	118° F.	115° F.
Flow	—	120 gallons per minute
Taste	Flat, strong hydrogen sulphide	Flat, strong hydrogen sulphide
Reaction to methyl orange	Alkaline	Alkaline
Specific gravity at 15° C	1·002	1·002
Properties of reaction, per cent—		
Primary salinity	2·66	2·16
Secondary salinity	83·80	83·92
Secondary alkalinity	13·54	13·92

Analyses

Constituents	Parts per million		Total inorganic matter in solution, per cent	Reacting value, per cent
	1916	1923	1923	1923
Carbonic acid (CO_3)	....	....	....	....
Bicarbonic acid (HCO_3)	133	130	11·8	6·77
Sulphuric acid (SO_4)	634	640	58·0	42·37
Chlorine (Cl)	10	9·5	0·9	0·86
Sodium (Na)	5·3	7·0	0·6	0·95
Potassium (K)	3·7	4·7	0·4	0·38
Lithium (Li)	0·1	....	....	....
Calcium (Ca)	239	240·5	21·8	38·22
Strontium (Sr)	3·2	....	....	....
Magnesium (Mg)	39·7	39·8	3·6	10·54
Iron oxide and alumina (Fe_2O_3 and Al_2O_3)	1·7	....	....	....
Silica (SiO_2)	31	32·4	2·9	....
Total	1,100·7	1,103·9	100·0	100·0
Total solids in solution, residue dried at 110°C.	1,098	1,168		

Hypothetical Combinations

	Parts per million		Total inorganic matter in solution, per cent
	1916	1923	
Ammonium chloride (NH_4Cl)	0·27	....	....
Lithium chloride (LiCl)	0·59	....	....
Potassium chloride (KCl)	7·08	8·9	0·8
Sodium chloride (NaCl)	9·82	8·8	0·8
Sodium sulphate (Na_2SO_4)	4·40	10·6	0·9
Magnesium sulphate (Mg SO_4)	196·50	197·0	17·9
Calcium sulphate ($CaSO_4$)	672·20	673·0	61·0
Calcium bicarbonate ($Ca(HCO_3)_2$)	165·80	172·8	15·7
Strontium bicarbonate ($Sr(HCO_3)_2$)	7·65	....	....
Ferrous bicarbonate ($Fe(HCO_3)_2$)	5·43	....	....
Silica (SiO_2)	31·0	32·4	2·9
Total	1,100·7	1,103·5	100·0

The agreement between these analyses is good and shows that the temporary cessation in flow had no effect on the concentration or composition of the dissolved mineral matter in the water.

THE UTILIZATION OF BANFF HOT SPRINGS

It was shown in a previous report that there is a great similarity between the Banff springs and the famous springs at Bath in England, although the greatest contrast exists between the historic and antique setting of Bath and the mountainous and natural surroundings of Banff.

Similar applications of the waters at Banff could be, and are, used for medical treatment to some extent. The chief ailments in which such waters have proved efficacious are diseases of the skin, gout, chronic rheumatism and for the treatment of stiff joints.

But the main value of the Banff springs is undoubtedly their attraction for the tourists, who come to Banff from all quarters of the globe, and it is mainly in this connexion that the springs have been developed by the Dominion Parks Branch authorities.

No better situated swimming baths can be found on the continent than those at the Cave and Basin and at Banff Springs Hotel, surrounded as they are by towering mountains and snow-capped peaks and fed by continual streams of hot sulphur water.

THE COLUMBIA VALLEY DISTRICT

Radium Hot Springs

The Radium Hot Springs are situated in the western edge of the Rocky Mountain range near the west end of Sinclair pass and lie close beside the Kootenay Park gateway to the Banff-Windermere highway. They are about 8 miles from the town of Invermere on lake Windermere in the Columbia valley and about 80 miles from Banff by the highway. The nearest railway station is Firlands, on the Cranbrook-Golden branch of the Canadian Pacific railway.

The springs have been known since the earliest explorations of the Rocky mountains, though no reference to them is made by Sir George Dawson in his description of the Sinclair pass in a geological[1] report on this area of the Rocky mountains, nor by Sir George Simpson[2] in his explorations in 1841, though he also traversed the pass and referred to the wild gorge at the western end and to the red rock that is so striking a feature of the landscape. He visited the Fairmont Springs, however.

According to Sir George Dawson in a report[3] on "The Mineral Wealth of British Columbia," the springs were discovered by John McKay, who recorded temperatures of 108°F. and 118°F.

The springs were frequently visited by Indians and by the early settlers in the neighbourhood, who had great faith in the curative powers of the waters, especially for rheumatism and for recovery from the effects of excess alcohol.

In 1888, Mr. G. R. Stuart obtained a town grant of 160 acres, on part of which land the springs are situated. Some time before the motor highway was commenced, a company was formed to develop the springs and neighbourhood as a health resort, but beyond the construction of a concrete swimming bath, little was accomplished.

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[1] Geol. Surv., Canada, Ann. Rept., New Series, vol. I, pt. B, pp. 10 and 117 (1885).

[2] "Narrative of an Overland Journey around the World," vol. I, London, 1847.

[3] Geol. Surv., Canada, Ann. Rept., New Series, Vol. III, pt. R, p. 162 (1887-88).

It was not until the completion of the national highway last summer (1923) that the full possibilities for their development were opened up.

The springs are most attractively situated at the foot of a well-wooded mountain side, close beside the creek which runs down the valley, entering the Columbia valley through a deep canyon in the narrow Sinclair pass a mile below the springs. The swimming bath, about 30 feet wide and 72 feet long, separates the spring from the creek. One side of the bath forms with the rocks of the hill-side a bow-shaped basin. Although the water rises in three places in the hill-side it undoubtedly all comes from the same source, a fault running diagonally across the valley in a northeasterly direction. This fault can be traced in the opposite hill-side, especially in winter when the ground is snow-covered, and there are several openings from it called "smoke holes" from which steam issues in cold weather.

The valley is narrow and although laid out for a townsite, the area available is limited.

The water rises in a bow-shaped basin 50 feet long and 5 to 6 feet across at its widest. The pool varies from 3 to 4 feet in depth and the water, issuing from fissures in the hill-side, flows over the concrete wall into the swimming bath. It empties from the bath over a weir into the creek. Gas bubbles up intermittently from the sandy bottom of the basin.

The water, both in the basin and in the bath, is of a pale green colour and is very clear. Little deposit is formed and there is no odour of hydrogen sulphide from the water.

TEMPERATURE

The maximum temperature observed in August, 1923, was 114°F., just where the main flow of water issued from the rock. The swimming pool had an average temperature of about 100°F. It was interesting to observe that the temperature six inches below the surface was a degree or two warmer than that on the floor of the bath.

The water of the creek running beside the bath was very cold, only about 40°F.

FLOW

The most reliable estimate of flow was made by taking the time required to fill the bath after it had been emptied and cleaned. The pool is 72 feet long and 30 feet wide, and the water varies in depth from 18 inches at the shallow end to 6½ feet near the deeper end. The approximate volume is about 9,500 cubic feet. On August 18 the bath took three hours to fill to its usual depth. The flow was, therefore, about 330 gallons per minute, or about 500,000 gallons a day. The water in the pool is, therefore, changed about once every three hours.

RADIOACTIVITY

The electroscope was set up in a small pump house near the spring and although the humidity was high, the air leak of the gold leaf was consistent and satisfactory.

After preliminary tests had been made to determine the activity of the water, the following results were obtained in a series of determinations.

Water from Spring

—	Volume used	Leak Div. per min.	Leak for 1 litre Div. per min.	Radio-activity units
August 7	250 c.c.	8·00	32·00	9,600
" 8	250 "	8·64	34·76	10,328
" 9	250 "	7·70	30·80	9,240
Mean	....	....	....	9,723

Water from Creek

August 8	4,000 c.c.	Nil	Nil	Nil

Gas Bubbling in Basin

August 9	1,068 c.c. at N.T.D.	162	151	45,753

Measurements of the dissolved radium content made during the winter in the laboratory gave the mean result of 96 units (96 x 10^{-12} curies).

Boyle and McIntosh who made measurements on this spring in 1912 obtained the following results:[1]

Temporary radioactivity.... 4,000 units (4,000 x 10^{-12} grm. Ra.)
Dissolved radium........... trace

Another determination made at McGill University was reported to give: Dissolved radium, 270 units (27 x 10^{-12} grm. Ra.)

CHEMICAL CHARACTER

The water of the Radium Hot Springs resembles that at Banff in general character, though it contains a slightly smaller quantity of material in solution. It is a saline calcic sulphated mineral water.

The report of analysis follows:—

Radium Hot Springs Water

Colour	Pale green
Turbidity	Clear
Taste	Flat
Reaction to methyl orange	Alkaline
Specific gravity at 15° C	1·0015
Properties of reaction, per cent—	
Primary salinity	5·94
Secondary salinity	59·46
Secondary alkalinity	34·60

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[1] Roy. Soc. Canada, Proc., vol. VII, p. 163 (1913).

Analyses

Constituents	Parts per million	Total inorganic matter in solution, per cent	Reacting value, per cent
Bicarbonic acid (HCO_3)	216	28·6	17·30
Sulphuric acid (SO_4)	306	40·6	31·00
Chlorine (Cl)	12·4	1·7	1·70
Sodium (Na)	12·0	1·6	2·68
Potassium (K)	3·1	0·4	0·39
Calcium (Ca)	140·5	18·6	34·18
Magnesium (Mg)	32·0	4·2	12·85
Iron oxide and alumina	....	....	....
Silica (SiO_2)	32·6	4·3	....
	754·6	100·0	100·00
Total solids in solution, residue dried at 110°C	696		

Hypothetical Combinations

	Parts per million	Total inorganic matter in solution, per cent
Sodium chloride (NaCl)	15·8	2·1
Potassium chloride (KCl)	6·0	0·8
Sodium sulphate (Na_2SO_4)	18·5	2·5
Magnesium sulphate ($MgSO_4$)	158·0	20·9
Calcium sulphate ($CaSO_4$)	237·0	31·4
Calcium bicarbonate ($Ca(HCO_3)_2$)	287·0	38·0
Silica (SiO_2)	32·6	4·3
Total	754·9	100·0

The following analyses were made in England by the *Lancet* in 1913. The samples were taken from the three pools which were in existence before the swimming bath was built. The results were reported in grains per gallon and have been converted into parts per million for comparison with the more recent analysis.

Constituents	A		B		C	
	Grains per gallon	Parts per million	Grains per gallon	Parts per million	Grains per gallon	Parts per million
Calcium sulphate ($CaSO_4$)	36·17	516·0	34·26	490·0	33·11	473·0
Magnesium sulphate ($MgSO_4$)	11·20	160·0	10·90	156·0	9·80	140·0
Aluminum sulphate ($Al_2(SO_4)_3$)	7·04	100·5	....	....	....	....
Sodium chloride (NaCl)	5·00	71·5	2·70	38·6	1·16	16·6
Strontium sulphate ($SrSO_4$)	1·71	24·4	3·36	48·0	1·82	48·6
Calcium carbonate ($CaCO_3$)	1·12	16·0	6·55	93·6	3·40	83·6
Silica (SiO_2)	2·66	38·0	2·59	37·0	5·85	26·0
Total	64·90	926·4	60·36	863·2	55·14	787·8

It would seem from these analyses that the concentration of mineral constituents has slightly decreased. Considering the time that has elapsed since these analyses were made and the conditions under which the samples were collected and shipped, the agreement is good.

THE POSSIBILITIES FOR DEVELOPMENT

The possibilities for the development of Radium Hot Springs are considerable. With the wonderful mountain scenery all around and with the excellent motor highway giving access to the beautiful Columbia valley and to Banff and Lake Louise, great numbers of tourists will pass through this locality. Already the Canadian Pacific Railway has established one of its bungalow camps with the customary high standard of comfort.

There are also other facilities for the supply of gasoline, oil, food, and accommodation. Many of the passers-by avail themselves of the opportunity of visiting the swimming pool while entering or leaving Kootenay Park, through the artistic gateway erected by the Dominion Parks Branch.

The Fairmont Hot Springs

The Fairmont Hot Springs are situated in the Columbia valley on the southwestern slope of the last range of the Rocky mountains, about 13 miles south of Windermere, and 2 miles from the lower end of lake Windermere. They lie about a mile up from the main road from Cranbrook to Golden, on a gently sloping, wooded bench, 500 feet above the river.

They are referred to by Sir George Dawson in a report[1] on the Columbia-Kootenay valley, and were visited by Sir George Simpson in 1841, who wrote as follows:—

> Near our encampment, we observed that the stones in the bed of a little stream were covered with a yellow crust. Before starting for the day Berland (his half-breed guide) conducted us to three hot springs, about three miles distance, which doubtless caused the phenomenon in question. The waters tasted slightly of alum, and appeared to contain a little magnesia, and though we neglected to take our thermometer with us yet on returning to camp we estimated the three temperatures respectively at about ninety, a hundred, and a hundred and twenty degrees. Two winters back, Berland while suffering from a severe illness, made a bathing place of the springs, and he actually was or believed that he was, benefited by them.[2]

The property on which the springs are situated comprises about one thousand acres and is owned by Mr. H. Heap Holland of Manchester, England. The springs are being developed as a health and tourist resort.

There are a number of springs in the vicinity. Four rise in the bed of a creek running down from the mountains to the Columbia river. The valley in which this creek runs is about one hundred yards wide at its maximum, and is filled with stones and timber brought down by a cloudburst in 1916. The creek, a few feet wide in summer, winds a circuitous path through the valley, and the springs issue in several places from under piles of debris, forming small pools, which are used for bathing by invalids. Two other springs issue from the ground at the top of a knoll five hundred yards to the northeast of the camp which has been made and at a higher elevation.

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[1] Geol. Surv., Canada, Ann. Rept., New Series, vol. I, pt. B, p. 154 (1885).
[2] Narrative of an Overland Journey around the World, Vol. I, p. 128.

DESCRIPTION OF SPRINGS

The several springs probably all come from the same source and the differences observed probably depend on the degree of infiltration of creek water with the original spring water. The names given to the various outlets were either the popular name or one chosen at random for purposes of reference. The first four springs are situated in the creek valley.

No. 1, "Indian Pool." This spring farthest up the valley, forms a pool almost circular in shape, about twenty feet in diameter. The water is two feet deep and the overflow runs away in several channels. Gas bubbles up intermittently from the sandy floor of the pool. The temperature was 98°F. (Aug. 13, 1923).

No. 2, Log Pool. Water flows from under a fallen tree into a pool eight feet long by four feet wide, formed by logs. The depth was about two feet and the temperature 107°F. The flow was good.

No. 3, Swimming Bath Spring. This spring, flowing strongly, runs into a rough log pool about four feet wide and six feet long. The water is led by a wooden flume down the hill to supply the swimming bath. The temperature was about 102°F. at the source.

No. 4, "Perrier" Spring. Spring No. 4 was noticeable for the gas which was evolved in the small pool in which it rises. The flow was smaller than the others, being only about 10 gallons per minute. The temperature was 86°F.

No. 5 and No. 6, Hot Bath Springs. Both these are situated on a knoll northeast of the camp. This hill is covered to a depth of several feet with calcareous tufa deposited from the waters flowing down it. Both springs issue from small holes in the hill and flow into small baths dug out of the rock. Small frame buildings have been erected over these baths.

RADIOACTIVITY

Tests were made on all these springs and the results are tabulated below. The determinations of total solids made by the conductivity bridge are included.

Spring	Temperature °F	Mineral matter in solution. Parts per million		Radioactivity	
		Bridge	Analysis	Temporary units	Dissolved radium units
No. 1 Indian Pool	98	1,950		2,052	
No. 2 Log Pool	107	1,995		1,416	
No. 3 Swimming Bath	102	1,828	1,832	1,044	
No. 4 Perrier	86	1,820		1,368	
No. 5 Hot Bath	112	2,340	2,449	3,180	105
Creek water	64	100		nil	

A sample of gas collected from the Indian Pool had a temporary radioactivity of 15,780 units per litre, measured at 0°C. and 760 mm. The radioactivity of spring No. 5, was measured by Prof. D. McIntosh of McGill University in 1912. He found the temporary radioactivity to be 3,500 units ($3\cdot5 \times 10^{-9}$ grm. radium per litre). These results agree closely with the recent determinations.

CHEMICAL CHARACTER OF THE WATERS

The waters resemble in some respects those at Banff and the Radium Hot Spring water in that calcium and magnesium are the predominating constituents. But they are more concentrated and contain greater quantities of calcium and magnesium bicarbonates which are deposited as the waters lose carbon dioxide after exposure to the atmosphere.

There is little or no hydrogen sulphide present.

The following results were obtained by the analysis of samples collected from Spring No. 3, which supplies the Swimming Bath, and Spring No. 5, the most concentrated and most radioactive.

Fairmont Hot Springs

	Spring No. 3	Spring No. 5
Colour	Pale blue	Pale blue
Turbidity	Slight	Slight
Taste	Flat	Flat
Reaction to methyl orange	Alkaline	Alkaline
Specific gravity at 15°C	1·0025	1·0031
Properties of reaction, per cent—		
Primary salinity	5·58	5·20
Secondary salinity	57·84	58·00
Secondary alkalinity	36·58	36·80

Analyses

Constituents	Parts per million		Total solids in solution, per cent		Reacting values, per cent	
	No. 3	No. 5	No. 3	No. 5	No. 3	No. 5
Bicarbonic acid (HCO_3)	574·0	770·0	31·3	31·4	18·29	18·40
Sulphuric acid (SO_4)	740·0	980·0	40·4	40·0	29·90	29·80
Chlorine (Cl)	32·5	43·5	1·7	1·8	1·81	1·80
Sodium (Na)	30·1	37·3	1·6	1·6	2·54	2·36
Potassium (K)	5·0	5·5	0·3	0·2	0·25	0·24
Calcium (Ca)	348·0	485·5	19·1	19·8	33·78	35·40
Magnesium (Mg)	84·0	100·0	4·6	4·1	13·43	12·00
Iron oxide and alumina						
Silica (SiO_2)	19·3	27·4	1·0	1·1		
Total	1,832·1	2,449·2	100·0	100·0	100·00	100·00
Total solids in solution, residue dried at 110°C.			No. 3 1,640	No. 5 2,300		

Hypothetical Combinations

—	Parts per million		Total solids in solution per cent	
	No. 3	No. 5	No. 3	No. 5
Sodium chloride (NaCl)	46·8	63·2	2·5	2·8
Potassium chloride (KCl)	9·7	10·4	0·5	0·5
Sodium sulphate (Na_2SO_4)	36·2	38·3	2·0	1·7
Magnesium sulphate ($MgSO_4$)	415·0	494·0	22·6	20·1
Calcium sulphate ($CaSO_4$)	544·0	782·0	29·9	32·0
Calcium bicarbonate ($Ca(HCO_3)_2$)	762·0	1,024·0	41·5	41·8
Iron oxide and alumina				
Silica (SiO_2)	19·3	27·4	1·0	1·1
Total	1,833·0	2,449·3	100·0	100·0

DEVELOPMENT OF THE SPRINGS

These springs offer good possibilities of development as a health resort and tourist centre. The situation is good and the views up and down the Columbia valley across to the Selkirks are exceptionally fine, and rival those from the Government swimming bath at Banff. In the summer of 1923 a number of bungalow tents were available for guests, and a dining room and other buildings were in course of erection. Camping sites were also prepared with stoves and water, etc. A splendid cement swimming pool 60 feet long and 40 feet wide, varying in depth from 2 to 6 feet, was built, together with comfortable dressing rooms.

The pool is fed from Spring No. 3, and had a temperature of 90°F. in August. The inflow of water is about 60,000 gallons per hour. The water is a deep blue colour but usually cloudy, owing to the calcium carbonate precipitated from solution and held in suspension in the water.

The small baths and pools formed by the various springs offer good facilities for the treatment of rheumatic patients and others. Some of the pools are reserved for and used by the Indians who live on the Shuswap and Kootenay reserves nearby.

Toby Creek Springs

Several springs are known in the west side of the Columbia valley. Dr. R. W. Brock refers[1] to a series of "soda" springs situated along the banks of a tributary stream to Toby creek which, itself, flows into the Columbia river near Athalmer at the head of lake Windermere.

These springs deposit lime and some iron, forming a reddish-coloured tufa.

It is probable that the waters resemble the Fairmont waters in composition. These springs were not examined during the recent investigation.

THE ARROW LAKES DISTRICT

Halcyon Hot Springs

Halcyon Hot Springs, on the northeast shore of the Upper Arrow lake, in the centre of the Selkirk mountains, was one of the earliest places in western Canada to be developed as a mineral spring resort. The springs were examined by Sir George Dawson during a reconnaissance of the west Kootenay district in 1889, who referred[2] to them as somewhat remarkable hot springs, situated on a rather steep, wooded mountain slope, 11 miles from the head of the Upper Arrow lake.

He found the temperature to be 123·5°F. and noted a strong smell of hydrogen sulphide. His study of the geology of the district showed that the springs flow through granitic and gneissic rocks and crystalline schists.

The sanitarium established in 1888 stands on a plateau about 1,450 feet above the level of the lake and the terraces and balconies afford a magnificent vista of lake and mountain. It is reached by C.P.R. steamboat either from Arrowhead or West Robson, and is, therefore, convenient to the main transcontinental line at Revelstoke, or to the Kettle Valley line.

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[1] Geol. Surv., Canada, Sum. Rept. 1909, p. 28.

[2] Geol. Surv., Canada, Ann. Rept., New Series, vol. IV, pt. B, p. 12 (1888-89).

There are three springs which rise from fissures in rock outcrops higher up the mountain side, 500 feet above the hotel. The overflow from the small pools, is conveyed by an 8-inch wooden pipe down the hill-side, where it supplies the baths in the sanitarium, generates electric power for lighting and supplies power to operate the necessary machinery.

The largest spring runs from a fissure in a rock outcrop, filling a basin 3 by 4 feet and about 2 feet deep. Much gas bubbles up from the sandy bottom, which is in continual agitation.

The water in each of the pools has a bluish tinge and the usual algae associated with sulphur waters abound, although there is no calcareous deposit.

The flow from the springs is considerable, probably about two thousand gallons per hour. Tests showed that the composition of the water in each of the three springs was identical. The temperature of the two main pools was 128°F. and that of the third pool was 120°F.

RADIOACTIVITY

Several determinations were made on samples taken from each spring, using different amounts of water. Similar results were obtained in each case, the tests giving a value of 300 units for the temporary radioactivity. Measurements on 15 litres of water from the main spring, carried out later in the laboratory, showed the dissolved radium content per litre to be 9 units. The radioactivity of these springs is therefore small.

CHEMICAL CHARACTER

The waters of the springs are lightly mineralized sulphur waters, containing chiefly sodium and calcium sulphates with small amounts of alkali chlorides. Hydrogen sulphide, which is present to the extent of 8 c.c. per litre, or 13 parts per million by weight, gives the predominant taste.

Halcyon Springs

	Lithia water
Colour	Pale blue
Turbidity	Clear
Taste	Strong of hydrogen sulphide
Reaction to methyl orange	Alkaline
Specific gravity at 15°C.	1·1016
Properties of reaction, per cent—	
Primary salinity	71·74
Secondary salinity	20·40
Secondary alkalinity	7·86

Analyses

Constituents	1923	Previous analysis	Total solid matter in solution,	Reacting value,
	Parts per million		per cent	per cent
Bicarbonic acid (HCO_3)	48·2		6·1	3·93
Sulphuric acid (SO_4)	433·0	363·43	55·0	44·83
Chlorine (Cl)	9·0	8·14	1·1	1·24
Sodium (Na)	161·0	5·71	20·5	34·83
Potassium (K)	8·1		1·0	1·04
Lithium (Li)		0·86		
Calcium (Ca)	57·2	84·0	7·3	14·13
Magnesium (Mg)	trace			
Silica (SiO_2)	71·3		9·0	
Total	787·8		100·0	100·0
Total solids in solution, residue dried at 110°C.	802			

Hypothetical Combinations

—	Parts per million	Total solid matter in solution, per cent
Sodium chloride (NaCl)	2·3	0·3
Potassium chloride (KCl)	15·6	2·0
Sodium sulphate (Na_2SO_4)	487·0	61·0
Magnesium sulphate ($MgSO_4$)	Trace	
Calcium sulphate ($CaSO_4$)	147·5	18·7
Calcium bicarbonate ($Ca(HCO_3)_2$)	64·0	8·1
Silica (SiO_2)	71·3	9·0
Total	787·7	100·0

The water was carefully examined in 1917 by Dr. McGill, then Chief of the Inland Revenue laboratory. He reported a relatively large amount of lithium to be present, a constituent at one time considered to be of great therapeutic value. Lithium was not determined in the recent analysis.

ECONOMIC CONSIDERATIONS

The present sanitarium at Halcyon springs was built in 1893 and at one time enjoyed a widespread reputation as a curative centre for many kinds of ailments. Of late years, it has felt the depression in business incident to the war. It depends almost entirely on invalids for its patrons. There are good plunge baths for ladies and gentlemen and the customary facilities for utilizing the curative effects of hot sulphur waters. The springs undoubtedly have considerable therapeutic value and compare most favourably with European and American waters of similar character.

Other Springs on the Upper Arrow Lake

One spring occurs situated near Nakusp, on the east side of the Upper Arrow lake. The water from this spring was examined in 1898 by F. G. Wait.[1] It was found to contain 510 parts per million of dissolved mineral matter, chiefly calcium sulphate, with smaller amounts of sodium chloride, and calcium and magnesium bicarbonates.

On the opposite side of the lake, about half-way between Nakusp and Halcyon, two springs[2] have been reported on mount Baldur between Fosthall and Pingston creeks. These contained respectively 1,960 and 740 parts per million of dissolved mineral matter, chiefly consisting of calcium sulphate and bicarbonate.

Ainsworth Hot Spring

The Ainsworth Hot Spring is situated on the west side of Kootenay lake, 8 miles north of the West arm and about 26 miles from Nelson. Before the advent of the railway, the spring was on one of the chief travelled waterways and attracted the attention of the prospectors engaged in opening up the mineral wealth of that area.

Sir George Dawson visited the district in 1888–1889 and referred to the spring in his report.[3] He described it as follows:—

> Unlike the hot springs on Upper Arrow Lake, these give rise to a copious calcareous deposit, which extends for about 300 feet along the edge of the lake, and forms a little terrace with a height at the front of about 20 feet, and sloping gradually up toward the foot of the hill. At the southern end, a lower floor of the deposit, nearly on the level of the lake-shore presents a number of basin-like pools with well-marked rims, into which the water trickles. The principal visible flow occurs on the summit of the little terrace, where there is one main orifice with several surrounding smaller ones. There are as well, however, several outflows along the edge of the water, where the terrace has been cut into a rough low cliff, and there are very probably others also beneath the surface of the water of the lake. It is thus impossible even to guess the volume of water rising from these springs, but that afforded by the principal orifice on the terrace was roughly estimated at about sixty gallons per minute. The temperature of the water on June 25, was found to be 101·5°F. It has a slightly saline and rather pleasant taste. The calcareous deposit is a porous travertin of a cream colour, which forms more or less parallel on concentric layers.

The only analysis of the water available is that made in 1899 by A. H. Holdich.

The results of this analysis,[4] recalculated to make the method uniform with that used in this report, were as follows:

Colour	Colourless
Turbidity	Slight
Taste	Salty and alkaline
Properties of reaction, per cent—	
Primary salinity	11·8
Primary alkalinity	47·6
Secondary alkalinity	40·6

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[1] Geol. Surv., Canada, Ann. Rept., vol. XI, pt. R, p. 54 (1898).
[2] Geol. Surv., Canada, Ann. Rept., vol. IX, pt. R., p. 49 (1896).
[3] Geol. Surv., Canada, Ann. Rept., vol. IV, pt. B., p. 26 (1889-90).
[4] Schofield, S. J.: "The Geology and Ore Deposits of the Ainsworth Mining Camp," Geol. Surv., Canada, Mem. 117, p. 1 (1920).

Constituents	Parts per million	Reacting value, per cent
Bicarbonic acid (HCO_3)	1,144·0	44·10
Sulphuric acid (SO_4)	37·6	1·76
Chlorine (Cl)	62·5	4·14
Sodium (Na)	290·1	29·70
Calcium (Ca)	150·0	17·65
Magnesium (Mg)	13·8	2·65
Iron oxide (FeO)	1·3	....
Silica (SiO_2)	66·9	....
Total	1,766·2	100·0

A part analysis of the earthy calcareous deposit around the spring was made in 1916 by H. A. Leverin, Chemical Division, Mines Branch, on a sample collected by A. W. G. Wilson.

The results were:—

	Per cent
Lime	53·64
Insoluble residue	0·52
Zinc	0·51
Lead, gold, silver	nil

In view of the ore deposits which exist in this region a more detailed study of the water and its deposit would be of great interest.

Harrison Hot Springs

Harrison Hot Springs are splendidly situated near the south end of Harrison lake, 5 miles northwest of Agassiz on the transcontinental line of the Canadian Pacific railway. They are about 50 miles from Vancouver but at present the best road is through Chilliwack, a distance of 80 miles.

The springs, two in number, rise from fissures in the rocky shore of the lake, about a quarter of a mile from the settlement. Concrete walls have been built around the springs to protect them from encroachment by the waters of the lake, which is normally about a foot lower than the level of the springs. The larger basin, enclosing the "sulphur" spring, is about 20 feet wide and 30 feet long, with a wooden platform built around. The "potash" spring rises in a similar basin about 15 by 15 feet. The depth of water in the pools is from 5 to 7 feet and has the appearance of boiling owing to the steam given off, and the constant evolution of large quantities of gas from various places in the bottom. The temperature of the sulphur spring was 145°F. and of the potash spring 140°F. in August, 1923. It is said not to vary much the year round. These are the hottest springs known in Canada. The flow of the sulphur spring was reported to be about 3,000 gallons per hour.

A frame house adjoining the springs encloses a cement pool 15 feet wide and 20 feet in length into which the hot water from the springs is pumped several times a day. The temperature of the water in the bath is maintained between 95° and 110°F.

RADIOACTIVITY

A frame building near the springs was used as a temporary laboratory in which the usual determinations were carried out. Duplicate experiments gave closely agreeing results, as follows:—

—	Temperature °F.	Amount water used litres	Radioactivity per litre units	Dissolved radium units
Potash spring	140	4	345	....
Sulphur spring	145	4	252	2
Gas from sulphur spring	....	....	6,940	....

CHEMICAL CHARACTER

The waters are of the usual lightly mineralized sulphur type, although the alkali chloride content is larger than in the Halcyon or Fairmont waters. Hydrogen sulphide is a noticeable constituent, occurring to the extent of 5 c.c. per litre or 8 parts per million.

Analyses of samples from both springs were carried out with the following results.

Harrison Hot Springs

	Sulphur spring	Potash spring
Colour	Pale green	Pale green
Turbidity	Very slight	Clear
Taste	Hydrogen sulphide	Hydrogen sulphide
Reaction to methyl orange	Alkaline	Alkaline
Specific gravity at 15°C	1·002	1·002
Properties of reaction, in per cent—		
Primary salinity	76·00	74·60
Secondary salinity	22·22	23·30
Secondary alkalinity	1·78	2·10

Analyses

Constituents	Parts per million		Total solids in solution, per cent		Reacting value, per cent	
	Sulphur	Potash	Sulphur	Potash	Sulphur	Potash
Bicarbonic acid (HCO_3)	21·3	24·0	1·6	1·6	0·89	1·05
Sulphuric acid (SO_4)	513·0	480·0	38·5	37·3	27·47	26·95
Chlorine (Cl)	300·0	290·0	22·5	22·4	21·64	22·00
Sodium (Na)	332·0	318·0	25·0	25·0	37·10	37·30
Potassium (K)	14·3	....	1·1	....	0·90	....
Calcium (Ca)	89·3	89·3	6·7	7·0	11·43	12·04
Magnesium (Mg)	2·7	3·0	0·2	0·2	0·57	0·66
Iron oxide and alumina	trace	....	....	....	....	....
Silica (SiO_2)	59·1	74·0	4·4	5·5	....	....
Total	1,331·7	1,278·3	100·0	100·0	100·0	100·00
Total solids in solution, residue dried at 110°C	1,367	1,285	....	....	....	....

Hypothetical Combinations

—	Parts per million		Total solids in solution	
	Sulphur	Potash	Sulphur	Potash
Sodium chloride ($NaCl$)	473·0	478·0	35·4	37·3
Potassium chloride (KCl)	27·6	....	2·1	....
Sodium sulphate (Na_2SO_4)	452·0	402·5	34·0	31·6
Magnesium sulphate ($MgSO_4$)	13·3	15·0	1·0	1·2
Calcium sulphate ($CaSO_4$)	279·0	277·4	21·0	21·6
Calcium bicarbonate ($Ca(HCO_3)_2$)	28·3	31·6	2·1	2·5
Iron oxide and alumina	trace	....	....	....
Silica (SiO_2)	59·1	74·0	4·4	5·8
Total	1,332·3	1,278·5	100·0	100·0

ECONOMIC DEVELOPMENT

The springs have been known as a health resort for many years and at one time, before the St. Alice hotel was destroyed by fire in 1920, were visited by many in search of health or pleasure. They are the property of the North Pacific Lumber Co., Ltd., of Barnet, forming part of a timber limit of a thousand acres. At present, accommodation is afforded at several cottages along the lake front and a number of persons suffering from rheumatism and other diseases come to bathe and drink the waters daily.

There are great possibilities for developing these springs both from the therapeutic and from the tourist point of view. They are the best situated of any of the hot springs in British Columbia in regard to a centre of population.

Hot Springs in Jasper Park

Hot springs occur in Jasper Park, on Sulphur creek, about 1¾ miles from its junction with Fiddle creek. They are about 10 miles from the Jasper Park station. Dr. Dowling reported[1]:—

> About 1¾ miles up Sulphur creek, at the centre of a broken anticline in which the limestones are standing at a high angle, great boulders of travertine are seen in the bed of the creek, and on the hillside to the north. These show that the springs, which deposited the material of which they are made, issued from points above the present surface. On account of the denudation of the gorge the springs are now tapped at a lower level, and issue by several openings, apparently, in the case of the larger spring, through loose fragments. The fissuring through which these springs emerge is confined to a zone possibly 200 feet wide and as many as 6 separate springs are to be found, mostly near the bed of the creek, and of differing temperatures from tepid to 120° F. The water is charged with gases that give off a smell of sulphur.

No measurements of the radioactivity of these springs have been made but samples have been analysed at different times.

The following results have been reported, though no particulars by which the springs sampled can be identified, were given by those who took the samples. However, it is evident from the analyses that they are not the same springs.

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[1] Dowling, D. B.: "The Coal Fields of Jasper Park," Geol. Surv., Canada, Sum. Rept. 1910, p. 166.

Jasper Hot Springs

	Sulphur Springs,[1] A	Jasper Park,[2] B
Sample collected	May, 1915	——
Taste	Slight taste of hydrogen sulphide	No marked taste
Turbidity	Clear	Clear and sparkling
Reaction to methyl orange	Alkaline	Alkaline
Specific gravity at 15°C.	1·0004	
Properties of reaction, per cent—		
Primary salinity	26·20	3·6
Secondary salinity	18·16	81·8
Secondary alkalinity	55·64	14·6

Analyses

Constituents	A	B	A	B	A	B
	Parts per million		Total solids in solution, per cent		Reacting value per cent	
Carbonic acid (CO_3)	....	116	....	....	....	7·3
Bicarbonic acid (HCO_3)	280·6	....	45·8	....	27·82	....
Sulphuric acid (SO_4)	114·8	1,068	18·7	....	14·46	42·3
Chlorine (Cl)	45·0	7	7·3	....	7·72	0·4
Phosphoric acid (PO_4)	....	....	....	....	....	....
Calcium (Ca)	85·9	299	14·0	....	26·00	38·0
Magnesium (Mg)	21·8	65·2	3·5	....	10·90	10·2
Strontium (Sr)	trace	....	....	....	....	....
Sodium (Na)	50·0	12·6	8·1	....	13·10	1·0
Potassium (K)	trace	17·3	....	....	....	0·8
Iron oxide and alumina	7·3	trace	....	....	....	....
Silica (SiO_2)	8·9	45·0	....	....	....	....
Total	614·3	1,740·0	100·0	....	100·00	100·00
Total solids in solution, residue dried at 110°C	503	1,825				

Hypothetical Combinations

——	A	B	A	B
	Parts per million		Total solids in solution, per cent	
Sodium chloride (NaCl)	82·4	11	13·4	0·6
Potassium sulphate (K_2SO_4)	....	39	....	2·2
Sodium sulphate (Na_2SO_4)	54·4	27	8·8	1·6
Calcium sulphate ($CaSO_4$)	....	1,104	....	63·4
Magnesium sulphate ($MgSO_4$)	100·0	324	16·3	18·6
Calcium carbonate ($CaCO_3$)	....	193	....	11·1
Calcium bicarbonate ($Ca(HCO_3)_2$)	348·0	....	56·7	....
Magnesium bicarbonate ($Mg(HCO_3)_2$)	13·3	....	2·2	....
Calcium phosphate (Ca_3PO_4)	....	trace	....	....
Iron oxide and alumina	7·3	trace	1·2	....
Silica (SiO_2)	8·9	45	1·4	2·5
Total	614·3	1,742	100·0	100·0

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[1] Analysis, Mines Branch, Rept. 472, p. 125.

[2] Analysis, Chemical Division, Experimental Farm, Dept. of Agriculture, loc. cit., p. 167. This analysis was recalculated to ionic for n for comparison.

Water No. B closely resembles the Banff waters while No. A is less concentrated and contains a higher percentage of constituents giving the property of secondary alkalinity.

Hot Springs in Lillooet River Area, B.C.

Several hot springs are known at widely separated points in this district. Samples of the waters from three springs examined in 1924 by C. E. Cairnes, of the Geological Survey, were submitted for analysis.

Dr. Cairnes has kindly supplied the following particulars of the location of these springs.

Sample A. August Jacob's Creek

The spring is located in the valley of August Jacob's (or Jacob) creek at an elevation of about 2,000 feet above and 1½ miles east of Lillooet river opposite I.R. No. 10 which is located about 11 miles northwest of Douglas, situated near the head of Harrison lake.

The temperature is 120°F. and the flow is small, the spring issues from a crevice near the centre of a belt of metamorphosed, probably sedimentary rocks about half a mile wide and lying between large bodies of coarse-grained intrusive batholithic rocks of the composition of diorite or quartz-diorite.

Sample B. Skookumchuck

This spring is located on the southern end of lot 1747, about 1½ miles above the cable crossing Lillooet river near the Indian village of Skookumchuck, and about 20 miles northwest of Douglas near the head of Harrison lake.

The spring is too hot for bathing. The underlying rocks are poorly exposed but are probably altered sedimentary types which have suffered considerable metamorphism from neighbouring intrusives which are abundantly represented on both sides of the river and include batholithic as well as hypabyssal types.

This spring is small. There are crude facilities for bathing which are utilized by the Indians in the valley.

Sample C. Sloquet Creek

The spring is located near the creek level of Sloquet (Spring) creek about 10 miles from its mouth. Sloquet creek enters Lillooet river from the west about 3 miles above the head of Harrison lake.

The spring was said to be very copious and hot enough to boil eggs in. It issues from sedimentary rocks probably of Jurassic age. No intrusive rocks were noted in the vicinity of this spring.

The results of the analyses[1] were as follows:—

Lillooet Hot Springs

	Sample A	Sample B	Sample C
Colour	Water white	Water white	Water white
Turbidity	Clear	Clear	Clear
Taste	Flat	Flat	Flat
Reaction to methyl orange	Alkaline	Alkaline	Alkaline
Specific gravity at 20°C	1·0006	1·0001	1·0009
Properties of reaction, per cent—			
Primary salinity	2·0	26·0	46·8
Secondary salinity	86·4	65·0	45·4
Secondary alkalinity	11·6	9·0	7·8

Analyses

Constituents	Parts per million			Total inorganic matter in solution, per cent			Reacting value, per cent		
	A	B	C	A	B	C	A	B	C
Bicarbonic acid (HCO_3)	36	109	48	9·8	8·5	6·5	5·8	4·5	3·9
Sulphuric acid (SO_4)	162	413	360	44·2	32·3	48·6	33·4	21·6	37·3
Chlorine (Cl)	39	338	63	10·6	26·4	8·5	10·8	23·9	8·8
Sodium (Na)	3	119	108	0·8	9·3	14·6	1·0	13·0	23·4
Calcium (Ca)	32	169	94	8·7	13·2	12·6	15·8	21·2	23·5
Magnesium (Mg)	41	76	7·7	11·2	5·9	11·0	33·2	15·8	3·1
Silica (SiO_2)	54	56	61	14·7	4·4	8·2	......	......	......
Total	367	1280	741·7	100·0	100·0	100·0	100·0	100·0	100·0
	A			B			C		
Total solids in solution, residue dried at 110°C	394			1,313			643		

Hypothetical Combinations

	Parts per million			Total inorganic matter in solution, per cent		
	A	B	C	A	B	C
Sodium chloride (NaCl)	5·8	504	103	1·6	23·8	13·9
Sodium sulphate (Na_2SO_4)	....	....	206	....	....	28·1
Magnesium chloride ($MgCl_2$)	47·6	206	37·9	13·0	16·1	5·1
Magnesium sulphate ($MgSO_4$)	142·5	116	....	38·9	19·0	....
Calcium sulphate ($CaSO_4$)	68·7	454	268	18·7	135·5	36·2
Calcium bicarbonate ($Ca(HCO_3)_2$)	47·8	144	63·2	13·1	11·2	8·5
Silica (SiO_2)	54·0	56	61·1	14·7	4·4	8·2
Total	366·4	1,280	741·2	100·0	100·0	100·0

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[1] Analyses by R. J. Offord.

Vancouver Island

Few springs are known in Vancouver island. The one that has received the most attention is the Sharp Point Hot Spring.

This spring is situated on the west coast of the island, near Sharp point, between Sidney inlet to the east and Refuge cove to the west.

It has been known for many years and an analysis was first carried out in 1898. The following information is taken from a report[1] on this spring made in 1913 by C. H. Clapp of the Geological Survey.

The water issues from a shear zone in the diorite and the flow in 1913 was estimated to be about 100 gallons per minute. The temperature at the orifice was 125°F. (52°C.). Clapp after comparing the nature and amount of the constituents of the spring water with those of seawater and of the Rotorua geyser water, New Zealand, comes to the conclusion that the origin of the spring is probably seawater which penetrates the sheared diorite to such depths that it becomes heated. He considers that the Sharp Point spring is favourably located for a summer resort on account of its situation and climate. The analysis, made by F. G. Wait[2] in 1898, recalculated to the usual form of statement, was as follows:—

Sharp Point Hot Spring

Temperature	125° F.	
Taste	Salt and of hydrogen sulphide.	
Specific gravity at 15·5° C	1·0005	
Properties of reaction, per cent—	Spring water	Seawater
Primary salinity	84·7	78·6
Secondary salinity	15·3	21·1
Secondary alkalinity	....	0·3

Analyses

Constituents	Sharp Point Hot Spring		Ocean water	
	Parts per million	Reacting value, per cent	Parts per million	Reacting value, per cent
Carbonate (CO_3)	....	....	70	0·16
Sulphate (SO_4)	47	6·89	2,700	4·62
Chlorine (Cl)	217	43·13	19,350	45·15
Bromine (Br)	....	none	60	....
Sodium (Na)	137	42·00	10,710	38·49
Potassium (K)	2	0·36	390	0·82
Calcium (Ca)	20	7·04	420	1·77
Magnesium (Mg)	1	0·58	1,300	....
Silica (SiO_2)	59	....	....	....
Total	483	100·00	35,000	100·00

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[1] Clapp, C. H.: "Sharp Point Hot Spring, Vancouver Island," Geol. Surv., Canada, Sum. Rept. 1913, pp. 80-83.

[2] Geol. Surv., Canada, Ann. Rept., vol. XII, pt. R, p. 56 (1899).

Hypothetical Combinations

—	Sharp Point Hot Spring	
	Parts per million	Total inorganic matter, per cent
Potassium chloride (KCl)	3	0·6
Sodium chloride (NaCl)	348	72·0
Calcium chloride ($CaCl_2$)	2	0·4
Magnesium chloride ($MgCl_2$)	5	1·1
Calcium sulphate ($CaSO_4$)	66	13·7
Silica (SiO_2)	59	12·2
Total	483	100·0

A further part analysis in 1913 by H. A. Leverin of the Mines Branch confirmed this earlier result and showed that no change had taken place in the fifteen years' interval.

Other Springs

Only one other hot spring is reported, situated a mile from the head of Fair harbour, Kyuquot sound. No particulars are known of this water. A cold spring, the water of which contained 420 parts per million dissolved mineral matter, situated on Mayne island off the southeast coast, was reported in 1896.[1]

Hot Springs on the Coast of British Columbia

A few springs have been reported to occur on the shores of the islands and the coast of British Columbia south and east of Princess Royal island, but there are no records of the existence of springs along other parts of the coast.

Hot springs are widely distributed in Alaska, and many have been examined[2] and the waters analysed. Most of these springs are situated on the shores of the islands and of the many channels and fiords, and are largely used for their therapeutic properties by the inhabitants. On account of the similarity of structure and geological formation of the coast line of British Columbia to that of Alaska, equally numerous occurrences of hot springs would be expected in British Columbia. Yet the existence of relatively few springs has been recorded in the accounts of the early explorers or in the more recent geological reports. It may be that many parts of the coast have not been sufficiently settled for the hot springs in these districts to have been discovered or developed to an extent beyond more than local interest.

Eight springs situated on the shores of islands or of the fiords lying between Burke and Douglas channels were reported on by V. Dolmage[3] of the Geological Survey in 1921.

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[1] Geol. Surv., Canada, Ann. Rept., vol. IX, pt. R, p. 50 (1896).
[2] U.S. Geol. Surv. Water Supply Paper No. 418, 1917. Mineral Springs of Alaska: G. A. Waring.
[3] Geol. Surv, Canada, Sum. Rept. 1921, pt. A., p. 40.

The temperature of the water in most of the springs was over 100°F. and, although the flows were not large, at nearly every spring rough bathing houses had been fitted up and used by loggers and fishermen of the neighbourhood. All the springs issue from fissures in the quartz diorite of the Coast Range batholith, except No. 5, recorded below. V. Dolmage makes the following statements:—

> Springs of the sodium sulphate and calcium sulphate types, although common in sedimentary rocks, are rarely found, as these are in igneous rocks. Sodium chloride springs are also commonly found in sedimentary rocks, but are equally common in igneous rocks associated with recent volcanic activity. Although recent igneous activity has taken place in this district it is doubtful in most cases if the springs have any genetic connexion with such activity. Most of the springs occur at great distances from any of the recent dykes or tuffs, and no hot springs occur within 24 miles of—and most of them are from 45 to 80 miles distant from—the centre of this vulcanism. Recent dykes were found near the Bishop Cove spring, but this spring differs in no respect from the other sodium sulphate springs. The absence of boron is a further indication that they are not related to the recent vulcanism. Similar springs of both the sodium sulphate and sodium chloride types occur in southeastern Alaska about 400 miles northwest of this district. These occur in similar rocks and their origin has been attributed by Alfred H. Brooks and Gerald A. Waring to the fact that they occur in a region which has been repeatedly subjected to deformation and fissuring, some of which took place during Tertiary time.
>
> The springs here described occur in the same general region of deformation and some of them, such as the Surf Inlet Mine spring and the Dean Channel spring, occur in the vicinity of pronounced faulting. It is probable that these springs owe their heat to the great depths from which they ascend through these fissures.

Samples from the following sources were collected and afterwards analysed in the laboratories of the Mines Branch.

Sample 1. Water from hot spring in Eucott bay, west side of Dean channel, opposite Labouchere channel, spring 300 feet from shore and about 15 feet above high tide. The water issues from a crevice in the quartz diorite at the foot of a steep cliff.

Sample 2. Hot spring at head of Klekano inlet off Fraser reach, 5 miles north of Butedale cannery. The spring is about 200 yards from the shore and 20 feet above high tide, issuing from a crevice in quartz diorite.

Sample 3. Hot spring on shore of Ursula channel, 2¾ miles north of Fisherman cove and 15 miles northwest of Butedale cannery.

Sample 4. Water from the west side of Bishops cove, Ursula channel, 24 miles northeast of Butedale cannery. The spring is 60 feet from the shore and 10 feet above high tide.

Sample 5. Hot spring on Gardiner canal, between Shearwater and Low points and about 12 miles from the entrance of the canal into Desolation channel. The spring is at the water's edge on a small vertical cliff about 2 feet above high tide.

Sample 6. Water from a hot spring on the southeast side of Brim river, which flows into Gardiner canal 20 miles from its entrance into Desolation channel. The spring was found about 200 yards above the mouth of the river and on its bank. The sample was probably diluted with river water.

The samples were all colourless and free from turbidity. The results of the analyses were as follows:

Analyses

	Sample 1		Sample 2		Sample 3		Sample 4		Sample 5		Sample 6	
Specific gravity at 15° C.	1·0005		1·0075		1·008		1·0012		1·002		1·0005	
Properties of reaction—												
Primary salinity	28·2		76·8		75·7		81·64		75·88		50·8	
Secondary salinity	49·6		22·4		16·5		12·84		6·76		31·8	
Secondary alkalinity	22·2		0·8		7·8		5·52		17·36		17·4	
Constituents—	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Carbonic acid (CO_3)	......	......	......	......	9·9	2·5	6·6	1·7	......	......	......	......
Bicarbonic acid (HCO_3)	33	17·2	58	0·7	2·0	0·5	3·3	0·8	167	13·6	40·0	14·2
Sulphuric acid (SO_4)	80	41·8	717	8·3	173·6	44·1	178·5	44·6	516	44·4	78·0	27·9
Chlorine (Cl)	8	4·5	4600	53·3	24·0	6·1	32·0	8·0	60	4·9	52·0	18·5
Sodium (Na)	16	8·3	2523	29·2	81·0	20·5	92·0	23·0	258·5	21·1	43·4	15·6
Potassium (K)	......	......	82	0·9	......	......	......	......	29·3	2·4	......	......
Calcium (Ca)	35	18·2	385	4·5	22·2	5·6	17·6	4·4	67·4	5·5	16·6	5·9
Magnesium (Mg)	tr.	......	179	2·1	0·3	......	0·3	......	5·4	0·4	12·2	4·3
Iron oxide and alumina	3	1·5	58	0·6	22·7	5·7	5·0	1·2	5·0	0·4	3·0	1·0
Silica (SiO_2..)	16·9	8·7	38	0·4	58·8	14·9	64·7	16·2	90·4	7·3	35·5	12·6
Total	191·9	100·0	8640	100·0	394·5	100·0	400·0	100·0	1229	100·0	280·7	100·0

Hypothetical Combinations

	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Sodium chloride (NaCl)	13	6·8	6410	74·3	39·4	10·0	52·2	13·0	55·0	4·4	85·2	30·4
Potassium chloride (KCl)	......	......	156	1·8	......	......	......	......	55·4	4·5	......	......
Magnesium chloride ($MgCl_2$)	......	......	701	8·1	......	......	......	......	......	......	......	......
Sodium sulphate (Na_2SO_4)	33·5	17·5	......	......	204·0	51·8	219·5	54·9	732·0	59·6	30·5	10·9
Magnesium sulphate ($MgSO_4$)	......	......	......	......	1·2	0·3	1·2	0·3	26·4	2·1	60·7	21·6
Calcium sulphate ($CaSO_4$)	81·7	42·6	1014	11·7	50·0	12·7	41·5	10·4	42·8	3·5	12·2	4·3
Calcium bicarbonate ($Ca(HCO_3)_2$)	43·8	22·8	76	0·8	2·6	0·6	4·1	1·1	221·9	18·0	53·6	19·1
Calcium carbonate ($CaCO_3$)	......	......	*188	2·2	16·0	4·0	11·0	2·8	......	......	......	......
Ferric oxide and alumina	3·0	1·5	38	0·4	22·7	5·7	5·0	1·2	5·0	0·4	3·0	1·0
Silica (SiO_2)	16·9	8·7	58	0·6	58·8	14·9	64·7	16·2	90·4	7·4	35·5	12·6
Total	191·9	100·0	8641	100·0	394·7	100·0	399·7	100·0	1229·0	100·0	280·7	100·0

(a) Parts per million.
(b) Total inorganic matter in solution per cent.
* Calcium chloride.

With the exception of No. 2, these waters have sodium as the chief constituent and sulphuric and carbonic acids as the chief acidic ions. They therefore belong to the class of alkaline-saline waters. They closely resemble many of the waters from the hot springs in Alaska, analyses of which are reported in the publication previously referred to.

Several other hot springs of the same type as those just discussed occur in the vicinity of Bella Coola. There is one spring rising in the tide flat close to Bella Coola settlement, though no steps have been taken to utilize it as a bathing place. Another, fitted up with a rough bathing-house, is situated on lot 237, on South Bentinck arm, about 25 miles from Bella Coola. Others are known at the head of South Bentinck arm, at Brynildsen inlet on Labouchere channel, and at Nascall bay. The analysis of the water from the spring at Eucott bay, also in this neighbourhood, is included among those collected by V. Dolmage.

GASES EVOLVED FROM THE SPRINGS

In all the pools in which the springs rise at Banff, Radium, Fairmont, Halcyon, and Harrison hot springs, quantities of gas bubble up intermit-

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[1] Harlan I. Smith, Archæologist of the Victoria Memorial Museum, kindly supplied this information.

tently from various places on the bottom. Samples of these gases were collected and measurements of the radioactivity were carried out immediately. Other samples were sent to Ottawa, where they were afterwards analysed. The following results were obtained for the radioactivity of the gases. This radioactivity was solely due to the presence of radium emanation, as no thorium emanation could be detected. The percentages of the various constituents as given by the chemical analyses, are included in the table:—

Spring	Temperature of water		Constituents					Radioactivity Units (1x10^{-12} curie)
	° F.	° C.	Methane CH_4	Carbon dioxide CO_2	Oxygen O_2	Nitrogen* N_2	Argon Helium	
Basin, Banff	94	34·5	0·23	1·34	0·50	96·68	1·25	2,370
Cave, Banff	85	29·5	0·20	1·11	0·45	98·24	....	3,340
Middle, Banff	92	33·5	0·22	1·18	0·81	97·79	....	1,910
Radium	114	45·4	....	2·79	9·97	87·24	....	45,300
Fairmont	112	39·0	....	54·16	11·60	34·24	....	15,780
Halcyon	128	53·0	0·61	0·29	0·64	98·46	....	4,260
Harrison	145	63·0	0·64	0·21	0·64	98·51	....	6,940
Kings Well, Bath	....	....	....	3·60	....	95·45	0·95	33,650

* Including argon and helium unless specified.

It will be seen that the gas from the Radium Hot Springs has a high radioactivity. It would have been interesting to have determined the helium present in this gas. It is probable that a larger amount than occurs in the Basin Spring gas[1] at Banff would be found.

The volume of gas given off daily from any of these springs is too small to make them of any economic value. They correspond in composition and properties with the gases from French and other European mineral springs, which have been studied so exhaustively by Professor C. Moureu.[2]

DISCUSSION OF RESULTS

It is interesting to compare the values of the various properties of the springs in British Columbia with other published results of investigations of the best known mineral springs in other parts of the world. Although in numbers, size, and prominence they cannot be compared to the geysers and hot springs in the Yellowstone Park in the United States, the famous geyser region of New Zealand, or the twelve hundred mineral springs of Japan, some of their properties show up very favourably.

The chief mineral springs in Europe have been the subject of many investigations, and the analyses and measurements are to be found all through the scientific literature.

Most of the mineral springs in the United States have been studied, particularly those at Saratoga, Yellowstone Park, in Arkansas, and in Colorado. The report of the Colorado Geological Survey, Bulletin No. 11, on the Mineral Waters of Colorado, by R. D. George and others, is a most valuable publication on mineral springs in general.

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[1] Elworthy, R. T.: Roy. Soc. Can. Trans., vol. II, Sec. iii (1917).

[2] "Les Gas Rares des Gas Naturel." Lecture before Chem. Soc. London., Jour. Chem. Soc. Trans. 124, p. 1905 (1923).

The report on the mineral springs of Japan, by Dr. R. Ishizu, published by the Tokyo Imperial Hygienic Laboratory for the Panama-Pacific International Exposition in 1915, very fully illustrated by 76 plates and maps, is perhaps the finest report ever issued on mineral springs.

There is thus ample material available for comparison of the properties of Canadian springs with those in other countries.

Radioactive Properties

The values of the radioactivity of the chief springs in Canada that have been measured are summarized in the following table, the results being given both in micromicro curies and in Mache units to enable comparison to be made with the many important European waters, the values of which are only given in these units.

It will be seen that Radium Hot Springs (No. 14) and several of the springs (Nos. 15 and 16) at Fairmont, B.C., are the most radioactive waters yet found in Canada, while the others, Halcyon and Harrison are well up in the list.

Further comparison with the following table, which gives the values of the radioactivity of a few of the best known and most radioactive springs in Europe and America, shows that Radium Hot Springs and Fairmont Springs compare favourably with the most radioactive waters known in the United States and that the water of the Radium Hot Springs comes close to being the most radioactive spring on the North American continent.

But the values are far lower than the highly radioactive waters found in France at La Bourboule and Bagneres de Luchon or in Austria at Joachimstal. These, of course, are the most radioactive waters known. The three Japanese springs included in the table have far higher values also.

Beyond being of scientific interest and perhaps not without some value for interesting and attracting tourists it is questionable whether radioactive properties, in no greater degree than in the Canadian springs, add economic value to the springs. This point is discussed in the following section.

Radioactivity of Some of the Chief Canadian Mineral Springs

No.	Spring	Temperature, ° C.	Classification	Emanation per litre		Dissolved radium per litre, $1x10^{-12}$ curie (units)
				$1x10^{-12}$ curie (units)	Mache units	
1	Sanitaris, Arnprior, Ont...........	9·0	Alkaline-Saline....	226	0·62	1·7
2	White Sulphur, Carlsbad, Ont......	8·9	" " ...	90	0·25	0·8
3	Magic, Carlsbad, Ont.............	9·1	Muriated Sodic...	87	0·24	25·0
4	Saline, Caledonia, Ont...........	8·5	Alkaline-Saline....	70	0·19	5·6
5	Duncan, Caledonia, Ont...........	9·0	" " ...	53	0·14	5·6
6	Adanac, Bourget, Ont.............	11·0	Alkaline Calcic...	202	0·55	....
7	Abenakis, Que....................	9·0	Muriated Sodic...	134	0·37	0·5
8	Radnor Forges, Que...............	9·5	" " ...	345	0·67	0·3
9	Philudor, St. Hyacinthe, Que......	8·3	Alkaline Sodic....	106	0·29	46·0
10	St. Genevieve, Que...............	8·3	Muriated Sodic...	145	0·40	0·8
11	Upper Hot Spring, Banff, Alta.....	46·0	Saline Sulphated..	221	0·61	8·6
12	Cave Spring, Banff, Alta..........	29·5	" " ..	470	1·29	8·5
13	Basin Spring, Banff, Alta..........	34·5	" " ..	232	0·64	8·5
14	Radium, Kootenay, B.C...........	45·4	" " ..	9,600	26·40	96·0
15	Fairmont No. 3, Columbia valley.	39·0	" " ..	1,045	2·87	....
16	Fairmont No. 5, Columbia valley..	44·2	" " ..	3,180	8·57	105·0
17	Halcyon, Arrow Lake, B.C........	53·0	Alkaline-Saline....	300	0·82	9·0
18	Sulphur, Harrison, B.C............	63·0	" " ..	252	0·67	1·3
19	Potash, Harrison, B.C.............	60·0	" " ..	345	0·95	....

Radioactivity of Gases Evolved

No.	Spring	Temperature °C	Chief constituents		Emanation per litre	
					1x10^{-12} units	Mache units
5	Duncan, Caledonia, Ont.	9·0	86% CH_4	11·5% N_2	204	0·56
9	St. Hyacinthe	9·4	85% CH_4	....	540	....
12	Cave, Banff	29·5	98% N_2	....	3,340	9·20
13	Basin, Banff	34·5	98% N_2	....	2,370	6·50
14	Radium, Kootenay, B.C.	45·4	....	....	45,300	124·60
15	Fairmont, Columbia valley	39·0	54·2% CO_2	34·2% N_2	15,780	43·41
17	Halcyon, Arrow lakes, B.C.	53·0	98·0% N_2	....	4,260	11·72
18	Harrison, B.C.	63·0	98·5% N_2	....	6,940	19·10
	Kings Well, Bath, England	45·0	94·5% N_2	....	33,650	92·60

Radioactivity of Springs in Other Parts of the World[1]

Country	Spring	Observer	Radioactivity	
			Water	Gas
			Units (1x10^{-12} curie) per litre	
England	Kings Well, Bath	Ramsay	1,730	33,650
	Cross Spring, Bath	Ramsay	1,190	....
	Hospital bath, Buxton	Makower	830	7,700
France	Choussy, La Bourboule	Laborde	22,900	141,662
	Capucins, Plombieres	Brochet	5,945	50,750
	Vauquelin, Plombieres	Brochet	4,750	73,694
	Source d'Alun, Aix-les-Bains	Curie	4,037	22,607
	Source Bordeu Luchon	Lepape	41,400	134,762
Austria	Joachimsthal	....	70,000	....
	Grabenbackerquelle, Gastein	Mache	56,400	2,936,000
Germany	Murquelle, Baden-Baden	Engler and Sieveking	8,720	....
	Buttquelle, Baden-Baden	“ “	45,800	....
	Eisenquelle, Carlsbad	Sieveking	19,800	....
United States	Imperial Spring, Arkansas	Boltwood	10,100	....
	Twin Spring, Arkansas	Boltwood	2,480	....
	Crystal Rock, Saratoga	Moore and Whittemoore.	880	847
	Emperor, Saratoga	“ “	70	221
	Hawthorne No. 1, Saratoga	“ “	142	213
	Hot River, Yellowstone Park	Schlundt and Moore	1,440	....
	Apollinaris Spring, Yellowstone Park	“ “	1,210	....
	Five Hole Lake, Lower Geyser basin	“ “	320	329,000
	Nymph, Yellowstone river	“ “	263	7,300
Japan	Nolata Shinyu, Ikeda	Ishizu	18,774	35,948
	Kamiga Waxa No. 1, Masutomi	“	82,834	....
	Ena-Kasen, Takayama	“	28,109	....
Canada	Radium Hot Springs	Elworthy	9,600	45,300
	Fairmont No. 5	“	3,180	15,780
	Cave Spring, Banff	“	470	13,340

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[1] The most complete lists are to be found in:
Mineral Springs of Japan. Tokyo Imperial Hygienic Lab., pp. 190-193.
Mineral Waters of Colorado. Colorado Geol. Surv. Bull. 11, pp. 179-198 (1920).
Handbuck der Radium-Biologie und Therapie. P. Lazarus (1913).
International Critical Tables, vol. I, pp. 373-377 (1926).

The Economic Value of Radioactivity in a Mineral Water

Some years ago when the earlier investigations on mineral springs in Europe proved the presence of small quantities of radioactive substances in the waters this fact was at once put forward to account for the undoubted therapeutic value of springs at many spas and watering places. To-day, this explanation is largely discredited, and the benefits derived from a course of treatment involving regular external and internal application of mineralized water, often hot, can better be accounted for by the solvent action of the water itself on the waste products of the human system.

Although a considerable number of researches into the effects of radioactive waters on all types of organisms and in therapeutic treatments have been carried out with a certain degree of success the solutions used have been almost always artificially prepared and were very many times stronger than the most natural radioactive waters known.

Such artificially prepared radioactive waters are on the market. The usual strengths are from 1 micro-curie (one million units of 1×10^{-12} curie) to 1 milli-curie, the weakest of which is many times stronger than the most radioactive natural water known. They cost comparatively little, a few cents per micro-curie, and can be obtained and used anywhere.

Natural radioactive waters are only of value at their source, as no spring has ever been found containing sufficient dissolved radium to produce when bottled a radioactive solution one hundredth the strength of solutions prepared for medical purposes.

Again, the European spas and mineral springs most noted for their therapeutic value have almost without exception been very low in radioactive properties.

There is no possibility of obtaining radium from radioactive waters, even if radium salts are present as is sometimes the case. The degree to which measurements of radioactive substances can be made is so fine and sensitive that amounts of material beyond recognition by any other method can be estimated and a false idea of quantities is thus obtained. Methods of recovering gold from seawater are far more within the bounds of possibility.

It was thought at one time that a strongly radioactive spring proved the existence of radioactive ore-bodies in the rocks through which it had come. It is not even necessary to postulate this idea to-day to account for radioactive properties. Many of the commonly known rocks can supply radioactive material sufficient to account for the phenomenon.

Although, scientifically, it is certain that radioactivity is of no economic value on account of the reasons put forward above, the fact remains that to the non-scientific man it is an attractive feature for a spring to possess.

Chemical Character

The waters of all the springs, at Banff, Radium Hot Springs, Fairmont, Halcyon, and Harrison, all fall into the general class of alkaline-saline waters, having as their principal constituents, calcium sulphate, and calcium bicarbonate, although the degree of concentration of the mineral constituents varies. In this respect they differ from the mineral springs in eastern Canada which are mainly saline waters, carrying sodium chloride as the chief constituent.

They probably all have the same origin, resulting from a flow of surface water which penetrates the limestone formations of the mountains, takes up calcium bicarbonate, sulphate, and other constituents, and at the same time assumes the temperature of the adjacent rock through which it is passing, which, as already mentioned, may be expected to be considerably in excess of the normal temperature gradient because of local conditions.

Waters of this type are of little use for bottling purposes. They very closely resemble the waters of the celebrated Bath springs in England and their utilization would be expected to proceed along the same lines. Full references to this subject are given in a previous report[1]. The main application of all these springs is undoubtedly in supplying water for baths and swimming pools both for recreational and therapeutic purposes and the development of the springs is proceeding along these lines.

Acknowledgments

Acknowledgment should be made of the great assistance rendered by many members of the Dominion Parks Branch staff, both in Ottawa and at Banff and at Radium Hot Springs, particularly Mr. J. Wardle, Chief Engineer; Mr. J. Woods, Assistant Superintendent, Rocky Mountain Park; Mr. J. Davidson, then Assistant Engineer on the Banff-Windermere highway, who arranged transportation; and Mr. Jones, Warden at Radium Hot Springs.

The owners and agents of Fairmont Hot Springs, Halcyon Hot Springs and Harrison Springs gave every facility and convenience for carrying out the work on these waters.

R. J. Offord, Senior Laboratory Assistant in the Chemical Division of the Mines Branch, accompanied the writer in the field and capably assisted in making many of the measurements and observations both at the springs and in the subsequent laboratory work.

Some of the analyses of the waters were made by G. P. Connell, Junior Chemist, and those of the gases evolved from the springs by J. Moran, Associate Chemist.

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[1] Mines Branch, Dept. of Mines, Canada, Rept. 472 (1918).

II

NATURAL GAS IN NEW BRUNSWICK

R. T. Elworthy

INTRODUCTION

In order that the investigation of the natural gas resources commenced by the Mines Branch in 1923, and carried on in that year in Alberta, and in 1924 in Alberta and Ontario, might be completed, the Stony Creek field, the only field now producing gas in New Brunswick, was visited in September, 1925. On this occasion the wells were examined and samples collected for later analyses in Ottawa.

The following report outlines the history, development, and condition of this field.

LOCATION OF FIELDS IN NEW BRUNSWICK

Natural gas and petroleum in commercial quantities have been found only in the counties of Westmorland and Albert, at the head of the bay of Fundy. The rocks of the area belong to the Carboniferous age and contain valuable economic deposits of oil-shale, salt, and coal, as well as petroleum and natural gas.

HISTORY OF DEVELOPMENT[1]

As early as 1859 the existence of oil seepages in Albert county attracted the attention of American petroleum experts.

Leases were taken out and a few shallow wells drilled. No production of oil resulted, however, although a certain amount of gas was struck.

In 1876 further drilling was done and oil was obtained in some quantity. However, the undertaking did not prove profitable and was soon abandoned. Twenty years later the New Brunswick Petroleum Company, Ltd., was organized, and from 1903 to 1905 considerable drilling took place. During this period several thousand barrels of oil were produced and marketed.

After investigation by English petroleum geologists in 1906, the Maritime Oilfields Ltd. took over the development. A little later this company was re-organized as the New Brunswick Gas and Oilfields Ltd., and since that time this company has gone ahead steadily, supplying Moncton and Hillsboro with gas and at the same time developing the oil production.

The D'Arcy Exploration Company, a subsidiary of the Anglo-Persian Oil Co., has carried out some exploratory drilling in Westmorland and Albert counties, but no commercial developments have yet resulted from

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[1] F. G. Clapp et al: Natural Gas and Petroleum Resources of Canada, Mines Branch, Dept. of Mines, Canada, Rept. 291, vol. II, p. 29 (1915).

their investigation. This company also carried on large-scale experimental work at Rosedale, on the distillation of the oil-shales which can be mined at many points in this area.

STONY CREEK OIL AND GAS FIELDS

The Stony Creek field is the only district at present where oil and gas are being produced. It lies in Albert county on the west bank of the Petitcodiac river and on the west side of the Moncton-Hillsboro highway, about 9 miles south and a little east of Moncton, and 4 miles north of Hillsboro. The area in which most of the wells have been drilled is about 2 miles long in a direction parallel to the river and about 4 miles wide. The field is situated on a dome-shaped hill which has an elevation of about 460 feet and is about 300 feet above the Moncton-Hillsboro road level. It slopes more steeply on the west or river side, on which slope a few wells are drilled. The majority are located on the eastern face. The country is well wooded, mostly with pine and fir, and unlike the oil and gas fields in Ontario and Alberta, clearings have to be made for the erection of the derricks.

Up to the present, about 70 wells have been drilled, and about half this number are productive of gas. Oil can be obtained from a lesser number. The wells are usually drilled to a depth of 2,000 to 2,500 feet. Four or five gas sands are encountered at intervals, the first being struck at a depth of 1,500 or 1,600 feet.

Water conditions are not difficult and usually three or four strings of casing are sufficient, commencing with 15-inch diameter and ending with 6⅝-inch pipe. The rock pressures vary considerably and range from twenty to thirty pounds to four or five hundred pounds per square inch. The open flows are usually from one to three million cubic feet per day.

More attention has been paid recently to the possibilities of this field and encouraging results have been obtained.

PRODUCTION AND UTILIZATION OF GAS AND OIL

The following table gives the natural gas and oil production for the last eleven years:—

Year	Natural gas		Petroleum	
	M cu. ft.	Value	Barrels	Value
		$		$
1915	430,692	60,383	1,020	1,423
1916	610,118	79,628	1,345	2,663
1917	796,775	103,735	2,341	5,460
1918	792,396	107,842	3,009	7,402
1919	682,890	120,510	4,225	13,141
1920	682,502	130,506	5,148	19,963
1921	708,743	139,375	7,479	33,022
1922	753,898	148,040	7,778	32,732
1923	640,300	126,068	8,826	35,642
1924	599,972	113,577	5.561	21,313
1925	639,235	122,394	5,376	18,756

All the gas was consumed in Moncton and Hillsboro. The Moncton Tramways and Electricity and Gas Company purchase the gas at the wells, and lay and maintain the pipe-lines supplying the towns.

The rate paid by the consumer is 50 cents per thousand cubic feet, a low price compared with the rates paid for artificial gas of lower calorific value, in Halifax and St. John, and other towns in Nova Scotia and New Brunswick.

The figures for the monthly consumption in 1924 are of some interest.

—	M cu. ft.	—	M cu. ft.
January	77,371	July	20,080
February	72,967	August	18,316
March	69,193	September	24,695
April	62,911	October	37,284
May	42,481	November	51,603
June	31,230	December	66,306

GEOLOGY

The geology of the province has been studied by members of the staff of the Geological Survey on several occasions. The earliest report was made by the late Dr. R. W. Ells[1] in 1907. From 1911 to 1915, further work particularly on the structure and extent of different horizons in the Carboniferous, was carried out by G. A. Young. A study of the Moncton map-area in which territory the gas and oil field and the oil-shale deposits are principally found, was made by W. J. Wright.[2]

In this report the various series of formations occurring in the Carboniferous are correlated, so far as evidence can be obtained, and particular attention is given to the oil-shale occurrences.

In regard to the structure in the Stony Creek area, W. J. Wright says:—

> Structure. On the east side of Petitcodiac river, along Downing and Boyd creeks, the measures dip regularly to the south and southwest at angles of less than 45 degrees. The rocks form part of the north limb of an undulating syncline cut off on the south by the Hillsborough fault. Except for small local crumples, the regular south dip prevails on the east side of Petitcodiac river. But the measures are severely crumpled in the shore section near Dover wharf and Stony creek and the crumple structure appears to extend west at least to where the measures are covered by Zone No. 1 of the Petitcodiac series in the Stony Creek gas field.
>
> In the early development of the Stony Creek gas field the crumpled zone from Dover wharf to Stony Creek was supposed to be the crest of an east and west anticline whose northern limb was concealed beneath the almost flat-lying conglomerate of Petitcodiac series No. 1. But the development of the field has not supported this supposition. Last summer, Dr. J. A. L. Henderson, manager of the New Brunswick Gas and Oil Fields, Ltd., expressed the opinion that the gas and oil came from a terrace on the limb of a fold, and not from the crest of an anticline. If this be so, it is quite possible that the south dip continues to the north where it brings up the base of the Albert series under the younger rocks. This possibility is supported by the presence of igneous rocks 500 feet below the surface in well No. 52, about 2 miles north of the Stony Creek gas field. The occurrence of igneous rocks at this point suggests the presence of a partly buried ridge of pre-Carboniferous rocks running northeast and southwest, parallel with the numerous ridges of pre-Carboniferous rocks in southeastern New Brunswick.

Very careful logs have been kept of all the wells drilled by the New Brunswick Gas and Oil Fields, Ltd., and a careful study of these has given the company much valuable information.

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[1] Ells, R. W.: "The Geology and Mineral Resources of New Brunswick," Geol Surv., Canada, Sum. Rept. 1907

[2] Wright, W. J.: "Geology of the Moncton Map-area," Mem. 129, Geol. Surv., Canada, 1922.

RESULTS OF EXAMINATION OF SAMPLES

Gas samples were taken from thirteen sources, widely separated, and as far as possible from wells in which the gas issued from sands at different horizons. The object was to sample and test gases from every productive sand, to see if any variation in composition and particularly in the helium content, could be found. It was very difficult, however, to be certain from what depth the gas issued, particularly in the older wells, and many of the samples are composite gases from several horizons.

Gas Analyses

The following results were obtained:—

	Well Nos.						Reg. Station
Constituents	9	12	22	24	64	68	
Methane (CH_4)	79·5	82·1	76·2	75·8	78·2	73·4	75·4
Ethane (C_2H_6)	19·4	16·6	20·4	17·9	14·5	18·5	23·2
Carbon dioxide (CO_2)	nil	nil	0·2	0·4	0·7	0·3	nil
Oxygen (O_2)	nil	nil	0·3	0·7	nil	0·5	0·3
Nitrogen (N_2)	1·1	1·3	2·9	5·2	6·6	7·3	1·2
Specific gravity (air=1)	0·669	0·654	0·671	0·672	0·650	0·698	0·675

Helium Content

The following table gives the well numbers, the depths of the gas sands and the helium content of the gases.

Well No.	Depth of Sand Feet	Rock pressure, lbs. per sq. in.	Total depth, feet	Helium content, cu. ft. per M cu. ft.
9	—	52		0·25
12	1,856, 1,886, 1935	415	1,955	0·35
14	977, 1,319-28, 1,365-78, 1,395-1,410, 1,458-65, 1,480-84	78	1,576	0·48
22	—	17	1,960	0·05
24	—	22	3,212	0·01
41	—	85	2,024	0·66
64	1,615-55, 1,805-20, 2,147-64, 2,271-75, 2,422-70, 2,589-2,634	505	3,810	0·69
68	1,318, 2,243-2,386	85	2,881	0·33
70	1,564-1,663, 1,746, 1,963	498	2,441	0·14
71	—		2,889	0·48
72	2,108-2,131			nil
72	2,053			nil
	Regulator station			0·07

It is usually considered that a gas to be of commercial value for the extraction of helium should contain at least 5 cubic feet helium per thousand cubic feet of gas. Few of these samples contain more than about one-tenth of this quantity.

The helium content of these gases varies greatly from one well to another. Most of the analyses were done in duplicate and independently, and the results obtained checked closely. With the rather scanty available data of depth of gas horizons and position of the wells, it is difficult to trace any relations between helium content and source of gas. Such a relation, if it exists, could only be satisfactorily studied by taking a series of gas samples, while the wells were being drilled, from each gas as it was struck. When the wells are completed, the smaller gas flows are usually shut off, and the larger flows unite and issue from one pipe.

Acknowledgments

Acknowledgment is due to Mr. A. Crichton, the resident manager of the New Brunswick Gas and Oil Fields, Ltd., who afforded every facility for collecting samples, and made all the data relating to the wells and the gas and oil production available.

R. J. Offord, Senior Laboratory Assistant, ably carried out the analyses of the gases and the helium determinations.

III

THE BUILDING AND ORNAMENTAL STONE TRADE IN GREAT BRITAIN

William A. Parks

INTRODUCTION

Stone for building is quarried for local use at many places in Great Britain, but the districts producing high-grade commercial stone are relatively few. In order to gain an idea of the condition of the industry visits were made to a few of the more important centres, although in most cases only one typical quarry was seen.[1]

In addition to the official figures of production, other figures and statements obtained verbally from leading operators are introduced.

The writer wishes to acknowledge the co-operation of all whom he had occasion to interview, more especially the gentlemen named below:—

Sir Richard Redmayne, K.C.B., Director of the Imperial Institute, London.

Major Henderson Scott, Superintendent of the Mineral Resources, Department of the Imperial Institute.

J. Allen Howe, B.Sc., F.G.S., Geological Survey of Great Britain.

Thomas Aubertin, Esq., Merbes-Sprimont, Ltd., 40 Leicester Square, London.

H. T. Jenkins, Esq., H. T. Jenkins & Sons, Ltd., Torquay, Devon.

John B. Johnson, Esq., John B. Johnson & Co., Ltd., Abbey House, Westminster, London.

W. D. Hobson, Esq., Penrhyn Slate Quarries, Port Penrhyn, North Wales.

John Freeman, Esq., John Freeman Sons & Co., Penryn, Cornwall.

Major Bunting, United Stone Firms, Ltd., No. 2 Bristol Chambers, Nicholas St., Bristol.

GENERAL STATISTICS OF QUARRYING INDUSTRY

A list of quarries in Great Britain and the Isle of Man published by the Mines Branch of His Majesty's Government in 1924 contains nearly 6,000 references to quarries, exclusive of those operated for such substances as salt, chromite, barite, fluorspar, etc., but inclusive of those worked for sand, gravel, china clay, chalk, ironstone, gypsum, and similar substances.

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[1] The following list of periodicals and books, which were freely used, may be of advantage to those requiring further information on the subject:—

The Quarry and Surveyors' and Contractors' Journal, 30, 31 Furnival St., London, E.C. 4.
The Stone Trades Journal, 36 Southampton St., London, W.C. 2.
The Builder, 4 Catherine St., Aldwych, London, W.C. 2.
The Geology of Building Stones, by J. Allen Howe; Edward Arnold, London.
The Stones of London, by Elsden and Howe; Chichester Press, London.
British and Foreign Building Stones, by John Watson; Cambridge University Press, Cambridge.
Marbles, by J. Watson; Cambridge University Press, Cambridge.
Building and Ornamental Stones, by Edward Hull; Macmillan Co., London.
Reports of the Secretary of Mines; H.M. Stationery Office, Kingsway, London.
List of Quarries: Year 1922; H.M. Stationery Office, Kingsway, London.

Minerals for Building and Roadmaking and all Other Purposes, 1924*

Material	Production	Value at quarry	Persons employed
	long tons	£	
Limestone	12,813,471	3,156,552	18,957
Sandstone	2,531,917	1,538,391	10,620
Igneous rocks	7,432,696	3,112,525	17,948
Chalk	4,402,560	337,995	1,769
Clay and shale	10,843,418	1,116,852	8,124
Slate	287,705	2,157,380	10,262
Chert, flint, etc	148,279	43,714	400
Gravel and sand	2,922,485	494,284	3,312
Total	41,382,531	11,997,693	71,192

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* Fourth Annual Report of the Secretary of Mines for the year ending December 31, 1924.

It is difficult to obtain statistics that clearly discriminate between stone used for building and that used for other purposes. The abovementioned materials are all related to the building industry. Only a small percentage of the output can be credited to stone used for building purposes; in the case of limestone only 3 per cent of the output of 1,300 quarries (327,000 long tons) was used for building in 1924.

Domestic consumption absorbs most of the building stone produced in the British Isles. The export trade is not extensive. Imports, also, are small, except in the case of marble and monumental granite.

Exports and Imports of Building Stone, etc., 1923

Description	Imports	Exports[1]
	long tons	long tons
Sandstone—		
British Empire	....	(£1)
All foreign countries	41	11
Limestone (other than marble)—		
British Empire	32	946
All foreign countries	....	20
Belgium	506	....
Italy	547	....
Other foreign countries	45	....
Marble (other than works of art)—		
British Empire	8	....
Belgium	1,342	....
Italy	25,663	....
Other foreign countries	243	....
Granite (monumental and architectural)—		
Canada	....	1,008
British India	....	6
British Empire	10	....
Germany	2,030	....
Norway	541	....
Sweden	684	....
Other foreign countries	65	....
New Zealand	....	190
Other British Empire	....	437
France	....	57
United States	....	764
Argentina	....	1
Chili	....	2
Other foreign countries	....	44

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[1] The manufactured and unmanufactured stones and slates probably include little of interest in connexion with our subject. The figures of export are slightly increased by including re-exports as follows: marble, 270 tons; architectural granite, 34 tons; other manufactured stones and slates, 137 tons; other unmanufactured stones and slates, 313 tons.

Exports and Imports of Building Stone, etc., 1923—Concluded

Description	Imports	Exports
	long tons	long tons
Granite (setts and pavement curbs)—		
British Empire	....	58
All foreign countries	....	101
Channel Islands	13,776	....
Other British Empire	2,722	
Belgium	480	....
Norway	108,080	....
Sweden	60,438	....
Other foreign countries	5	....
Granite (other than setts, pavement curbs, monumental and architectural)—		
British Empire	254,785	22
All foreign countries	....	30
Belgium	160,842	....
Finland	3,468	....
France	27,379	....
Netherlands	10,954	....
Norway	6,619	....
Sweden	4,791	....
Other foreign countries	54	....
Roofing slates—		
Irish Free State (from April 1, 1923, only)	....	7,906
Channel Islands	....	212
Australia	....	1,179
New Zealand	....	327
Other British Empire	....	244
Belgium	479	79
Denmark and Faroe Islands	....	381
Netherlands	....	320
Other foreign countries	83	136
France	1,935	....
Portugal	2,614	....
United States	11	....
Other unmanufactured stones and slates—		
British Empire	7,668	429
United States	....	1,727
Belgium	1,825	....
France	1,700	....
Italy	85	....
Netherlands	6,500	....
Portugal	6,374	....
Other foreign countries	38	316
Other manufactured stones and slates—		
Canada	....	142
British India	....	45
Australia	....	149
Irish Free State (from April 1, 1923, only)	....	374
British Empire (imports only)	427	....
Belgium	5,362	78
France	203	61
Norway	....	1,300
United States	358	754
Argentina	....	202
China	....	24
Other foreign countries	243	526
Italy	13,119	....
Portugal	203	....

It will be observed that the chief items are the export of 2,509 tons of monumental and architectural granite and 10,684 tons of slate, and the import of 27,256 tons of marble, chiefly from Italy and Belgium, and of 3,300 tons of granite. A comparison of statistics for the past three years shows that there has been a general advance in production, imports, and exports. The imports far outweigh the exports and the trade with Canada is almost negligible at present.

The domestic trade in sandstone and limestone for building is in a prosperous condition. The demand for granite for building is not so satisfactory. The use of this material for monumental purposes, however, is so great that the value of the finished article has not declined even if the volume of output is less than before the war. The production of domestic marble is slight being almost entirely confined to Devonshire.

OCEAN RATES AND TARIFFS ON STONE

It is obvious that any attempt to place Canadian stone on the British market will be vitally affected by transportation charges and by duty.

The writer is indebted to the Canadian Pacific Railway Company for the following schedule of ocean rates on stone:

Ocean Rates from United Kingdom Ports to Canadian Atlantic Ports

Description	Shillings per long ton
Sandstone or limestone, up to three gross tons per piece or package	25
Granite, polished or not polished, up to two tons per piece or package	35
Marble, polished, up to two tons per piece or package	45
Marble, unpolished, up to two tons per piece or package	37½

Ocean Rates from Canadian Atlantic Ports to United Kingdom Ports

Description	Dollars per long ton
Limestone, sandstone, and granite, in the rough, on pieces or packages not exceeding two gross tons	9.00
Marble, in the rough, on pieces or packages not exceeding two gross tons	10.00
Sandstone, limestone, granite, or marble, polished or carved, in crates, in pieces or packages not exceeding two gross tons (or 40 cts. per cubic foot, ship's option)	16.80

There is no import duty on stone, manufactured or unmanufactured, entering Great Britain. The Canadian and American tariffs on stone are given below:—

Canadian Tariff on Building and Ornamental Stone

Description	British Preferential tariff	Intermediate tariff	General tariff	War tax
Grindstones, not mounted, and not less than thirty-six inches in diameter	10 p.c.	12½ p.c.	15 p.c.	7½ p.c.
Grindstones, mounted or not, not otherwise specified	17½ p.c.	22½ p.c.	25 p.c.	7½ p.c.
Flagstone, sandstone, and all building stone, not hammered, sawn, or chiselled, and marble, and granite rough, not hammered or chiselled	10 p.c.	12½ p.c.	15 p.c.	7½ p.c.
Marble, sawn or sand-rubbed, not polished; granite, sawn; paving blocks of stone; flagstone and building stone, other than marble or granite, sawn on not more than two sides	15 p.c.	20 p.c.	20 p.c.	7½ p.c.
Building stone, other than marble or granite, sawn on more than two sides but not sawn on more than four sides, per 100 pounds	10 cts.	15 cts.	15 cts.	7½ p.c.
Building stone other than marble or granite, planed, turned, cut or further manufactured than sawn on four sides, per 100 pounds	30 cts.	45 cts.	45 cts.	7½ p.c.
Marble and granite, not otherwise specified, and all manufactures of marble or granite, n.o.p.	30 p.c.	32½ p.c.	35 p.c.	7½ p.c.
Manufactures of stone, n.o.p.	30 p.c.	32½ p.c.	30 p.c.	7½ p.c.
Roofing slate, per square of 100 square feet	50 cts.	70 cts.	75 cts.	7½ p.c.
Slate mantels and other manufactures of slate, n.o.p.	20 p.c.	27½ p.c.	30 p.c.	7½ p.c.

In addition to the above tariff the Government imposes a sales tax of five per cent. By an Order-in-Council, 21st September, 1923, the Irish Free State was added to the list of British countries entitled to the British Preferential Tariff.

American Tariff on Building Stone

Stone, building or monumental (except marble, breccia and onyx, n.s.p.f.[1]), hewn, dressed or finished or otherwise manufactured	50 p.c.
Stone, unmanufactured, or not dressed, hewn, or polished, per cubic foot	15 cts.
Grindstones, finished or unfinished, per ton	$1.75
Marble blocks, roughly sawn by cable, per cubic foot	65 cts.
Marble monuments	50 p.c.
Unmanufactured granite, not suitable for use as monumental or building stone, n.s.p.f.	free.

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[1] n.s.p.f.: not specially provided for, and signifies that the rate given governs except under special conditions named in the law.

CHIEF BUILDING AND ORNAMENTAL STONES PRODUCED IN GREAT BRITAIN

Excepting certain rare materials used in decorative work, all the ordinary stones employed in building, decorative and monumental work may be classified as follows:—

Granite, including various igneous rocks.
Sandstone
Limestone
Marble
Slate (not strictly a building stone but herein included).

Granite

The chief quarries of building and ornamental granites are in Cornwall, at Shap Fell in Westmorland, and at Aberdeen and Peterhead in Scotland. The Cornish, Aberdeen and Peterhead granites are best known. The two former are grey in colour, and the latter is pinkish.

Cornwall. Granite is quarried from a number of the bosses characteristic of the district, more particularly from those near Penryn, and from the exposure at St. Breward, near Bodmin.

The stone is generally grey, but it varies in colour according to the tint of the feldspar constituent, and in grain from fine to coarsely porphyritic. In general, the coarser types occur toward the centre of the county and the finer toward the borders. The fine-grained stones are suitable for architectural and monumental work, and the coarser varieties for purposes of heavy construction—piers, lighthouses, dock walls, etc.

There are many quarries, but none are of great extent and each produces a slightly different type of stone.

Transportation rates to London and Aberdeen are as follows:—

	London	Aberdeen
	s. d.	s. d.
By sailing vessel, summer, per long ton	7 6	10 6
" " winter " "	9 0	12–14 0

Aberdeen and Peterhead. Aberdeen is commonly regarded as the centre of the monumental granite industry of great Britain. Fine-grained, grey granite is quarried at Aberdeen and in the vicinity of that city; pinkish to red granite is quarried near Peterhead (Stirling Hill and other localities). The importance of Aberdeen in the granite industry does not lie in the domestic production alone, but more particularly in that the manufacturing of imported monumental stone is concentrated at that point. Much of the granite imported into Canada as "Aberdeen granite" is really stone of continental origin manufactured at Aberdeen.

The manufacturing of monumental granite is controlled by the "Aberdeen Granite Manufacturers' Association," an organization of 57 independent firms, each operating one or more mills. The association has established certain minimum rates for each class of work, which are not available for publication. The operators, in consequence, are averse to quoting prices, and it is impossible to secure reliable figures bearing on the price of manufactured stone.

The importation of monumental stone, and the supplying of both domestic and imported stone to the various manufacturers is controlled by the "Granite Supply Association."

At both Aberdeen and Peterhead it is becoming increasingly difficult to obtain large, flawless blocks for monumental work. There is little demand for Peterhead stone for this purpose, but some of the Aberdeen granite is used. The building stone industry is in an unsatisfactory condition and the competition of foreign-made setts is a serious drag on that branch of the industry. Notwithstanding the falling-off in the use of domestic stone, the Aberdeen mills are busy with monumental work in imported stone.

Sandstone

Sandstone for building, monumental, and engineering purposes has been quarried at numerous places from formations of various age—more particularly, Old Red sandstone, Millstone Grit, Coal Measures, and Triassic.

The chief sandstones at present on the market are:—

Forest of Dean, Gloucestershire: fine-grained, grey and blue stones of high reputation for strength, durability, and permanence of colour.

Red Wilderness, Gloucestershire: warm red colour, desirable for interior work.

Derbyshire: Millstone Grit, used for building, monument bases, paving, pulpstones, grindstones.

Bristol Pennant: A fine-grained blue sandstone quarried at several places near Bristol.

Corsehill stone: A warm, reddish sandstone of varying tints. This stone has been exported to Canada. Quarried near Annan in Dumfriesshire.

York stone: Soft and hard, blue and brown sandstones, much used for steps, flooring, flagging, and engineering work; also, for interior work as mantels, staircases, etc.

Limestone

To compile a list of the limestones that have been used for building in Great Britain would be difficult, however, the high-grade stones at present being quarried on a large scale primarily for building fall into three groups: Portland stone, Bath stone, and the Hopton-Wood stone of Derbyshire.

Portland. The isle of Portland, off the coast of Dorset, yields the finest and most widely used building stone in Great Britain. Quarrying dates from time immemorial, and a great commercial industry has existed since the building of old St. Paul's cathedral. Portland stone has been used throughout the United Kingdom and has been shipped abroad, but it is in London that the greatest market is found. Several contracting firms in London stated that 95 per cent of the stone used by them is Portland. Owing to the reconstruction of Regent street, the stone is in great demand at present.

Bath. Next in importance to Portland stone is that quarried from the Great Oolite (Jurassic) in the vicinity of Bath. The trade is largely controlled by three companies, with twelve quarries now in operation. Bath stone is soft and of pleasing buff colour, the product of each quarry differing somewhat in hardness, grain, and tint. Owing to its softness, Bath stone is not suitable for outdoor work where corrosive fumes abound, but its durability is good when employed for flat work in pure air. For fine interior carvings, particularly for ecclesiastical work, the stone is of a high order of merit.

Despite a duty of 15 cents per cubic foot, Bath stone is now being exported to the United States for use in the interior decoration of the Leslie Lindsey memorial in Boston, and for a cathedral church in New York; for the latter structure 46,000 cubic feet will be shipped.

Derbyshire. In the vicinity of Wirksworth in Derbyshire, the Carboniferous strata contain layers of fossiliferous limestone, soft, durable, fine-grained, of handsome appearance, and capable of being easily worked. The stone may be described as semi-marble and it enjoys an excellent reputation. The chief quarries are the Hopton-Wood, Manystones, and Middleton.

Marble

The coloured marbles of Devonshire and the "birdseye" of Derbyshire are the only marbles now being quarried in Great Britain. In both localities the production is small and the total volume of domestic marble used is insignificant when compared with that of the imported stones.

Devonshire. The only present operator in this district is the firm of H. T. Jenkins & Sons, Ltd., Torquay, which is now working the Petitor and Ashburton quarries. The Red Ogwell quarry of this company was recently closed.

The Devonshire marbles are all strongly coloured, large-figured stones of about ten varieties. The chief types are Ashburton, Red Ogwell, Red and Grey Ipplepen, Royden, Buckfastleigh, Chudleigh, and Petitor (four colours). The Ashburton is the best known and has been used extensively for ecclesiastical work and the interiors of public buildings.

Derbyshire. The Mountain limestone, near Wirksworth, Derbyshire, is quarried for marble by the Hopton-Wood Stone Firms, Ltd. Three types are produced—Black Birdseye, Grey Birdseye, and Fossil. Blocks up to 5 by 3 feet can be quarried, but it is difficult to obtain stone of larger dimensions. The production is slight and intermittent. The stone is chiefly used for flooring.

Ireland. Irish marbles are favourably known in Great Britain and before the war were much used for the higher types of decorative work. During and since the war the production has been negligible, but the outlook is becoming more promising. The industry is now controlled by the Irish Marble Company of Kilkenny, with quarries in Kilkenny, Galway, Cork, and Kerry.

Slate

The well-known Welsh slates are obtained from two localities in North Wales—from the Cambrian strata in Carnarvonshire, and from Ordovician strata in Merionethshire.

The industry in Carnarvonshire is represented chiefly by two enormous quarries, the Penrhyn and the Dinorwic, which produce about 67 per cent of the total output.

The Merionethshire quarries with centre at Festiniog, are worked by underground mining.

VOLUME OF THE DOMESTIC TRADE

The official figures of production given on page 40 do not indicate the uses of the stone. In consequence, official figures as to the quantity of stone used solely for building purposes are lacking. Through the kindness of certain operators, however, it is possible to quote figures in some instances. It will be understood that these statements are unofficial, and in no sense complete.

Granite

Cornwall. The production of Cornish granite, before the war, was in round figures about 300,000 tons per annum; in 1924 it was about 50,000 tons, but it is estimated that during the present year 100,000 tons will be quarried. Although the volume of output is less than formerly, the actual value of the finished stone is probably as high, as more is going into monumental work and less into heavy construction. The industry as a whole may be regarded as being in a satisfactory condition as no granite cutters are lacking employment.

Aberdeen and Peterhead. Definite figures as to production in this area are not available. However it is stated that the demand for building stone and for setts is almost negligible but that there is a constant, if not large, demand for monumental stone. From 700 to 800 men are engaged in actual quarrying in the Aberdeen district. The total output must be considerable but it was not possible to ascertain how much of the output is used for building and monumental purposes.

Sandstone

Forest of Dean. The production from this district is probably about 150,000 cubic feet per annum.

Derbyshire. The output of sandstone is estimated at 320,000 cubic feet for 1924. This includes 60,000 cubic feet of pulpstones and grindstones.

Limestone

Portland. The production of Portland stone varies greatly from year to year. According to one informant, it is from 75,000 to 100,000 tons per annum; according to another the average is about 60,000 tons or 960,000 cubic feet. The total number of men employed in the stone trade on Portland isle is about 1,200.

Bath. As in the case of Portland stone the output of the Bath quarries varies greatly. Roughly it ranges from 5,000 to 10,000 tons per annum.

Derbyshire (Hopton-Wood only). The normal production is about 8,000 cubic feet per annum but recently it has been much higher owing to a contract to supply 25,000 cubic feet a year for a number of years for war-grave memorials. In 1924 the total production was about 28,000 cubic feet, of which 80 per cent was used for headstones and the balance for flooring, panels, staircases, etc.

Marble

Devonshire. The present production of Devonshire marble is about 500 tons of Petitor and 1,000 tons of Ashburton per annum. The latter marble has been exported to Australia and to America.

Ireland. The production in 1924 is stated to have been more than 1,000 tons most of which was shipped, finished or unfinished, to England, United States, and Belgium.

Slate

The importance of the North Wales slate industry may be judged from the following statistics of employment: 1870, 12,000 men; 1898, 16,000 men; 1904, 14,925 men; 1910, 11,589 men; 1914, 10,155 men.

During the war the number of employees declined 60 per cent but there has since been a gradual resumption of the former activity. At present about 15,000 men are employed.

The demand is constant for mill stock for electrical switchboards and cisterns. The output of roofing slate is insufficient to meet the requirements of the home market and some foreign slate is imported for this purpose. There is very little export of slate.

The production in 1924 was 287,705 long tons, valued at £2,157,380. The number of men employed in that year was 10,262. In 1898, the year of maximum production, the output exceeded 500,000 long tons.

"It is reported that there are many signs of a revival in the Welsh slate trade, and although it cannot be said that prewar outputs or demand have been altogether attained, there are a continuity of orders and a steady week-to-week working which are most satisfactory."[1]

CHIEF STONES IMPORTED INTO GREAT BRITAIN

At present there is no demand in the British market for foreign building stone. Occasionally, foreign stones, more particularly Caen stone, have been imported, but such instances are rare and do not indicate any failure of the domestic supply to meet the requirements of the trade.

Granite

The table of imports given on pages 40 and 41 shows that the importation of setts, curbs, and crushed granite amounted in 1923 to 651,325 tons. The imports of monumental and architectural granite were 3,330 tons, the sources being, in order of quantity, Germany, Sweden, Norway, other foreign countries, British Empire. A comparison of the figures for the period 1920-23 reveals a considerable fluctuation in importation of this class of stone:

Imports of Monumental and Architectural Granite

	1920	1921	1922	1923
	long tons	long tons	long tons	long tons
British Empire	942	2	0	10
Germany	44	420	610	2,030
Norway	85	347	232	541
Sweden	87	76	29	684
Other foreign countries	19	144	25	65

The more important foreign granites imported into Aberdeen, the centre of the monument industry, in order of quantity, are as follows:—

Black granite (Ebony and Bon Accord), Karlshamn, Sweden.

Grey granite (Glencoe), Nystad, Finland.

Red granite (Balmoral), Nystad, Finland.

Pearl granites (Emerald Pearl, Royal Blue), Larvik, Norway.

About 12,000 tons of these granites are used in a year in the mills at Aberdeen. There is an evident disparity between this figure and the official figures of imports. It may be that the large quantity indicated is supplied from stocks in the yards of the Granite Supply Association.

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[1] Stone Trades Journal, February, 1925.

Marble

The marble industry is much more specialized in England than in America as each firm devotes its attention to a particular type of work. Some use only the most expensive foreign marbles for highly decorative purposes, as mosaics, inlaid work, etc.; others specialize in panel work, floors, and general decorative work, using stones of medium value; others use the cheaper marbles for utilitarian purposes.

As a result of this diversity it was difficult to arrive at satisfactory general conclusions. However, all the operators who were interviewed, with the possible exception of those engaged in the highly decorative type of work, agreed that the industry was in a flourishing condition.

Several firms in England own or control foreign quarries and naturally advocate the use of the stone in which they are particularly interested.

The following firms control the output of certain foreign quarries:—

Anselm, Olding & Co., Italian quarries.
Walton, Goody & Cripps, Italian quarries.
Fabricotta & Co., Italian quarries.
H. T. Jenkins & Sons, Bianco d'Aquilla quarry, Italy.
Farmer & Brindley, Cipollino quarry, Greece.

Architects are using marble in increasing quantity for the interiors of all public buildings. Recent contracts for decorations in marble run from £3,000 to £50,000.

The sources of the foreign marbles and the fluctuations in the imports are indicated in the following table:—

Imports of Marble into Great Britain

	1920	1921	1922	1923
	long tons	long tons	long tons	long tons
British Empire	2	0	(£10)	8
Belgium	2,416	2,018	1,550	1,342
Italy	25,003	18,120	21,734	25,663
Other foreign countries	550	564	644	243
Total	27,971	20,702	23,928	27,256

In order of importance the chief sources of marbles imported into England are Italy, Belgium, Greece, France. In addition, a relatively small quantity comes from Switzerland, Canada, United States, Spain, Africa, and Scandinavia.

The London market doubtless absorbs in small quantity almost all the known marbles of the world—a complete list is almost impossible and would be out of place here. The writer is indebted to Mr. T. Aubertin for the lists below: the first shows the marbles that are commonly used in large quantity, and the second is an abridged list of the better known marbles actually available on the London market.

List of the Chief Marbles Used in Quantity in London

Sicilian: white and clouded marbles from Seravezza and Carrara, Italy; purposes of general utility. ("Sicilian" has no relation to Sicily. The origin of the name is obscure.)

Belgian Black: black marble, the best varieties being devoid of other colour; considered to be one of the best black marbles of the world.

Belgian Reds: friable marbles of uneven hardness, not of high decorative value, but cheap.

Skyros, Verde Antico, Cipollino, Tinos; marbles of great beauty used in decorative work.

Onyx marble: on account of delicate beauty used for decorative purposes of the highest type.

List of Marbles Available in the London Market, but in Some Cases Used in Small Quantity Only

Utilitarian:

- Switchboards
  - Sicilian and Dove: Carrara and Seravezza, Italy.
  - Belgian black; poorer qualities.
- Tables and washstand tops
  - Sicilian.
  - Belgian Reds: St. Annes, Belgium.
  - Petit Granit: Anthisnes, Belgium.
- Underground sanitary work
  - Belgium Red: St. Annes, Belgium.
  - Bleu Belge: Bioulx, Belgium.

Decorative:

- Monumental
  - Sicilian, almost entirely Carrara, Seravezza, Lucca, Italy.
- Public buildings, etc.
  - English alabaster: wall linings and ceilings, Chellaston, Derbyshire.
  - Allomite: blue sodalite from Dungannon, Ontario; not really a commercial stone at present.
  - Arabescato: blue-veined white, staircase and wall linings, Seravezza, Italy.
  - Arni Alto: greenish-veined white, staircase and wall linings, Carrara, Italy.
  - Bleu Fleuri: wall linings, Italy.
  - Black and Gold (Portor): shop fronts and interiors, Spezia.
  - Brèche Violette: panels and exterior columns, Seravezza, Italy.
  - Brèche Stazzema: wall linings, panels, Italy.
  - Brèche Rosé: many uses in small quantity, Fauske, Norway.
  - Calacata: softly grey-veined white, tiles, panels, wall linings, Italy.
  - Cipollino: green, much used in columns panels, etc., Euboea, Greece.
  - Cipollino: green, columns and panels, but not for exteriors, Valais, Switzerland.
  - Cork Red: for interiors, Ireland.

List of Marbles Available in the London Market, but in Some Cases Used in Small Quantity Only—Concluded

Decorative:—concluded

Public buildings, etc.—concluded.

Ashburton: highly figured, shop fronts, counters, skirting, Devonshire.
Escalette: columns and panels, Pyrenees.
Connemara Green: various uses in small quantity, Ireland.
Fleur de Pêcher: panels, Italy.
Jaune Jaspé: panels.
Jaune St. Baume: panels.
Jaune Lamartine: panels, Department of Jura, France.
Languedoc: bright red with pink patches, various uses, Gard, France.
Levanto: rich red with veins of dark green, shop fronts and exteriors.
Lunel: dado rails and panels, Pas de Calais, France.
Napoleon: dado rails and panels, Pas de Calais, France.
Onyx: for delicate work; Algeria, Fontrabiouse, Pedrara, Argentina.
Ringborg: green, various uses, Ostergothland, Sweden.
Rouge Griotte: various uses, Belgium.
Rouge Imperial: various uses, Belgium.
Rouge Jaspé: various uses, Belgium.
Rouge Royal: various uses, Belgium.
St. Annes' Red: chimney pieces and various uses, Belgium.
St. Edouard: various uses, Belgium.
Skyros: extensively used for many purposes, Greece.
Subiaco: yellowish and veined, much used, near Rome, Italy.
Tinos: very popular now, interior and exterior, Greece.
Travertine: much used for floors and wall linings, not really a marble, Bagni, Tivoli, Italy.
Verde Antico: much used in high-class work, Greece.
Vert d'Estour: interiors, Haute Garonne, France.

In the preparation of such lists as the above, the personal equation as in all selective matters, is unavoidable. Other lists differ somewhat, e.g., the list from "Quarry," quoted on page 57.

Mr. H. T. Jenkins, one of the largest operators in England, has kindly furnished the following statement as to the relative consumption of marble in his mills. "In general we find that we use approximately 50 per cent of good quality white Sicilian, Blanc Clair, second Statuary, and Piastraccia marbles from the Carrara and Seravezza districts, Italy, and the remainder consists of qualities such as Sienna, Tinos, Verde Antico, Greek Cipollino, Vert des Alpes, Genoa Green, Fleur de Pêcher, and Skyros."

NOTES ON QUARRYING

In nearly all the quarries in Great Britain the stone is won by very simple methods—usually by taking advantage of the joints and bedding planes and dislodging the blocks by wedges or by the use of black powder.

Channeling machines are not used, although they have been tried on Portland isle. Their efficiency is doubted; this is probably due to the shattered nature of the formation.

The quarrying of Bath stone is effected by sinking shafts or running inclined adits to the ground beds. The stone is won by hand-picking a horizontal channel or jad over the top of the good beds, and then sawing with toothed handsaws to the desired depth of floors. The block thus set free above and on two sides is broken out by wedging along the floor line.

The usual method of quarrying granite is by the use of black powder in deep holes a considerable distance from the face. Large masses are thus dislodged by one explosion.

In the marble quarries of Devonshire the wire saw replaces the channeling machine of American practice. Cuts 100 feet long and 25 feet up are sometimes made.

The quarries are equipped with the usual machinery and in some of the larger quarries aerial ways in part replace derricks and cranes. There is a strong tendency toward electrically equipping the plants.

NOTES ON MILL PRACTICE

Most of the larger quarry operators own mills at the quarries, but there are numerous extensive mills in London and in other of the larger centres. Slight difference in practice was observed from that employed in the larger Canadian mills.

The use of the pneumatic tool is less than in Canada, not because of conservatism, but from a conviction that they are unsuitable for certain kinds of work. In some instances workmen refuse to use them on account of their alleged injury to the operator.

Most of the mills are supplied with small rubbing-beds, but in all the mills visited, not one was seen in actual operation. Reversing planers are replacing the single-acting type and the pendulum polisher is much used in the granite mills.

The working of Bath stone is unique. Toothed saws, either hand or power-driven, are employed for cutting the stone to size. Surfacing is accomplished by "drags," semicircular pieces of steel, toothed on the straight edge, and operated with a peculiar sweeping motion by hand.

A practice not seen in America is that of coating the dressed stone with "slurry"—a paste made by mixing the powdered stone from the saws with water. This coating is to protect the stone until used in building.

The wire saw is extensively used in the marble mills: it is considered to be more economical than other cutting devices both in cost of operating and in the saving of material.[1]

The numerous mills at Aberdeen all follow essentially the same practice. Each operation is regarded as a separate trade and the men seldom attempt work of another kind. The practice for plain work is briefly as follows:—

Squarers. By hand work the required faces are rendered plane and given the proper angle with one another. One, two, four, or five faces may be thus prepared.

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[1] Wire saws have not found favour in America. The few that have been installed were soon discarded. Channeling machines have replaced the wire saw in American practice. In Italy the wire saw is universally used in the great marble quarries, and it is installed in most of the marble mills in England and on the continent. The wire is usually made of three strands, forming a rope four and a half millimetres in diameter. The direction of the twist is reversed every 100 feet, and the total length of the rope is often as great as 1,200 metres.

Surfacers. Known locally as "dunters." Surfaces are smoothed by pneumatic bush hammers.

Smoothers. The surface is further smoothed by scroll wheels working with crushed steel and carborundum powder.

Polishers. Jenny Linds with putty powder.

Carvers. Carving is special work, pneumatic tools are used for carving and sand blast for lettering.

An interesting innovation in the marketing of stone has been introduced by one of the operators in the Bath area. This company has introduced the practice of supplying sawn ashlar in standard sizes—6¼ inches high, 4½ inches deep, and of random lengths not less than 9 inches nor more than 2 feet 3 inches.

SCALE OF WAGES

Workmen in the quarries and mills of Great Britain are generally paid on a time basis, but piecework is done in some instances as in the case of sett-makers, and in the slate industry of North Wales. The working week is 44 hours but, in some cases, it is 49½ hours in the summer.

The following tables have been compiled from information received at the places indicated:

Scale of Wages. Rate per Hour on Basis of 44-hour Week unless Otherwise Indicated

	s.	d.
Granite—		
Cornwall—		
Cutters	1	4½
Quarrymen	1	0⅜
Aberdeen—		
Quarrymen	1	3½
Plug-drill men	1	0
Labourers, quarry	1	1
Masons (stonecutters)	1	6
Polishers	1	5
Labourers, mill	1	0½
Sett-makers, piecework, £3 to £4 per ton.		
Sandstone—		
Derbyshire—		
Cutters (block makers)	1	4½
Bankerhands (stonecutters)	1	8
Sawyers	1	0½
Machine hands	1	7
Getters (quarrymen)	1	4½
Limestone—		
Portland Isle—		
Masons	1	8
Labourers, skilled	1	4½
Labourers, unskilled	1	3½
Quarrymen, piecework, minimum rate per eight-hour day	12	7
London mills—		
Masons	1	9½
Labourers in yard	1	4½
Labourers on buildings	1	5
Setters (stonemasons)	1	10½
Derbyshire—		
Ordinary quarrymen	1	2
Getters	1	4
Labourers	0	11
Sawyers	1	2
Masons	1	6½
Mill labourers	1	0
Marble—		
Devonshire—		
Quarrymen	1	3
London mills—		
Masons	1	9½
Polishers	1	7½
Sawyers	1	6½

Slate

North Wales. Quarrymen work in parties of two and are paid by the ton of good slate produced. As the facility with which the product can be obtained varies with the formation, the rate per ton is arranged by bargaining for a particular part of the face; hence, a given extent of face is known as a "bargain." The rate for mill stock and writing slate is generally about 6s. 6d. per ton, but for roofing slate it may vary from 3s. to 9s. per ton. A minimum rate of 10s. per day is also in force.

Splitters employ their own assistants who are known as "journeymen" or "trimmers." The rate of payment is carefully graded and depends on the size of the sheets and on the price received by the company for the finished article. Working on good slate, the rate may be, for example, 5s. 6d. per pound sterling received by the company. A good splitter will earn about 15s. per day after paying his journeyman.

PRICES OF STONE, DOMESTIC AND FOREIGN

The Canadian consumer who wishes to purchase stone in Great Britain, or the Canadian producer who hopes to compete in the British market is vitally concerned in the market prices. It is almost unnecessary to state that prices vary with quality and at different times; in consequence, many published price lists are unreliable. However, quotations on the better known stones are revised monthly in such journals as "The Quarry" and "The Builder." It has been thought advisable to insert here lists of current market prices of the more widely known stones.

Granite

	£	s.	d.
Cornwall—			
Prices f.o.b. or f.o.r. Penryn.			
Building stone, fine, in ordinary sizes, per cu. ft.	0	6	6
" " coarse " " "	0	5	6
Monumental, large sizes, per cu. ft.	1	0	0
Aberdeen—			
Delivered at mills by Supply Association.			
Balmoral (red), Nystad, Finland, per cu. ft. (under 40 cu. ft.)	0	14	0
Glencoe (grey), Nystad, Finland, " " "	0	16	0
Emerald Pearl, Larvik, Norway, " " "	0	17	0
Royal Blue, Larvik, Norway " " "	0	17	0
Ebony Black, Karlshamn, Sweden " " "	1	1	0
Bon Accord, Karlshamn, Sweden, " " "	0	18	0
Red Swede " " "	0	13	0
Beer's Red and Victoria Red, " " "	0	15	0
Silver White, Kirkcudbrightshire " " "	0	15	0
Birsemore (Birsemohr), Aboyne " " "	0	13	0
Peterhead " (under 30 cu. ft.)	0	18	0
Peterhead " (under 50 cu. ft.)	1	0	0
At Rubislaw quarry, Aberdeen.			
Best monumental, small sizes, per cu. ft.	0	12	0
Monumental, over 25 cu. ft., per cu. ft.	1	0	0
" large sizes, "	1	5	0
Ashlar, per cu. ft.	0 0	6 7	0 0

Sandstone

	f.o.r. quarries		Delivered station, London (north of) Thames)	
	s.	d.	s.	d.
York—				
Delivered at Station, London.				
Blue, Robin Hood quality—				
Landings, 6 in., sawn two sides to sizes (under 30 sq. ft.) per sq. ft....			5	6
Landings, 6 in., rubbed two sides, (under 30 sq. ft.) per sq. ft.........			6	0
Landings, 3 in., sawn two sides, random sizes, per sq. ft..............			2	3½
Landings, 2 in. to 2½ in., sawn one side, random sizes, per sq. ft.......			1	6¾
Landings, 1½ to 2 in., sawn one side, random sizes, per sq. ft..........			1	4
Hard York—				
Random blocks, scappled, per cubic foot............................			6	3
Landings, 6 in., sawn two sides to sizes (under 40 sq. ft.), per sq. ft...			5	1½
Landings, 6 in., rubbed two sides, (under 40 sq. ft.), per sq. ft.......			6	1½
Landings, 4 in., sawn two sides, random sizes, per sq. ft..............			2	10
Landings, 3 in., sawn two sides, random sizes, per sq. ft..............			2	1½
Flagging, 2 in., self-faced, random sizes, per sq. yd..................			9	0
Corsehill—				
Rough quarry scappled blocks, random sizes; no block less than 12 in. thick, per cubic foot...	2	½	3	10½
Rock face ashlar, 1st quality, to sit on natural quarry bed, machine planed bed, 7 in. by 12 in. high, random lengths, jointed ready to fix in building, per superficial foot...	3	4½	5	1
Rock face ashlar, 2nd quality, machine ribbed beds, not guaranteed to sit on natural quarry bed, otherwise sizes and description as above, per superficial foot..	2	3	4	0
Ashlar, 1st quality, 7 in. by 13 in. high, random lengths, rubbed faces, jointed ready to fix in building, per superficial foot.................	3	10	5	7
Ashlar, 1st quality, but faces merely fine sand sawn, not rubbed, per superficial foot..	3	8	5	5
Derbyshire (Stancliffe)—				
f.o.r. Darley Dale.				
Coursing stone, 7 and 8 in., 6 in. on bed, bedded and jointed (scutched), per superficial yard..	7	6		
Random blocks, roughly squared, not scappled, per cubic foot........	3	6		
Dimension blocks, scappled to size, per cu. ft.......................	5	0		
Pulpstones, brown, per cu. ft....................................	12 30	6 0		
Forest of Dean—				
f.o.r. quarries.				
Roughly squared blocks, per cu. ft................................	3 4	6 0		

Limestone

	s.	d.
Portland—		
f.o.b. or f.o.r. Portland, 20 cu. ft., average		
Random blocks, general average, up to 20 cu. ft., per cu. ft.....................	3	6¾
Sawn stock, general average, per cu. ft..	9	0
Alongside rail at Portland, 20 cu. ft., average.		
Whitbed, per cu. ft...	3	6
Basebed "	3	9
On railway truck at Paddington, South Lambeth or Nine Elms, London.		
Whitbed, per cu. ft...	4	4
Basebed, "	4	7
Selected or monumental quality, extra per cu. ft.............................	0	1
Every cubic foot over 20 cu. ft., extra per cu. ft............................	0	1
Every cubic foot over 30 cu. ft., extra per cu ft.............................	0	½*

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* Loading rates are placed at 9d. per ton. Freight rate to London is 11s. 8d. per ton. Blocks to cut 16 cu. ft. are called a ton by the railways, *i.e.*, no charge is made for the carriage of the excess stone that must be cut away.

Limestone—Concluded

Bath—		
f.o.r. quarries.		
Standard ashlar, per sq. yd	7	0
Standard ashlar, 4 in. to 8 in., in 10 in., 12 in. and 14 in. courses, random lengths, per cu. ft.	1	9
Random blocks, per cu. ft.	2	0
At Paddington or South Lambeth, not less than 4 tons.		
Standard ashlar, per sq. yd	9	6½
" " per cu. ft.	2	6½
Blocks, per cu. ft.	2	9½†
Derbyshire (Hopton-Wood)—		
f.o.r. quarries.		
Roughly squared random blocks, per cu. ft.	15	0
Slabs, sawn two sides, per cu. ft.	25	0
Slabs, sawn three or four sides, per cu. ft.	30	0
f.o.r. London stations.		
Small random blocks, up to 10 cu. ft., per cu. ft. (to reduce stock)	7	0
Random blocks from 10 cu. ft. and over, per cu. ft.	17	0
Sawn two sides, per cu. ft.	27	0
Sawn three or four sides, per cu. ft.	32	0

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† The freight rate, Bath to London, is 12s. 8d. per ton, equivalent to 2s. 6½d. per superficial yard of standard ashlar. Random dimension blocks can be placed on dock, Montreal, for 4s. 10d. to 5s. per cu. ft.

Domestic Marbles

	£	s.	d.
Devonshire—			
f.o.b. British ports.			
Sawn blocks, per cu. ft.	0	14	0
Derbyshire—			
f.o.r. quarries.			
Blocks, per cu. ft.	0	15	0
Slabs, sawn two sides, per cu. ft.	1	7	6
Slabs, sawn three or four sides, per cu. ft.	1	12	6
Ex London depot.			
Slabs, ¾ in. thick, per sq. ft.	0	2	9
" 1 " " "	0	2	9
" 1¼ " " "	0	4	1
" 1½ " " "	0	4	1
" 2 " " "	0	5	5
Ireland—			
f.o.r. Dublin or Cork.			
Connemara Green, Cork Sunset Pink, or Cork Red—			
Blocks, up to 2 feet long, per ton	8	0	0
" between 2 and 3 feet long, per ton	10	0	0
" " 3 " 4 " "	12	10	0
" " 4 " 5 " "	16	10	0
" " 5 " 6 " "	20	0	0
" " 6 " 7 " "	24	0	0
Ex store, London—			
Extra, per ton	2	0	0

Foreign Marbles

Ex London depot
Slabs, random sizes, rough from saw, per square foot—

	¾ in.		1 in.		1¼ in.		1½ in.		2 in.	
	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.
White—										
Sicilian	1	11	2	4	2	10	3	3	4	2
Vein	2	1½	2	7	3	1½	3	7	4	7
Bastard Statuary	2	6	3	0	3	6	4	0	5	0
Pavonazetto	3	9	4	6	5	6	6	6	8	3
Pavonazza	5	0	6	0	7	0	8	0	9	6
Red—										
Belgian Rouge	2	9	3	6	4	3	5	0	6	6
Rosso Antico	3	6	4	0	4	6	5	6	7	6
Red Verona	3	0	3	6	4	2	4	9	5	10
Bryscom	3	1	3	11	4	9	5	8	7	0
Green—										
Genoa Green	4	4	5	2	5	11	6	10	8	6
Tinos	4	6	5	4	6	1	7	0	8	8
Swedish	5	0	6	0	7	0	8	0	9	8
Grey—										
Dove	2	1½	2	7	3	1½	3	7	4	7
St. Anne	3	2	4	0	4	10	5	8	7	4
Yellow—										
Jaune Fleuri	6	6	8	3	10	0	11	9	13	0
Sienna, light	7	6	10	0	12	6	15	0	19	6
Sienna, blue-veined	9	0	12	0	15	0	18	0	23	0
Jaune Foncé	5	0	6	5	7	10	9	2	11	6
Black—										
Belgian	2	9	3	6	4	3	5	0	6	6
Black and gold	5	3	6	7	7	10	10	1	11	6
Blancil Black	3	0	3	9	4	6	5	3	6	9
Onyx—										
Mexican Onyx	11	6	14	0	17	6	20	6	25	0
Melato Onyx	3	6	4	6	5	6	6	6	8	6
Rose Onyx	4	6	5	6	6	0	7	0	9	0

	£	s.	d.
Blocks—			
Average Carrara, per cu. ft.	0 1	19 10	0 to 0
Sicilian flooring, laid and finished, ⅞-in., per sq. yd.	1	5	0

f.o.b. quarries—	
Black Belgian, f.o.b. Mazy, per cu. metre—Belgian francs	550 to 1,200
Statuary, H, f.o.b. Seravezza, per cu. metre—lire	4,500 to 6,600
White Carrara “ “ “ “	1,000 to 3,300
Arabescato “ “ “ “	1,040 to 3,400
Piestraccia “ “ “ “	1,200 to 2,500
Arni Alto “ “ “ “	975 to 2,250
Fleur de Pêcher “ “ “ “	1,950 to 4,320
Blanc Clair.. “ “ “ “	750 to 2,010
Tinos, f.o.b. Eckeren (Anvers), carload lots, per cu. metre—French francs	2,225 to 2,950
Verde Antico, f.o.b. Eckeren (Anvers), per cu. metre—French francs	4,000 to 4,800
Cipollino, “ “ “ “ “	2,800 to 4,100
Skyros, per kilogram, French francs	1·20 to 2·2
Swiss Cipollino, f.o.b. Saillon, Valais, per cu. metre—French francs	500 to 1,100
Vert d'Estour, f.o.b. St. Girons, France, per cu. metre—French francs	900 to 1,650

Slate

North Wales. The price of roofing slates varies with colour and size. The product is sold by the ton or by the "Mille"—a "mille" being twelve hundred sheets (M. = 1,200)[1]. This method of sale is about equivalent to the American practice of estimating roofing slate by the "square."

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[1] In practice 60 additional sheets are allowed for breakage.

The officials of the Penrhyn quarry have kindly permitted the following selections from their price list:

Prices of Penrhyn Slate

On dock or railway siding, Port Penrhyn—	£	s.
First quality.		
Queens—24, 26, 28, 30 in. long, without specifying quantity of each, blue, per long ton	11	16
Queens—32, 34, 36 in. long, without specifying quantity of each, blue, per long ton..	11	12
Ton slates—12 in. by 6 in., green and wrinkled, grey, blue, and red, per long ton....	5	10
Ton slates—11 in. by 7 in., green and wrinkled, grey, blue, and red, per long ton....	5	0
Ton slates—10 in. by 8 in., green and wrinkled, grey, blue, and red, per long ton....	5	0

Size	Tally slates													
	First Quality Per Mille of 1,200 slates						Second Quality Per Mille of 1,200 slates							
	Blue and Red		Grey and Green and Wrinkled		Grey Mottled		Blue and Red		Grey		Grey and Green and Wrinkled		Grey Mottled	
	£	s.	£	s.	£	s.	£	s.	£	s.	£	s.	£	s.
24 x 14	43	0	41	15	39	0	39	10	40	0	36	17	36	10
24 x 12	38	5	36	17	35	0	36	10	36	10	34	6	33	7
22 x 12	34	10	33	10	31	18	32	10	35	16	31	0	31	18
22 x 11	31	10	31	0	29	0	30	0	32	2	27	11	28	10
20 x 12	29	15	29	5	27	5	28	4	30	4	25	18	26	18
20 x 10	26	15	25	8	24	8	26	14	26	14	24	6	24	6
18 x 12	25	10	25	0	23	8	24	14	26	4	22	15	23	4
18 x 10	21	4	20	15	19	14	19	6	21	16	18	8	18	6
18 x 9	19	0	18	5	17	10	16	10	17	10	16	0	15	8
16 x 12	20	15	20	5	19	4	18	12	21	18	18	3	18	3
16 x 10	17	15	17	5	16	13	16	10	18	16	15	12	16	14
16 x 9	15	12	15	0	14	8	13	8	14	18	12	4	12	18
16 x 8	14	0	13	8	12	18	12	6	14	0	11	5	12	4
14 x 12	16	4	15	18	14	17	13	15	15	16	12	0	13	15
14 x 10	13	18	13	5	12	15	12	0	13	18	10	10	11	16
14 x 8	10	16	10	4	9	16	9	16	12	0	9	4	10	14
13 x 10	11	6	10	16	10	2	10	2	12	0	9	4	10	14
13 x 7	8	0	7	5	7	3	7	2	8	0	6	10	7	14
12 x 10	9	16	9	4	8	12	8	12	10	2	7	14	9	4
12 x 8	7	14	7	2	7	2	7	14	8	12	6	10	7	14

Third quality slates vary from £33 7s. to £6 10s. per M of 1,200.

The "Quarry" of October, 1925, gives the following quotations:

Best Quality Bangor or Portmadoc Slates, f.o.r., Quarries

Sizes	Price per Mille of 1,200 £	s.	d.
24 x 12	37	12	6
22 x 12	34	0	0
22 x 11	31	5	0
20 x 10	25	12	6
18 x 10	21	2	6
18 x 9	18	12	6
16 x 10	17	12	6
16 x 8	13	15	0

Mill slabs are classified for marketing in two grades, known as "lotted slabs". The slabs are sawn all around, and split as near the thickness required as possible, and are of promiscuous dimensions, as follows:—

	Per long ton £	s.	d.
Lot 1: ½ inch, ¾ inch, 1 inch, 1¼ inches, 1½ inches, thick, between 3 feet 6 inches and 7 feet long, and 2 feet 6 inches and upwards wide.......	8	15	0
Lot 2: 1 inch, 1¼ inches, 1½ inches, 2 inches, 2½ inches thick, between 6 feet and 9 feet long, and 3 feet and upwards wide....................	10	15	0

CANADIAN STONE AND THE BRITISH MARKET

It will have been observed from the tables already given, that Great Britain imports very little, if any, stone solely for building purposes. The only building stone available on the Atlantic seaboard of Canada is the sandstone of New Brunswick and Nova Scotia. Should an attempt be made to place it on the British market, it is extremely doubtful whether the quality of this stone would command a sufficiently high price to offset the transportation charges.

Granite suitable for building occurs at many places in Nova Scotia, New Brunswick, and Quebec. In the latter province, particularly, the formational features of certain granite masses are such that the stone should be quarried more cheaply than in any of the quarries of Great Britain. According to shipping facilities, Canadian granite must be quarried at from 75 cents to one dollar a cubic foot more cheaply than in Great Britain in order to compete with Cornish or Aberdeen granite.

Great Britain's imports of granite are practically all of monumental stone. The deep red granites are in demand; some of the imported stones are not superior to the red granite of St. George, New Brunswick, and none of the Peterhead granites are equal to it. This stone has been shipped in small quantity to Aberdeen and increased trade is entirely a matter of costs.

Black granites are always in demand and command a high price and it is possible that a trade might be established in Bocabec or Mount Johnson stone. The writer is of the opinion, however, that the quality of Canadian black granites is not high enough to successfully compete with those from other countries.

The highly decorative stones (pearl granites) from Larvik, Norway, have a possible competitor in the syenites of Port Coldwell, Ontario, but these stones are not on the market at present.[1]

There is a possible sale in London for marbles of all kinds but the most prominent dealers and operators, men thoroughly conversant with most of the decorative stones of the world, have little or no knowledge of our Canadian marbles. When it is remembered that some of the marbles of Ontario and Quebec are unique in colouring and clouding, and of a beauty comparable with that of many of the stones imported into England, it is regrettable that no serious attempt has been made to draw the attention of the British dealers and architects to the advantages of Canadian marble.

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[1] Ont. Bureau of Mines Rept., vol. XI, pp. 208-213.

IV

NOTES ON ZINC AND LEAD IN EASTERN CANADA

A. H. A. Robinson

Throughout 1925 interest in the commercial possibilities of the zinc and lead deposits of eastern Canada was very keen; some of the older abandoned properties have been re-opened for examination in the light of changed economic conditions; newer prospects are being explored, and there are very few known occurrences of these metals that have not been given at least a preliminary examination by prospective purchasers or operators. The present interest in lead and zinc, which is not confined to Canada, but appears to be world-wide, is largely due to the rapidly increasing consumption of these metals and consequent high prices without a corresponding increase in visible sources of supply. In the case of zinc, other causes possibly of equal importance are the advances in ore-dressing and metallurgy that have made it possible to work profitably ores that formerly had little or no commercial value, and the re-arrangement that is now going on in the world's zinc industry largely as a result of the success of these new processes. Differential flotation affords a comparatively cheap and easy method of separating lead from zinc in many complex ores in which the zinc, formerly detrimental, is now a source of profit; moreover, electrolytic methods for the production of metallic zinc from its ores have given rise to new zinc-producing centres at points where cheap electric current is available and supplies of raw material can be readily secured. If present activities succeed in putting in sight sufficient zinc ore to warrant its erection, the establishment of a zinc reduction plant in connexion with some of the hydro-electric power developments in eastern Canada may be looked upon as a foregone conclusion.

A review of the present conditions and activities at some of the better known zinc mines and prospects in eastern Canada follows:

Maritime Provinces

Sterling Prospect, Sterling, Richmond County, Cape Breton, N.S.

The Sterling deposit is made up of an intimate mixture of iron-zinc-lead and copper sulphides. The first work is said to have been done on it about 22 years ago, with the idea of opening it up as a copper mine. About 1915, attention was drawn to its zinc possibilities, and between that date and 1924 it passed through several hands, and a certain amount of exploratory work, including surface trenching and diamond-drilling, was done on it. Early in 1925 it was taken over by the American Cyanamid Co., of New York, by whom it is now being explored. A gasoline prospecting plant has been installed and a shaft is being sunk on the deposit in an endeavour to prove up a commercial ore-body.

An idea of the composition of the Sterling ore as found at the surface is given by the following analyses of 10 trench samples, published by D. D. Cairnes in the Summary Report of the Geological Survey for 1916.

Copper	Lead	Zinc	Gold	Silver
per cent	per cent	per cent	oz. per ton	oz. per ton
2·09	4·21	29·44	0·08	1·96
1·36	1·76	11·71	0·06	Trace
0·52	1·40	3·71	0·06	"
0·23	0·11	3·88	0·04	0·25
0·67	2·34	7·90	0·04	Trace
0·25	1·04	3·71	0·04	"
3·43	7·52	27·05	0·06	7·38
2·20	4·78	17·66	0·08	1·26
0·32	2·18	5·71	0·04	0·20
0·82	0·26	6·84	0·03	Trace

Smithfield Mine, Colchester County, N.S.

In the eighteen-eighties an attempt was made to work a deposit of galena, accompanied by pyrite and a little sphalerite in limestone gangue at Smithfield, 14 miles from Truro, in Colchester county, Nova Scotia. Ore was obtained from shallow underground workings and a small experimental lead furnace was built. The enterprise was soon abandoned, however, and the property lay idle till 1925. When visited in that year the workings were inaccessible and nothing was to be seen but some small piles of ore at the mouths of the old pits and some remnants of the old lead furnace. All the information now obtainable concerning the workings is contained in reports made to the owners in 1889 by Edwin Gilpin, Jr., then Inspector of Mines for Nova Scotia, and Captain Francis Evans, M.E., of Oswestry, Salop, England. According to these reports, four shafts were sunk. The first was a small prospecting shaft showing ore; the second, about 100 feet east of the first, was a timbered shaft 35 feet deep, from the bottom of which a cross-cut driven through the deposit showed a thickness of 30 feet of ore consisting of carbonate of lime carrying galena and iron pyrites; the third shaft, about 50 feet farther east, was 55 feet deep and showed better ore than number two; the fourth shaft, the position of which is not specified, is said to have been sunk till it reached the top of the ore. Some 300 tons of ore are said to have been extracted from the workings, and Gilpin says: "the ground already proved to carry ore extends over 450 feet in length, the width being estimated at 30 feet" and "the proportion of No. 1 galena that could be hand-dressed out of the ore at 16 per cent" giving "in the ground already opened about 25,000 tons of galena." Evans says "both ends and bottom of the mine are rich in ore" and "the lode is well defined, running on an east and west line through the property for 6,000 feet. Only a small portion of this is proved, although the measures appear to be ore-bearing throughout."

Gilpin gives the results of the assays of eleven samples of Smithfield ore, which show lead from 20 to 80 per cent, silver from a trace to 144 oz. per ton, and gold a trace to 17 dwt. per ton.

A specimen, typical of the ore in one of the old piles, consisting of a fine-grained mixture of galena and pyrite, fractures of which are filled with rather coarse, pure galena and a little honey-yellow sphalerite, was taken in 1925 and analysed in the Mines Branch laboratory, with the following results:—

Lead	39·52 per cent
Zinc	10·78 "
Silver	0·21 oz. per ton
Gold	trace

At the present time the Smithfield mine is being dewatered and put in shape for thorough underground exploration, under the superintendence of Mr. R. E. G. Burroughs, of Moose River Gold Mines, acting for a syndicate of local capitalists.

Dunbrack Prospect, Musquodoboit Harbour, Halifax County, N.S.

In 1888, a vein averaging about 2½ feet in width, carrying galena and a little chalcopyrite in granite country, was discovered about 3 miles from Musquodoboit harbour, Halifax county. Some work was done on it and, later, between 1916 and 1920, by various parties.

The occurrence is irregular in both composition and continuity. A number of analyses show lead from a fraction of one per cent to over 20 per cent and silver from a trace to 2·5 ounces per ton. Two shafts have been sunk on the occurrence, one to a depth of 152 feet, with drifts at 90 feet and 140 feet. A small pocket of ore is said to have been found in the north drift at the 90-foot level, but very little ore was found in the lower levels. Considerable ore was found at places in the shaft, but it lacked continuity. Some 600 tons of 20 per cent lead ore is said to have been blocked out ready for stoping. No work is reported on the property since 1920.

North Carleton, Yarmouth County, N.S.

In 1923, the American Smelting and Refining Company are reported to have done some work on an occurrence of zinc, lead, and copper at North Carleton, Yarmouth county. There is a shaft on the property, said to be 66 feet deep, with some drifting and a dump containing about 60 tons of ore. Results are said to have been so disappointing that work was stopped and the property abandoned.

Teahan Prospect, Kerry, Albert County, N.B.

The Teahan prospect occurs near the junction of Barrett and Keirstead brooks, on the headwaters of the upper Salmon river, in Alma parish, Albert county. It is about 8 miles by road from Elgin village on the Canadian National railways; and about the same distance from Alma, on tidewater on the north shore of the bay of Fundy. The present discovery was made in 1919 by J. E. Teahan, Sr., of Kerry P.O., on the bank of the brook about 1,000 feet from an old shaft and the remnants of an old copper smelter, where an attempt was made about 40 years ago to open what appears to be the same lode or vein as a copper mine (probably the old Goodfellow or Mineral Vale mine).

The only exposure, about 40 feet in diameter, in some shallow pits and strippings, at the edge of the brook, shows a heavily mineralized zone about 30 feet wide, striking about S.55 degrees W. magnetically with an apparent dip to the north. The country rock is a thinly laminated extremely fissile crumpled talcose or chloritic schist. In the southerly part of the exposure the mineralization consists chiefly of fine-grained pyrite but on the northerly side this is accompanied by considerable amounts of zinc, lead, and copper sulphides irregularly distributed through a gangue made up chiefly of magnesite and dolomite, with smaller amounts of quartz. Structurally the deposit shows a fine-grained portion (banded in places parallel to the schistosity of the country rock), which has been fractured and faulted and the interstices filled with coarser-grained massive material. Most of the quartz and the richer copper concentrations appear to be associated with this interstitial material which is chiefly magnesium-calcium carbonate, whereas the finer-grained banded portions contain little or no lime but some magnesium carbonate.

Two specimens of different types of the ore, No. 1, showing rather coarse-grained copper minerals (chalcocite or tennantite) in quartz and carbonate gangue; No. 2, a fine-grained mixture of pyrite, galena, sphalerite, and carbonate, were analysed in the Mines Branch laboratory with the following results:—

		No. 1	No. 2
Lead	per cent	2·62	13·65
Zinc	"	7·44	23·69
Copper	"	11·86	0·13
Arsenic	"	3·57	nil
Gold	oz. per ton	0·44	0·07
Silver	"	14·94	5.60

A general sample weighing 116 pounds, sent by Mr. Teahan to the Mines Branch Ore Testing Laboratories, to determine the possibility of separating the lead and zinc constituents of the ore, analysed as follows:

Lead	1·26	per cent
Zinc	14·27	"
Copper	2·35	"
Arsenic	0·76	"
Antimony	trace	
Gold	0·03	oz. per ton
Silver	3·91	"

A small-scale test on this sample yielded as follows:—

Ore taken, 1,000 grammes—14 mesh—ground in ball mill for 40 minutes and then treated by flotation.

Reagents used:—

Soda ash, 10·0 lb. per ton, added in ball mill.
Thiocarbanilide, 0·25 lb. per ton, added in ball mill.
Sodium cyanide, 0·24 lb. per ton, added in ball mill.
Pine oil, 2 drops per ton, for lead-copper flotation.
Copper sulphate, 1·5 lb. per ton, for zinc flotation.
Potassium xanthate, 0·3 lb. per ton, for zinc flotation.

Product	Weight		Analyses					Per cent of values				
	Grms.	%	Cu	Pb	Zn	Au	Ag	Cu	Pb	Zn	Au	Ag
			%	%	%	oz./ ton	oz./ ton					
Copper-lead concentrate......	169·7	17·0	12·32	6·62	13·86	0·08	14·76	90·3	93·3	16·3	41·6	70·0
Zinc concentrate.	231·0	23·0	0·56	0·25	49·60	0·04	3·0	5·5	4·2	80·5	29·1	19·6
Tailing..........	600·0	60·0	0·16	0·05	0·7	0·015	0·56	4·1	2·5	3·0	28·3	9·5

These results indicate the feasibility of making commercial products from this ore by differential flotation.

Elm Tree Prospect, near Bathurst, Gloucester County, N.B.

The occurrence of argentiferous galena and blende on Elmtree river, in Gloucester county, has been known for many years and has been described by G. A. Young.[1]

The vein, which is about 6 feet wide, cuts black slates in a north-westerly direction and has a perpendicular dip. It is exposed in the bed of Elmtree river at a point about 1½ miles due west of the Canadian National railway and 3 miles northwesterly from Petit Rocher station, where there is a good shipping wharf on deep salt water. At Tetagouche falls, about 6 miles south, there is a hydro-electric plant, at present idle, capable of producing about 350 h.p. the year round. There is a fairly good road to the property on which a little trenching and test-pitting has been done from time to time. It is stated that old diamond-drill records show the vein to have been 15 feet wide at a depth of 80 feet.

The ore in the chief exposure, in the river bed, consists of rather coarsely crystalline, dark zinc blende, galena, and pyrite with some calcite and quartz. It carries from 4 to 8 ounces of silver per ton. Some tests carried out at the Halifax Technical College by George S. Gilbert, in 1924, would appear to indicate that a good separation of the lead and zinc can be made by combined gravity and flotation methods.

Quebec

The Federal Zinc and Lead Mine, Lemieux Township, Gaspe District

The Federal Zinc and Lead Company's property has been fully described by F. J. Alcock,[2] and in a paper read before the Canadian Institute of Mining and Metallurgy in March, 1924, by Mr. J. C. Beidelman. Since that date the only further work of importance that has been done on the property was some diamond-drilling in the spring and summer of 1925, the results of which have not been made public. A wagon road has been built from New Richmond to the mine, but there has been no production as yet.

Tetrault Mine, Notre-Dame-des-Anges, Portneuf District

This well-known property, which is one of the only two producing lead-zinc mines in eastern Canada, has passed into the hands of The British Metals Corporation (Canada) Ltd. The mine workings have been carried

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[1] Geol. Surv., Canada, Mem. 18 (1911).

[2] Alcock, F. J.: Geol. Surv., Canada, Mem. 144, pp. 55–62 (1926).

to a depth of 500 feet and laterally about 1,600 feet. The mill on the property has been remodelled to treat the ore by flotation and when it was visited in July was handling about 250 tons of feed per day and producing some 200 tons of zinc concentrates and 60 tons of lead concentrates per week. It is intended to increase the milling capacity to 350 or 400 tons of ore per day.

The concentrates, which are shipped to Europe, are carried from the mill to the Canadian National railway station at Notre-Dame-des-Anges, a distance of about 4 miles, in 4-ton motor trucks, which make 13 round trips per 24 hours between the mine and the railway.

The company also have a smaller, 100-ton mill at Notre-Dame-des-Anges station, which is being used to treat material from the old zinc middlings dump left by former operators. When this dump has been cleaned up the machinery from the mill at the station will probably be moved in to the mine.

Bowie, or Reeder Mine, Calumet Island, Ottawa River

During the last decade of the nineteenth and the first decade of the twentieth centuries there was a small production of lead and zinc from lots 3 and 12, range IV, Calumet township (island), Pontiac district, Quebec, on the Ottawa river, about 50 miles above the city of Ottawa. The property, however, has lain idle since 1913.

There are six shafts on the property, all now full of water. The greatest width of ore found on the property is said to be 20 feet and the deepest working 120 feet. Typical ore consists of a rather intimate mixture of ferriferous zinc blende and galena, with which are associated pyrite, chalcopyrite, magnetite, and pyrrhotite, the pyrite in places in considerable quantity. The gangue consists of country rock, quartz, calcite, and lime-alumina silicates.

There are two zones of mineralization, both parallel to the strike of the adjoining rocks and only a few hundred feet apart. The ore occurs as a series of lenticular deposits separated from one another by barren stretches. The underground workings are said to have shown the same character of mineralization in depth.

A sample of the ore from the old stock piles sent to the Mines Branch Ore Dressing Laboratory for treatment yielded on analysis:—

Lead	3·35 per cent
Zinc	7·08 "
Iron	4·82 "
Silver	9·50 oz. per ton

Wright Mine, Lots 61, 62, and 63, Range I, Duhamel Township, Temiscamingue District

The deposit of argentiferous galena on the east shore of lake Timiskaming, that is now known as the Wright mine, is one of the earliest known ore-bodies in Canada, its position being marked on a map of the lake published in 1744. The first development work was done on it in 1886, but extensive work was not undertaken until 1890, when a very complete plant was installed and mining actively prosecuted. There was a small intermittent production from that date till 1902, since when the mine has lain idle and the plant has fallen into ruins. Meantime the property had passed into the hands of Timmins interests, of La Rose and Hollinger fame. During the summer of 1925 the mine was pumped out, the old workings surveyed and systematically sampled, and some diamond-drilling done from the bottom of the shaft (this is 330 feet deep, with drifts at four levels). The ore-body, as determined by the sampling of the old workings appears to be roughly cylindrical or pipe-shaped, the cylinder varying from 50 to 100 feet in diameter.

The deposit occurs in a breccia-conglomerate, in which ore has been formed by the replacement, by galena, together with a little pyrite and some pink dolomite, of the green chloritic matrix, in which the pebbles or fragments of the conglomerate are embedded. The proportion of galena in the rock varies considerably in different parts of the deposit. The galena entirely freed from gangue has been found to yield 13 to 26 ounces of silver to the ton, about 52 per cent lead, and traces of gold.

Should the present exploration result in the discovery of ore of workable grade in sufficient quantity, it is the intention of the owners to operate the property.

Rouyn-Abitibi Goldfields of Western Quebec

Zinc, in the form of sphalerite, is found associated with the copper-gold ores of the Rouyn district in western Quebec, in many places in considerable quantity, and it is altogether likely that when this district reaches the productive stage, zinc will be one of the metals produced.

Ontario

Galetta Mine, Galetta

The Kingdon Mining, Smelting and Manufacturing Company's Galetta mine, on lots 22, 23 and 24, Fitzroy township, Carleton county, the only lead-zinc mine producing in Ontario, and one of the only two in eastern Canada, again increased its output in 1925. The mine workings have now reached a depth of 1,025 feet and extend laterally over 2,000 feet. The workings are all on one vein. Between 300 and 400 tons of ore are hoisted per day and concentrated on jigs and tables producing about 15 to 20 tons of galena concentrates and some 200 pounds of zinc concentrates. The concentrates are worked up into pig lead at the mine, in a Newnam hearth, having a rated capacity of about 15 tons of lead per day, the grey slag from which is smelted in a blast furnace operated intermittently as slag accumulates. The small quantity of zinc concentrates produced are stored until a sufficient quantity has accumulated and then sold to zinc smelters.

Preparations are being made to increase the capacity of the mill and a still larger production from this mine is in prospect.

Frontenac Lead Mine, Lots 15 and 16, Concession IX, and Lot 14, Concession X, Loughborough Township, Frontenac County

This old property, on which the first work is said to have been done as early as 1866, and which yielded a small output of lead at various times up to 1913, since when it has been idle, is at present under option from the owners, the North American Smelting Co., Ltd., of Kingston, to Mr. C. N. Thompson, of Perth Road. Mr Thompson has interested Ottawa capitalists in the property, and expects to be able to put the old workings at the No. 1 shaft in shape for operating in the spring of 1926.

The deposit is a typical fissure-filling consisting of calcite gangue through which galena is scattered in grains and clusters, cutting gneiss and crystalline limestone. Sphalerite also is found, chiefly in the northwestern part of the vein, where it occurs in fine-grained tabular masses separated from one another by bands of calcite, affording striking examples of a banded, or crustified vein.

The old workings are clustered around two points on the vein, about 4,000 feet apart; the No. 1 shaft, 270 feet deep, near the mill at the railway, and the No. 3 shaft, 146 feet deep, to the northwest across a swamp. An aerial tramway connects the No. 3 shaft with the mill at No. 1.

The vein is said to vary in thickness from 9 inches to 22 feet and to average about 10 feet. The distance along the vein between the extreme exposures is in the neighbourhood of 5,000 feet.

The old workings at No. 1 shaft were pumped out for examination early in 1925, but when the property was visited in October they had been allowed to fill again. The parties at present in control of the property announce their intention of re-timbering No. 1 shaft, possibly building a new mill, and expect to be in shape for productive operation in 1926.

Ramsay Lead Mine, Lot 3, Concession VI, Ramsay Township, Lanark County

Some 60 years ago shafts were sunk and a smelting furnace built in an unsuccessful attempt to exploit a deposit of galena on lot 3, concession VI, of Ramsay township, near the town of Carleton Place. The attempt was soon abandoned, and there is no record of anything further having been done on the deposit until 1925. An exploration and development company have now secured control of the mining rights on a large tract of land in this vicinity, and the possibilities of the lead-bearing veins are being investigated.

The vein worked in 1858 is said to have been 2½ to 5 feet thick, carrying galena with smaller amounts of pyrite, chalcopyrite, and zinc blende in a calcite gangue. The country rock is dolomite. Other veins of a similar type have also been noted in the locality.

Other old lead-zinc properties in south central Ontario from which there has been a small production at various times in the past, the reopening of which has been mooted, but on which no new work had been done up to the time they were visited, are:—

Long Lake Zinc Mine, Lot 3, Concessions V and VI, Olden Township, Frontenac County (also known as the Olden, or Richardson, zinc mine).

Hollandia Lead Mine, Lot A, Concession VI, Madoc Township, Hastings County.

Katherine Lead and Zinc Mine, Lot 6, Concession XI, Lake Township, Hastings County.

Union Creek Lead Mine, Lot 20, Range A, Galway Township, Peterborough County.

There are also a number of other long-known but undeveloped lead-zinc prospects scattered through the country between Victoria county on the west and Carleton on the east, that have recently attracted some attention, but concerning which there is nothing new to report.

A comparatively recently discovered deposit of zinc and lead somewhat similar to the Notre-Dame-des-Anges deposit in Quebec, is now being explored on the third concession of Admaston township in Renfrew county, close to the town of Renfrew.

In northern Ontario, also, there has been much activity in the investigation of old and in the search for new deposits of lead and zinc.

V

LITHIUM-BEARING MINERALS IN CANADA

L. Heber Cole
and
V. L. Eardley-Wilmot

INTRODUCTION

The mineralogical occurrence of lithium minerals in Canada has been noted for many years but it has been only since such minerals have been encountered in appreciable quantities that their possible economic utilization has been considered.

LITHIUM MINERALS

The principal lithium minerals of commerce together with their lithia (Li_2O) content are listed below:

Name of mineral	Lithia content, per cent	
	Theoretical	Average
Amblygonite	10·1	8 - 10
Spodumene	8·4	4 - 8
Lepidolite	*(a)*	3 - 6

(a) Variable from one locality to another.

Amblygonite is a phosphate of lithium with aluminum and fluorine. Sodium in some cases replaces part of the lithium and hydroxyl part of the fluorine.

Amblygonite, when pure, has a hardness of 6, with a specific gravity of from 3·01 to 3·09. Its colour runs from white to pale greenish, bluish, yellowish, greyish, or brownish white, and the mineral is sub-transparent to translucent. It occurs usually as coarse, white, cleavable aggregates or rounded masses chiefly in pegmatites, associated with other lithium minerals as well as the usual typical pegmatite minerals. "Montebrazite" is a variety of amblygonite.

Spodumene is a lithium, aluminum silicate. It generally contains a little sodium as well as varying percentages of iron, calcium, or manganese.

Its colour varies from greenish white to greyish white, yellowish green, emerald green, yellow, and amethystine purple. The hardness ranges from 6·5 to 7 and specific gravity from 3·13 to 3·2. The transparency is from opaque through translucent to transparent. The mineral generally occurs as white or greenish white crystals in, or associated with pegmatite dykes, together with quartz, feldspar, mica, and other pegmatitic minerals. *Hiddenite* is a yellowish green or emerald green variety containing small percentages of chromium to which its colour may be due. *Kunzite* is a clear lilac-coloured variety of spodumene found in San Diego county, California.

Lepidolite, often known as lithium mica, is a complex silicate of aluminum, potassium and lithium with fluorine and water, the ratio of fluorine and hydroxyl being variable. It generally contains small percentages of iron, manganese, and sodium, and in some varieties the rarer elements of rubidium and caesium.

It has a hardness of from 2·5 to 4 and a specific gravity of 2·8 to 2·9. The colour is usually pink or lilac but sometimes rose-red, violet grey, yellowish brown, greyish white, and white. The common occurrence of lepidolite is as a compact aggregate of small scales or granular masses in pegmatite dykes, granites or gneisses, and is generally associated with other lithium-bearing minerals as well as tourmaline, feldspar, quartz, etc. Occasionally it occurs in short prismatic crystals or in large plates or sheets.

Other less common minerals containing lithium are *triphylite*, a phosphate of iron, manganese and lithium, containing from 8 to 9 per cent lithia; *petalite*, a silicate of aluminum and lithium, with from 2 to 5 per cent lithia; *lithiophilite*, a phosphate of manganese, iron and lithium, containing from 8 to 9 per cent lithia; *zinnwaldite*, a complex silicate resembling lepidolite and containing from 3 to 4 per cent lithia.

CANADIAN OCCURRENCES

There are two localities so far known in Canada where lithium-bearing minerals occur in such quantity as to warrant further examination and development.

Quebec

Hull District, Wakefield Township, Range VII, S½ Lot 25, LeDuc Mine[1]

The property is one mile west of Glenlivet, west of Wakefield lake. The deposit is situated on top of a range of hills west of Blanche creek, and is approached by trail for a distance of three-quarters of a mile west of the road. The nearest railway shipping point is at Diotte station, 12 miles to the west, a station 30 miles north of Ottawa, on the Gatineau branch of the Canadian Pacific railway.

The country rocks of the district are sillimanite-garnet-gneiss and quartzite, which at the prospect are intruded by an irregular, coarse pegmatite dyke striking about 15 degrees east of north. This dyke contains numerous minerals including large and sometimes radiating crystals of black, green and pink tourmaline; various feldspars, such as perthite (exhibiting colour play), amazonite (green) and the common types; large quantities of white (bull) quartz; hornblende, garnet, etc.; also small quantities of uraninite, gummite and fluorite have been recorded. The mica, which is exclusively of the lepidolite variety of a grey bronze colour, occurs in pockets as large flakes and "books" up to 1 or even 2 feet in diameter and 1 to 2 inches in thickness. The occurrence of this mica in the surface showings at the deposit is local and irregular. As far as can be ascertained this is the only recorded occurrence in the world in which lepidolite occurs in such large flakes and of this colour, since it is usually found in compact aggregates containing very small scales of a pink or lilac colour.

The LeDuc property was first opened up about 1884, for gem tourmaline, but this mineral, though of a good green colour, was found to be smoky and too highly fractured to warrant further mining. During these operations several tons of lepidolite were extracted, as it was mistaken for muscovite, but after it was found to be commercially useless as a mica owing to its hardness, brittleness and fusibility, its true character as a lithium-bearing mineral was ascertained.

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[1] Compiled by V. L. Eardley-Wilmot, Mines Branch.

The workings are about 100 feet down the southwestern slope of the hill and consist of a cutting about 100 feet long and about 20 feet wide, which exposes a face in the north end, 30 feet high. Into this face a short tunnel has been driven for a distance of 10 feet. There is very little evidence of lepidolite in the southern part of the cutting, but in the north face and in the tunnel numerous large books of the mica, embedded in quartz and feldspar, are exposed. This northerly part appears to be capped by several feet of coarse pegmatite, barren of mica and with little evidence of tourmaline.

Immediately above the cutting the rock is covered by brush, but at the top of the hill about 200 feet north, along the general line of strike, a bare knoll of pegmatite is exposed for a distance of 100 feet, but no surface indications of the mica were seen. This outcrop may possibly be a continuation of the barren pegmatite capping already referred to, but at present it is not possible to say whether the valuable mica continues under this highest outcrop, or is merely a local occurrence at the north end of the workings. A considerable amount of development work will have to be done on this property before its possibilities are known.

The chemical analyses show the composition of the lepidolite. An analysis of a lepidolite from Pala, San Diego county, California, is given for comparison.

—	1	2	3
	%	%	%
Silica (SiO_2)	47·89	n.d.	50·18
Alumina (Al_2O_3)	21·16	n.d.	22·81
Lime (CaO)	....	n.d.	0·18
Magnesia (MgO)	0·36	n.d.	0·16
Ferric oxide (Fe_2O_3)	2·52	n.d.	....
Manganous oxide (MnO)	4·19	n.d.	....
Manganese oxide (Mn_2O_3)	....	n.d.	0·41
Soda (Na_2O)	1·34	n.d.	....
Lithia (Li_2O)	5·44	5·14	4·92
Fluorine (F)	7·41	6·71	1·20
Potash (K_2O)	10·73	n.d.	17·48
Rubidium oxide (Rb_2O)	....	n.d.	0·97
Caesium oxide (Cs_2O)	....	n.d.	0·30
Water (H_2O)	1·90	n.d.	2·10
	102·94		100·71
Less oxygen equivalent to fluorine	3·12		
	99·82		
Sp. gr. of material at 15·5°C	2·858		

1. Sample from LeDuc mine, lot 25, range VII, Wakefield tp., Hull district. Analyst, R. A. A. Johnston. Ref. Geol. Surv., Canada, Ann. Rept., vol. XII, pt. R, pp. 12, 13 (1899).
2. Sample from LeDuc mine as above. Analyst, E. A. Thompson, Sept. 1st, 1925.
3. Sample of lepidolite mined at Pala, San Diego county, California. Ref. R. B. Ladoo, "Non-Metallic Minerals, Occurrence, Preparation, Utilization," McGraw-Hill Book Company, New York, 1925, p. 306.

Manitoba

Silver Leaf Mining Syndicate Lepidolite Deposit[1], *Section 17, Township 16, Range 16, East of the Principal Meridian*

A deposit containing a number of lithium-bearing minerals has been found 100 miles northeast of Winnipeg. The claim in which this deposit occurs is located in sec. 17, tp. 16, range 16, east of the Prin-

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[1] For more detailed geological description of this deposit the reader is referred to Geol. Surv., Canada, Sum. Rept. 1924, pt. B, pp. 100-105.

cipal Meridian. A pole line railway 3¾ miles in length has been built from the deposit to the Winnipeg river at Lamprey falls, and a crushing plant has been erected at this point. From the crushing plant to Pointe-du-Bois, the nearest railway shipping point, is 8 miles by motor launch.

The deposit consists of a pegmatite dyke carrying the lithium-bearing minerals associated with quartz and feldspar. The principal lithium minerals appear to be lepidolite, amblygonite (montebrazite) and spodumene, though further examination may disclose the presence of other important minerals.

The exposure occurs on the west side of a hill, the top of which is some 70 feet above the level of a muskeg lying to the west. The dyke has been exposed for a width varying from 45 to 55 feet. The strike of the dyke is approximately east and west, and in trenching the muskeg 200 feet west of the foot of the exposed rock, lithium minerals were also encountered. Only a small amount of development work, consisting principally of stripping, trenching, and a few test pits, has been done. Six tons of rock have been taken out, crushed and shipped to England for large-scale experimental tests.

The discovery was made by F. B. Evans, a prospector of Winnipeg, in the fall of 1924, and a company has been formed to operate the property. This company, the Silver Leaf Mining Syndicate, Ltd., with head office in Bradford, England, and Canadian office at 506 McIntyre Block, Winnipeg, with a capitalization of £10,000, has already spent a considerable sum in machinery and preliminary development work.

A number of analyses of samples taken from this deposit have been made by different analysts as follows:—

—	1	2	3
	%	%	%
Silica (SiO_2)	n.d.	46·98	36·64
Phosphorus pentoxide (P_2O_5)	n.d.	....	18·22
Alumina (Al_2O_3)	n.d.	25·85	25·62
Ferrous oxide (FeO)	n.d.	....	2·79
Ferric oxide (Fe_2O_3)	n.d.	0·64	....
Aluminum fluoride (AlF_3)	n.d.	8·40	....
Manganous oxide (MnO)	n.d.	....	traces
Lime (CaO)	n.d.	0·36	2·03
Magnesia (MgO)	n.d.	0·12	0·25
Lithia (Li_2O)	4·02	3·98	5·23
Potash (K_2O)	n.d.	3·55	1·28
Soda (Na_2O)	n.d.	6·50	4·40
Fluorine (F)	4·21	....	1·26
Loss on ignition	n.d.	3·62	2·60
		100·00	100·32
Less oxygen equivalent to fluorine	....		0·53
			99·79

1. General sample of lepidolite mineral from the deposit, Sept. 2, 1925. E. A. Thompson, analyst, Mines Branch, Ottawa.
2. Analysis furnished by Silver Leaf Mining Syndicate of lepidolite said to be from above deposit. Analysis by Daniel C. Griffith & Co., London, England.
3. Analysis furnished by Silver Leaf Mining Syndicate of spodumene (?) said to be from above deposit. Analysis by Daniel C. Griffith & Co., London, England. (The sample was probably a mixture of amblygonite and spodumene.)

Other Occurrences

In addition to the above deposits, lithium-bearing minerals have been noted as occurring in Canada as follows:—

Lunenburg County, Nova Scotia. Lepidolite occurs in scaly masses with quartz, feldspar, apatite, fluorite, etc., in a pegmatite dyke near lake Ramsay, New Ross, (Geol. Surv.,. Canada, Sum. Rept. 1907, p. 82). Triphilite has also been found, according to Mr. H. Piers, near lake Ramsay, New Ross, (Department of the Museum, Halifax, p. 93, 1906.)

New Quebec Territory, Quebec. Spodumene occurs in greyish green, sub-translucent prisms in a micaless, orthoclastic, granitic veinstone cutting a syenite on Walrus island, Paint Hills group, east coast James bay (Geol. Surv., Canada, Ann. Rept., vol. XII, pt. R, pp. 15-16 (1899)).

Lanark County, Ontario. Spodumene is mentioned by Hunt as having been observed in a small rolled mass of granite near Perth (Geol. Surv., Canada, Ann. Rept., vol. IV, pt. T, p. 59 (1888-89).

York County, Ontario. Dr. Bigsby reports the occurrence of petalite with tremolite in a large boulder on the lake shore at Toronto. (Geology of Canada, 1863, p. 481.)

Revelstoke Mining Division, British Columbia. Lepidolite was noted in pearly scales with calcite in rust-stained quartz at the Gold Hill claim, 10 miles northeast of Illecillewaet (Geol. Surv., Canada, Ann. Rept., vol. VI, pt. R, p. 29 (1892–93)).

UTILIZATION OF LITHIUM MINERALS AND LITHIUM COMPOUNDS

Lithium minerals are used in their natural state and as a source of lithium compounds.

Probably the most extensive use of lithium minerals is in the glass industry, in which lepidolite is employed in the manufacture of opal and white glass, and to an increasing extent in the production of certain types of flint glasses. According to a number of writers, the high fluorine content of lepidolite is partly responsible for its value in glass-making, since both fluorine and lithia are active fluxing agents. When lepidolite is used in a glass batch, the coefficient of expansion of the resultant glass is said to be lowered, thus decreasing the tendency to breakages due to sudden heating and cooling. Lepidolite increases the index of refraction of a glass and also produces a harder surface on the finished glass. On this account lithium glass is finding an increasing use for the manufacture of electric light bulbs. Lithium glass is also much more permeable to the transmission of X-rays than is soda glass. When lepidolite is used in the manufacture of opal glass instead of cryolite, the corrosion of the glass tanks is greatly reduced. According to Ladoo[1] as much as 28 per cent of the batch for opal glass is lepidolite. For glass manufacture, lepidolite should be finely ground and free from tourmaline, quartz, and other foreign minerals.

The native lithium minerals are also used to a small extent in special glazes and enamels.

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[1] Ladoo, R. B.: "Non-Metallic Minerals," McGraw-Hill Book Co., New York, 1925, p. 322.

Lithium compounds find a limited use in commerce, the two most widely used being lithium hydroxide (LiOH) and lithium carbonate (Li_2CO_3). The hydroxide is used extensively in the manufacture of storage batteries of the alkaline type, and although it is not definitely known what its action is, it has been found to greatly prolong the life of the batteries. Lithium carbonate is used to a small extent in the manufacture of artificial mineral waters as well as for medicinal purposes. Other compounds used medicinally are lithium citrate and lithium bromide, but their use in medicine is probably not so extensive as in the past. Lithium bromide and lithium iodide find a use in photography, and the chloride is employed in small percentages in the flux used for welding aluminum. The chloride also gives a red light when used in fire works and signal lights. The carbonate when mixed with certain pigments is employed for staining and dyeing.

Several of the transparent varieties, such as hiddenite and kunzite, when occurring in sufficient size and purity are employed as gem stones.

METHODS OF EXTRACTION

Although by far the larger percentage of the lithium-bearing minerals mined is employed in the raw state in the glass industry, a small proportion is required for treatment for the recovery of the lithium salts. Amblygonite, from its high lithia content, is the mineral most desired for this purpose. Commercial requirements for this mineral call for a minimum of 8 per cent lithia (Li_2O) content free from detrimental impurities such as iron-bearing minerals. The material as sold for this use is ground to a powder 80 to 90 per cent passing through a 200-mesh screen.

There are a number of processes employed for the extraction of the lithium salts from their minerals, varying according to the mineral employed.

From Amblygonite, Triphylite, or Lithiophilite.

The ground mineral is first dissolved in hydrochloric acid to which nitric acid is gradually added and ferric chloride added to unite with the phosphoric acid present. After evaporation to dryness, the residue is treated with hot water, and to the solution thus obtained barium sulphide is added to remove the manganese and any iron which has remained. By treating the solution with sulphuric acid the barium is removed and the filtrate is evaporated with oxalic acid, which yields lithium oxalate. By ignition, lithium carbonate is obtained. Any other alkali present may be removed by treating with water, lithium carbonate being comparatively insoluble.

From Lepidolite or any other Silicate.

Several methods have been employed with varying success for the recovery of lithium compounds from lepidolite.

One method consists of fusing the mineral at red heat in a crucible, after which it is rapidly cooled in water and pulverized. Hydrochloric acid is added to the material which has been made to a paste by the addition of water, and allowed to stand for 24 hours. It is then heated and more acid added, upon which the silica separates out. Nitric acid to oxidize the iron is added and the whole is filtered to remove the silica.

Sodium carbonate added to the filtrate removes the iron, calcium, magnesium, manganese, etc. The liquid obtained from these is evaporated to small bulk and the lithium carbonate is precipitated by the addition of more sodium carbonate.

Another process is to fuse a mixture of lepidolite, barium carbonate, barium sulphate and potassium sulphate at a high temperature with the result that the heavy silicate and sulphate of barium sink to the bottom of the fused mass while a layer of potassium and lithium sulphates forms on the top. These are extracted by lixiviation and converted to chlorides by the addition of barium chloride. The chlorides are evaporated to dryness and the lithium chloride extracted by some suitable solvent such as pyridine.

A modified method for the recovery of lithia from lepidolite is described by Schieffelin and Cappon[1]. This method is to decompose the mineral with concentrated sulphuric acid by careful ignition after which the mass is leached with water and the silica removed by filtration. By the addition of potassium sulphate the aluminum sulphate is converted to potash alum which partly separates out as crystals, the remainder being removed by the successive addition of calcium carbonate and aluminum hydroxide. The filtrate from this is concentrated and the calcium salts removed as calcium oxalate. The solution of lithium sulphate thus obtained is converted into the carbonate by treatment with a solution of potassium carbonate.

MARKET CONDITIONS

The principal markets for the lithium-bearing minerals are the United States and Europe. The requirements for the United States market are served from the several large deposits already being operated in that country and it is probable that for many years to come these deposits will be sufficient to supply that country's demands even though new uses are found. It is, therefore, logical to assume that, unless a home market can be built up for the material from the Canadian deposits, a market in Great Britain or the rest of Europe will have to be found. That such a market exists is evidenced by the interest manifested in Great Britain concerning the Canadian deposits as shown by the numerous inquiries received, but it still remains to be proved whether the Canadian material is in sufficient quantity and of a high enough grade to be commercially shipped to the foreign markets.

Quotations on lithium minerals in the United States vary greatly according to the mineral and the demand, amblygonite ranging from $50 to $60 per ton at the mine; spodumene and lepidolite range from $20 to $30 per ton.

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[1] Schieffelin, W. J., and Cappon, T. W.: "Notes on Manufacture of Lithia from Lepidolite," Mining World, p. 57, July 11, 1908.

VI

THE PRESENT STATUS OF THE ABRASIVE INDUSTRY

V. L. Eardley-Wilmot

There has recently been a decided improvement in the abrasive materials used, as well as a better knowledge of their application.

ABRASIVES PRODUCED AND USED IN CANADA

The abrasive materials produced in Canada are natural abrasives such as grindstones, sharpening stones, pulpstones, certain forms of silica (quartz), volcanic dust, and diatomite, and to a very limited extent, feldspar. There was an output of garnet in 1924 and it is expected to be produced again in 1926. The production of the artificial abrasives, silicon carbide and the aluminous abrasives is now very considerable. Both the natural and artificial are made up into abrasive products such as grinding wheels and coated papers.

The Canadian consumption of imported abrasives, in addition to the above materials, includes diamond, corundum, emery, pumice, sand, buffing and polishing powders, such as amorphous silica, tripoli, rouge, crocus, Vienna lime, etc., also metallic abrasives, such as steel shot and grit.

The various kinds of abrasives used, new developments in type and application, are briefly reviewed in the following pages.

Grindstones

The natural grindstone has in many plants been entirely superseded by artificial grinding wheels and except for domestic purposes there is no demand for the small-sized natural stones. A considerable tonnage of stones of 5 and 6 feet in diameter are still used, particularly by the saw, file, and machine knife manufacturers. This is mainly due to the slow speed at which the grindstones are run so that danger of burning of the metal is reduced to a minimum.

Grindstones are also almost universally used in one of the stages of glass bevelling, but these are usually made from a special sandstone near Newcastle, England, no suitable material having yet been found in Canada.

Canadian Grindstone Localities. There are now only two operating grindstone quarries in Canada. The majority of the Canadian stones are obtained from the Read Company's Stonehaven quarries in northern New Brunswick and the remainder from the Mic Mac quarry near New Glasgow, Nova Scotia.

Pulpstones

The natural sandstone still holds its own for pulpwood grinding. Recent statistics show that the fifty-four pulp grinding companies in Canada use about 4,500 tons of stones valued at over half a million dollars, sixty per cent of which are 54 by 27 inches. The tendency, however, is towards higher speed and larger stones of the five-foot magazine type.

Canadian Pulpstone Localities. Only five per cent of the stones used in Canadian pulp mills are produced in Canada from two quarries, one on the Miramichi river and the other near Sackville in New Brunswick. Recently the McDonald Company of Vancouver have opened up a mottled grey sandstone quarry on an island opposite Nanaimo. Tests on these western stones have given excellent results as to durability of the stones and the quality of the pulp produced. There is a large ready market in Canada for pulpstone of the desired quality.

The Norton Company of Worcester, Mass., have put an artificial pulpstone made from silicon carbide on the market. Preliminary trials are said to be very satisfactory.

Corundum

Corundum is now rarely used, though for many purposes excellent work can be obtained by its use and there are some users who still have a high opinion of this mineral when made up into grinding wheels. Irregularity of supply and inconsistency of quality are drawbacks to its wider use.

Canadian and Imported Corundum. The corundum from Canada, which was the world's leading producer fifteen to twenty years ago, is still considered the best of its kind though there has been no production since 1921. The mineral in the form of large, brown crystals is now obtained from South Africa, the 1924 output amounting to about 1,500 tons.

A New Use for Corundum. Recently corundum has been successfully employed in the manufacture of a certain type of artificial aluminous abrasive. Owing to its high percentage of alumina (96 per cent or over) corundum is used in the place of bauxite. The corundum must be pure and free from titanium. Some of the Canadian deposits of the mineral, particularly the blue corundum from the York river in Dungannon township, would be well suited. It is, however, questionable whether the Canadian corundum, which would have to be in the form of concentrates, could be produced at a low enough cost to compete with the imported South African or with the low-priced bauxite.

The 1925 consumption of corundum for this purpose on the American continent is believed to have been about 1,000 tons. A few hundred tons were used in wheels and a small quantity as loose grain for plate glass surfacing.

Prices. Graded grain corundum is valued at 6 to 7 cents per pound, and South African crude at about $65 per ton.

Emery

Natural emery, a mixture of corundum and iron oxides, which comes from Greece or Turkey, was at one time the main abrasive grain used in wheels and metal sanding, but is now hardly ever used in these forms, though a few wheels are still employed mainly for rough work and snagging cast iron. It is, however, used more in fine grits, coated on flexible wheels for the finishing of metal parts, for which purposes the artificial are often considered too harsh. As a coating for papers and cloths it is now very rarely employed. Emery is not produced in Canada.

Garnet

Garnet coated stock in the form of belts, disks, and rolls, is now almost universally employed on the American continent in all of the harder wood-working industries.

Garnet, which is a red-brown colour, is obtained from mines at North River, New York, and from New Hampshire. The United States output now amounts to about 9,000 tons annually, 95 per cent of which is used for these papers and cloths.

Canadian Garnet Localities. There are a large number of deposits in Canada, several of which should be well suited for the production of abrasive garnets. One company shipped during 1923-24 over 1,000 tons of rough concentrates from a deposit in the northwest corner of Ashby township, Ontario, but none has been mined since, although good results were obtained with the product.

Plans are, however, now under way to ship garnet concentrates from Parry island in Georgian bay, Ontario, by Garnet Abrasive Corporation of Toronto.

An excellent abrasive of garnet occurs 2 miles southwest of Labelle, Quebec, 100 miles north of Montreal. The mineral occurs as large, deep wine-coloured masses associated with solid pyrrhotite. This garnet has been favourably reported on by some of the leading abrasive paper manufacturers, and preparations are now being made to exploit the property.

Recent Developments in the Use of Garnet. Waterproof garnet coated abrasive paper is a comparatively new product that has met with increased success and has now superseded the use of pumice in rubbing down of the paint or varnished surfaces of automobile bodies.

The demand for garnet for the surfacing of plate glass is increasing, and there are now several firms using very fine grades in the "fining" operations between the coarser sand and the final polishing with rouge. Excellent results are claimed by a large manufacturer who crushes the ore (which carries about 35 per cent garnet) to about 300 mesh and water grades the pulp without concentration, into four grades for direct use on the surfacing machines.

There is a demand for the very best quality garnet and the difficulty of obtaining regular supplies has led to some manufacturers making an open-coated aluminous paper to replace the garnet coated papers in the wood-working industries. The product is more expensive than the garnet, but for some hardwood sanding, better results are claimed.

American or Canadian garnet concentrates are valued at about $85 per ton, and Spanish or inferior grades, $50 to $60.

The Abrasives, Limited, of Brantford, Ontario, a subsidiary of the American Glue Company, is the only firm in Canada now making garnet coated papers or cloths.

Volcanic Dust and Pumice

A pure siliceous material known as volcanic dust, is largely used as the abrasive base in scouring and cleansing powders, and for the last year or two extensive deposits in the vicinity of Swift Current, Saskatchewan, have been worked for this purpose. Volcanic dust also occurs in several localities in British Columbia, but so far have not been exploited to any extent. A large tonnage of similar material called "pumicite" from Nebraska, is imported into Canada. It is the abrasive base of "Old Dutch Cleanser" and similar products.

Pumice is not produced in Canada, but is imported mainly from Italy and the United States. It is used, when ground, for similar purposes to those of volcanic dust, and in the glass-grinding industry.

Diatomite

Composition and Canadian Localities. Diatomite, which is composed of microscopic siliceous skeleton shells, is found in numerous parts of the Dominion, particularly in the Maritime Provinces and in British Columbia. The only production is by one firm at Oxford, Nova Scotia, but there has recently been some activity in the Muskoka region, Ontario, where several deposits are known to occur. The largest known deposits are at Quesnel, British Columbia, but they have not yet been exploited.

Uses of Diatomite. The main uses for diatomite are for insulation and filtering, but the list of uses is continually increasing, and recently diatomite has been successfully employed as an ingredient in concrete. As an abrasive it is used in liquid and paste metal polishes, dental and finger nail powders, etc. The Maritime material, when graded and pure, is particularly well suited for abrasive purposes.

Prices. The price is $12 to $15 per ton for the crude dry material and about $30 for the calcined, but some of the finest air-float grades fetch as high as $120.

Artificial Abrasives

There are two types of artificial abrasives which are universally used to-day, namely, silicon carbide and the oxide of alumina. Although these abrasives, made by different manufacturers, are essentially the same, each type has a variety of trade names. There are, however, several grades of the aluminous, depending mainly on the proportion of alumina present.

New Types of Aluminous Abrasives. The ordinary grades are the hardest and are high in titanium, whereas the special grades are the toughest, almost free of this metal, and very high in alumina. The special material, which has recently been put on the market, is white to pale grey in colour, and its use is becoming widespread, especially for wheels for certain types of precision grinding. Either pure alumina or pure natural corundum is used in the place of bauxite. Some makers are preparing to use a considerable tonnage of corundum for this purpose for which certain deposits of low titanium Canadian material would be suitable.

Commercial deposits of pure bauxite, for which there is a very large demand, have not yet been found in Canada.

Canadian Artificial Abrasive Production. Canada is the largest producer of artificial abrasives and the output is increasing annually. There are four companies operating five plants, having a total annual output of 45,000 tons of crude material valued at about five million dollars. The whole of this output is sent to the parent companies in the United States for crushing, cleaning, and grading.

Uses. Artificial abrasives are used for almost every abrasive purpose. However, the largest consumption is in the manufacture of grinding wheels.

Wheels made with silicon carbide are harder than the aluminous but the grain is more brittle. They are mainly used for the grinding of all materials of low tensile strength, such as iron, brass, copper, aluminum, hard rubber, bone, etc. The tougher aluminous wheel is used for all classes of steel grinding.

Types of Grinding Wheels and their Uses. Grinding wheels are now made by several processes, but the vitrified wheel, on account of the fusion of its bond, is the hardest and most durable, and is used more than any other type. The silicate wheel is also used to a considerable extent and is very suitable for certain classes of work. On account of the difficulty of making large vitrified wheels, all wheels over 36 inches in diameter are silicate. Very thin wheels, run at high speed, which are used for grooving, cutting saw teeth, cutting off, etc., are made by the elastic or shellac process. A wheel made with "bakelite" bond in place of the shellac is a new type, which is increasing in favour and is said to be superior to the elastic, especially for cutting off. Rubber bond wheels are often used for semi-finishing or preparing metal surfaces for polishing. These wheels are efficient only when they are run at high enough speeds to melt the rubber by friction against the work. The use of this type of wheel is increasing, but none are at present made in Canada.

Standardization of Wheel Shapes. Owing to the innumerable different shapes and sizes of wheels that now have to be stocked by the wheel manufacturers, the leading makers have combined, and succeeded in cutting these down by half a million forms. These designs have recently been published in booklet form.

Flexible Wheels. Flexible wheels are commonly made up from canvas disks glued and bolted together. The face is then coated with glue and the wheel immediately rolled in a trough of abrasive grains of the required size. The aluminous abrasive is almost always used, even for low tensile materials, since there is at present some difficulty in holding the silicon carbide grains in place. Turkish emery is also sometimes used either alone or mixed with the carbide, as it gives a better bond with the glue. The flexible wheel is very largely used for some finishing and rough polishing of metal parts, particularly curved surfaces, upon which the revolving wheel, under pressure spreads over a large uneven surface. Final polishing of steel parts is usually performed on canvas or leather wheels using the very fine grades of aluminous abrasive and frequently emery.

Canadian Production of Grinding Wheels. There are eight abrasive wheel manufacturers in Canada; the annual production amounts to about half a million dollars. The two largest of these companies have their head office in the United States. All the ball and slip clay, feldspar, and other bonds used are imported, but it is hoped that search will discover material, in Canada, suitable for bonding purposes.

Recent Developments in Grinding Operations. A great saving of work and time has been brought about by the use of centreless grinding machines whereby pieces from the size of a gramophone needle to steel bars 20 feet long by 3 inches in thickness can be ground with the utmost precision in the same machine. The work is continuously and automatically fed between the set faces of two wheels opposite each other and revolving in the same direction, one of these (usually a rubber bond wheel) acts as a feeder and the other, the grinder. Three or more cuts can be performed in one operation.

Another time saver is the magnetic chuck whereby a number of small pieces can be ground simultaneously and is particularly useful for grinding piston and other rings.

In some plants where heavy duty work has to be performed the large solid grinding wheels have been replaced by segmental wheels. The advantages claimed are: lower initial cost; clearance space between segments, thus decreasing clogging of the face by the abraded metal; chips or breaks in the wheel can be easily and cheaply repaired by replacing the faulty segments instead of the solid wheel.

Coated Papers and Cloths

Manufacture. The prepared grain is automatically fed onto the glued surface of the stock which passes from a continuous roll under the abrasive feed hopper, after which it is given another coating of glue to hold the grain firmly in place. The durability of the finished product depends largely on the glue which must be of the very best quality.

Recent Development. Waterproof and open-coated papers are the latest productions in this class of material. The adhesive in the former is not glue but Chinese nut oil and other ingredients. The paper is used, either wet or oiled, for the rubbing down of varnished surfaces, thus preventing to a very large extent the clogging of the paper by the abraded varnish. Open-coated paper, having the grit spaced farther apart, is used for sanding wood.

Abrasives used for Coated Backings. Artificial abrasives have replaced emery to a very large extent and are mainly used for metal work and also in leather and shoe factories. The abrasive employed for sandpaper is usually made by crushing quartz. It is sometimes called flint paper, but is different from the better, true chalk flint paper from England or France. Sandpaper is the cheapest and is mainly employed for soft wood sanding, but its use is now declining. Some of the quartz from a deposit near Perth, Ontario, is now used for this purpose.

The use of garnet for sanding the harder woods has already been discussed under "Garnet".

As a coated abrasive, natural grain corundum has not met with much success, due possibly to its somewhat slivery nature, but, on account of the competition from other abrasives, it has probably not been thoroughly tried out.

Canadian Manufacturers. Abrasive coated papers and cloths are made by the Abrasives Limited, Brantford, Ontario.

Metallic Abrasives

Steel shot and grit abrasives are not manufactured in Canada, but are used by several Canadian firms for the cleaning of castings of all kinds and also in the stone trade for sawing, cutting, and polishing of granite, marble, etc.

The shot is manufactured by continuously discharging the molten metal in small streams. These small streams of metal are subjected to air and steam pressure which divides the metal into particles of varying size which drop into a water tank where they are chilled, and after drying are screened into the various sizes required by the trade. The grit is made by crushing the metal in a large steel ball mill and screening.

Buffing and Polishing Operations

The buffing of steel, brass, copper, nickel, etc., is performed by means of flexible wheels made from canvas, muslin, leather, felt, and other materials. The canvas disks are sewn together and the abrasive in the form of a grease brick is applied to the revolving wheel.

Abrasives Employed and Their Uses. Numerous materials such as very finely ground quartz, amorphous silica, tripoli, unhydrated lime, crocus, red and green rouge, etc., are also used as abrasives with a grease bond, which consists of tallow, stearic acid or petrolatum. Tripoli, which is of a pink colour, and amorphous silica which is white, are the most universally used. They are believed to be decomposition products of novaculite and chert. The former comes from Missouri and the latter from Illinois.

Neither of these materials have been reported as occurring in Canada though the Illinois product closely resembles the white volcanic dusts from the Deadman river, British Columbia, and from the vicinity of Swift Current, Saskatchewan.

Although diatomite, which occurs extensively in Canada, would make an excellent buffing material, it is not so used because of its high absorption of grease, whereas tripoli, which is a harsher abrasive, absorbs the requisite proportion.

Crocus is a hard, purple-red oxide of iron, and was at one time extensively used, but has been replaced by lime. The lime is made by calcining a magnesium limestone which formerly came from Austria (Vienna lime) but is now made from a fine-grained, greyish white dolomite from Wisconsin. The finely crushed calcined product is shipped in sealed containers to the buffing composition makers, and the finished lime bricks have to be kept sealed since the hydrated material will not function. The product contains approximately half lime and half magnesia and poor results are obtained with excess of either. It is used extensively for copper buffing and almost universally for "colouring" nickel after plating.

There are several dolomite deposits in Canada which are very similar to the Wisconsin material, both in appearance and chemical composition, and would doubtless make a suitable lime buffing compound for nickel.

Rouge, which is a red oxide of iron, is used for the buffing of various metals including silver, gold, etc., and in the powdered form is employed for the final polishing of plate glass. Green rouge, the oxide of chromium, is particularly adapted for platinum and stainless steels such as "stellite". The brilliant finish now seen in the best grades of stainless cutlery knife blades is obtained by the use of this buff.

The growing importance of abrasives warrants further search for raw materials within the Dominion as well as a careful study of their application in the industries.

Canadian Production of Abrasive Materials

The following tables show the production of the various abrasive materials in Canada during 1924-25, as well as the available data on imports and exports.

Canadian Abrasive Production

—	1924		1925	
	Tons	Value	Tons	Value
		$		$
Natural Abrasives—				
Grindstones	2,031	69,111	1,735	61,784
Pulpstones	584	56,113	781	57,781
Scythestones	36	3,600	46	4,600
Garnet[1]	360	7,200	nil	nil
Volcanic dust	245	1,103	70	315
Abrasive feldspar[2]	nil	nil	2,000	13,000
Abrasive quartz[2]	100	350	100	350
Diatomite	33	838	nil	nil
Grinding pebbles	209	1,821	105	945
Total Natural	3,598	140,136	4,837	138,775
Artificial Abrasives—				
Silicon carbide	15,207	1,773,864	16,945	1,864,009
Aluminous	29,822	3,170,205	30,337	3,281,708
Total Artificial	45,029	4,944,069	47,282	5,145,717
Grinding wheels	....	423,533	....	440,000
Abrasive papers and cloths[2]	....	130,000	....	200,000

[1] Shipments only—no production.
[2] Figures only approximate.

Imports of Abrasives[1]

—	1924	1925
	Value	Value
	$	$
Artificial abrasives in bulk, crushed or ground, when imported for use in the manufacture of abrasive wheels and polishing composition	125,303	123,651
Carborundum wheels or stones, not further manufactured than moulded or burned	64,351	69,350
Diamond dust or bort, and black diamonds for borers	399,835	523,163
Emery in bulk, crushed or ground	53,208	223,598
Emery wheels and carborundum wheels, n.o.p	76,971	129,082
Emery or carborundum, manufactures of, including carborundum stones, n.o.p	63,019	59,775
Grindstones,[2] not mounted, and not less than 36 in. in diameter 578,221 641,369 Grindstones, n.o.p 15,449 19,983	593,670	661,352
Pumice and pumice stone, lava and calcareous tufa, not further manufactured than ground	28,127	27,581
Sandpaper, glass, flint and emery paper or emery cloth	279,586	305,042
Burrstones, in blocks, rough or unmanufactured, not bound up or prepared for binding into mill stones	791	584
Iron sand or globules, or iron shot, and dry putty, adapted for polishing glass or granite or for sawing stone	17,985	11,702
	1,702,846	2,134,880

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[1] Monthly reports—"Trade of Canada."
[2] Mainly pulpstones.

Exports of Abrasives[1]

—	1924		1925	
	Tons	$	Tons	$
Abrasives, natural, n.o.p., in ore or bulk, crushed or ground, including diatomite, rottenstone, tripoli, etc.	287·8	10,321	23·2	464
Abrasives, artificial, crude, including carborundum, etc.	39,593·2	2,591,310	47,759·2	2,978,639
Abrasives, artificial, made up into wheels, stones, etc.	....	13,264	....	32,030
Corundum	2·0	251	....	45
Stone, for the manufacture of grindstones, rough	120·0	1,080	93·0	794
Grindstones, manufactured	....	49,630	....	61,429
	40,003·0	2,665,856	47,875·4	3,073,401

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[1] Monthly reports—"Trade of Canada."