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MINERAL AND THERMAL WATERS OF CANADA

J.G. Souther and E.C. Halstead

DEPARTMENT OF ENERGY, MINES AND RESOURCES

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FOREWORD

A growing, world-wide interest in geothermal development has been reflected in a steadily rising demand for information concerning Canadian mineral and thermal waters.

In some parts of the world, especially Iceland, the use of naturally heated water for domestic and commercial heating is widespread; similar systems are under development in Hungary and the Soviet Union. In Italy, existing geothermal power generating facilities have a capacity of nearly 400,000 kw and in New Zealand, 170,000 kw are currently available mainly from the Wairakei area. Studies already completed indicate that the thermal energy available from the Geysers area of California can produce 633,000 kw.

Although geysers are unknown in Canada, thermal springs have long been known from the Cordilleran region and several are now very well-known resort centres. Mineral springs in the Ottawa Valley, first discovered more than 150 years ago, were for a time developed as health spas in the tradition of their famous European forerunners.

Publications of the Mines Branch, released between 1917 and 1926, dealing with mineral springs and hot springs, have long been out of print. Scattered references to thermal waters have appeared from time to time in the Canadian geoscience literature but it was not until presentation of this report by two members of the Geological Survey of Canada, for inclusion in the Proceedings of Symposium II, Mineral and Thermal Waters of the World, at the XXIII International Geological Congress, that an up-to-date compilation became available.

It is hoped that this reprint of a paper originally published in Volume 19 of the Proceedings of the Twenty-third Session of the International Geological Congress (Prague, 1968), will reach a wider audience than the original publication and that it will meet a current need for information and stimulate interest in the study of thermal waters.

R.G. Blackadar,
Chief Scientific Editor.

February 15, 1973

Fairmont Hot Springs Resort, in British Columbia, is a year-round vacationland. Two indoor pools and two indoor swirlpool baths are fed by natural, odorless, mineral springs. (Canadian Government Travel Bureau Photo No. 102018).

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Mineral and Thermal Waters of Canada

J. G. SOUTHER and E. C. HALSTEAD

Canada

Introduction

The distribution and character of mineral and thermal waters in Canada are closely related to regional topographic and geologic features. Each of the six main physiographic regions (Fig. 1) is underlain by distinctive rock types and structures that control the circulation of ground water and hence influence the temperature and quality of water issuing from springs and flowing wells. Most springs including all known thermal springs in Canada, occur in the Cordilleran Region where high topographic relief permits deep circulation of meteoric water through local and regional flow systems and where relatively high precipitation provides an ample supply of recharge water. Nonthermal springs in other regions of Canada are mainly brine springs. They are commonly associated with Palaeozoic marine sedimentary rocks, chiefly limestone, dolomite and shale interbedded with rock salt, gypsum and anhydrite, that overlap the Canadian Shield on the eastern edge of the Interior Plains and occupy sedimentary basins in the Saint Lawrence Lowland and Appalachian regions.

A number of thermal springs in Western Canada have been developed as recreational and health resorts and water from several nonthermal springs in Quebec is bottled and sold for therapeutic use. Many springs in remote parts of Canada have never been described by a geologist and little or no information is available on the temperature or chemistry of their waters. Undoubtedly many more have yet to be discovered in unexplored valleys of the western Cordillera.

Terminology

The writers have restricted this paper to an account of mineral and thermal waters issuing from natural springs, defined here as discharges of groundwater of sufficient volume to cause flowage at the surface. Stagnant basins, artificial wells and boreholes are not included.

Following terminology of White (1957) springs are considered to be thermal if their temperatures are more than 5 °C or 10 °F above the mean annual air temperature of the region. Thermal springs are further classified as hot springs with water temperatures higher than 90 °F and warm springs with water temperatures higher than the local mean annual air temperature but lower than 90 °F.

Thermal and nonthermal springs are also classified by the amounth and type of dissolved mineral salts and gasses. Total dissolved solids and other constituents reported by chemical analysis are expressed in parts per million (ppm). One part per million equals one part by weight of dissolved matter in a million parts by weight of water. In general the term mineral spring is restricted to springs that contain more than 1,000 parts per million of total dissolved solids. A few springs with less than this amount are included because their water is reputed to have therapeutic value and is marketed as mineral water.

The flow, or rate at which water is discharged by a spring is expressed in Imperial gallons per minute (I gpm).

The origin of thermal water has been discussed by White (1957) and the writers have adopted his terminology. Meteoric water, is water that was recently involved in atmospheric circulation, whereas fossil or connate water has been out of contact with the atmosphere for a least an appreciable part of a geological period. Magmatic water is a general term for water that is in, or derived from magma and metamorphic water is defined as water that is or that has been associated with rocks during their metamorphism.

Geographic distribution of springs

The locations of mineral and thermal springs are shown on the generalized physiographic map of Canada (Fig. 1) and a list of chemical and physical data for each spring is given in Tables 1 and 2. In the sections that follow representative springs in different regions of Canada are described. Each region is characterized by distinctive elements of geology, topography and climate which together influence the distribution and character of the springs within it. Thermal springs, for example, are confined to the tectonically young Cordilleran region where young plutons are believed to be associated with high thermal gradients and where high local relief results in deep circulation of groundwater. Nonthermal mineral springs occur mainly in the Interior Plains and lowlands where the underlying strata include beds of salt and gypsum. Both thermal and nonthermal mineral springs tend to occur in groups of several similar springs, each group related to the same geological feature or the same large flow system.

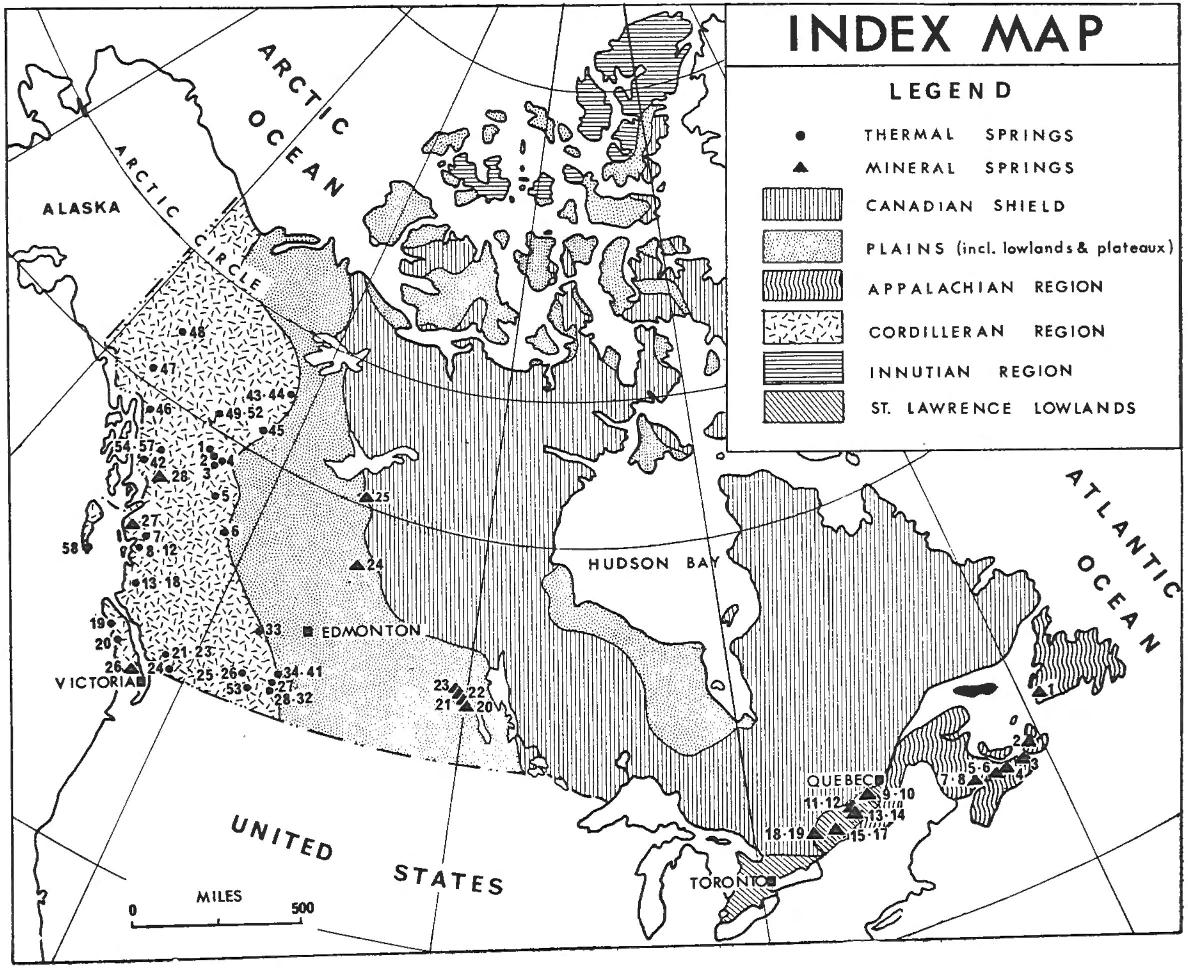

Fig. 1 — Index map showing physiographic regions and locations of mineral and thermal springs in Canada

Cordilleran Region

The Canadian Cordillera is part of the great mountain barrier that bounds the Pacific Margin of North America. It is divided into three northwesterly trending physiographic sub-provinces: a Western System of mountain, an Interior System of plateaux and mountains, and an Eastern System of mainly mountains (Fig. 2). The Western System is dominated by the Coast Mountains which rise abruptly from sea level to elevations of more than 10,000 feet. They are underlain almost entirely by granitic and metamorphic rocks that reflect a history of repeated plutonic and tectonic activity that began in the late Palaeozoic and continued into Tertiary time.

The Interior System consists of a number of plateaux and lesser mountain ranges underlain by folded and faulted Mesozoic eugeosynclinal sedimentary and volcanic rocks intruded by numerous stocks and batholiths ranging in age from Triassic to Tertiary. Much of the central plateau of British Columbia is covered by flat-lying, late Tertiary, flood basalts and more than 130 centres of Pleistocene and Recent volcanic activity are scattered throughout the western and interior systems.

The Interior and Eastern systems are separated, in the south, by the Rocky Mountain Trench, a discontinuous rift system over 800 miles long. East of this lineament the Mackenzie and Rocky Mountains are underlain mainly by Palaezoic strata including a large proportion of carbonate rocks that have been folded and cut by a complex system of northeasterly directed thrust faults. The principal deformation of the Rocky Mountains took place during early Tertiary time.

Thermal and mineral springs are found in each of the physiographic sub-provinces of the Cordillera (Fig. 2).

Thermal springs of the Cordilleran Region

Western System

Coastal Islands (19, 20 and 58) — Three thermal springs, all in granitic rock, are known on the Coastal of British Columbia. The largest and best known issues from fractured diorite at Sharp Point (20) on the west coast of Vancouver Island. The rate of flow, 100 gpm., and temperature 125 °F, have remained constant since they were first measured in 1898. The springs give off small quantities of both carbon dioxide and hydrogen sulphide. The water has a relatively high content of sodium chloride

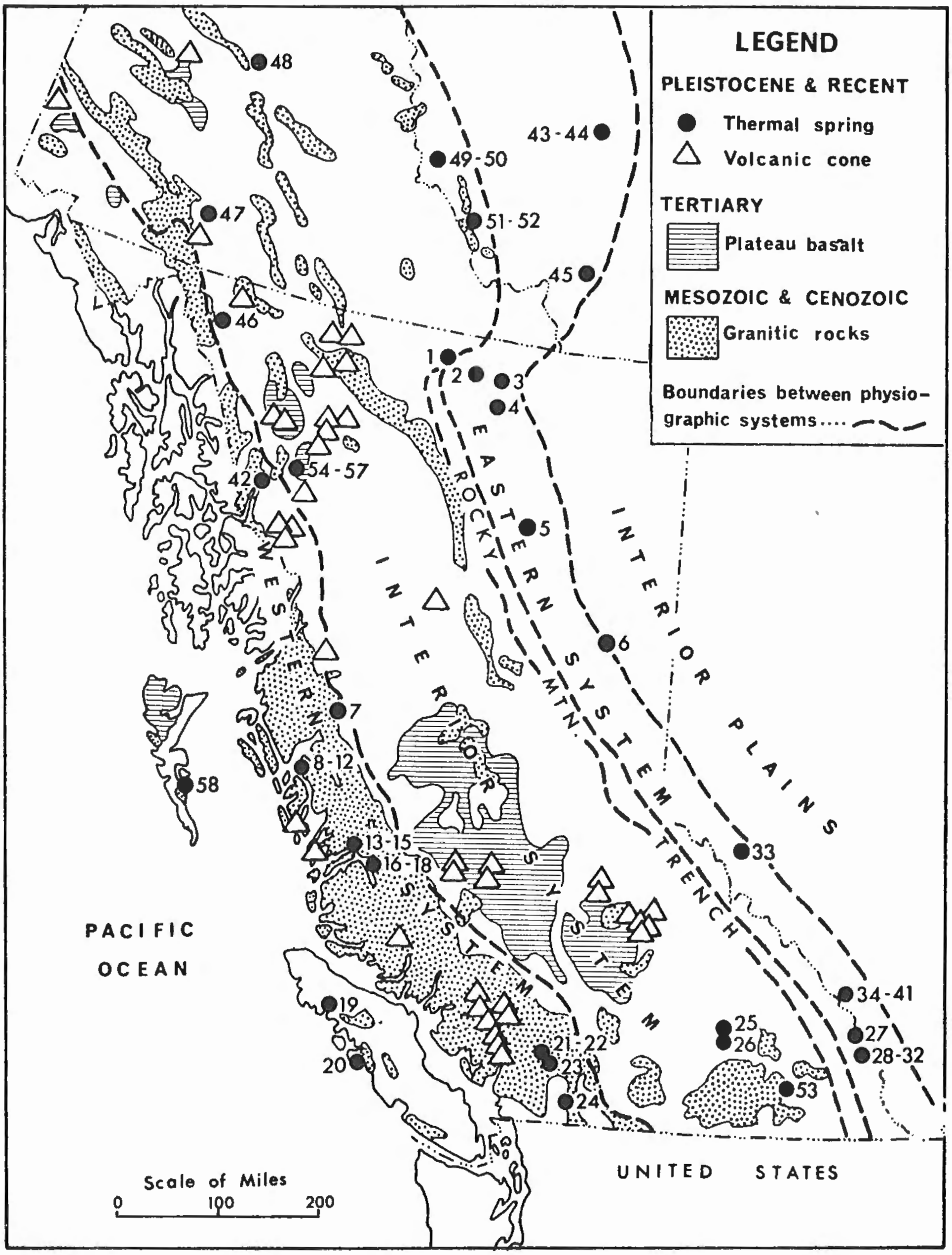

Fig. 2 — Map of the Cordilleran region showing the locations of thermal springs and their relationship to granitic and young volcanic rocks

which lead Clapp (1914) to conclude that the spring is probably discharging sea water which penetrated sheared diorite to such dephts that it became heated. The spring is in a region of late Tertiary plutonic activity and the water may be in part of magmatic origin.

No quantitative data are available on either the Kyuquot Sound springs (19), which occupy several pools in the bottom of a drift-covered valley, or the hot spring (58) on Queen Charlotte islands. The latter is reported to have a large flow and a temperature near boiling.

Lillooet Valley Group (21 to 24) — The four springs of this group occur in Lillooet Valley, the lower part of which is occupied by Harrison Lake. The valley is controlled by a system of steep northwesterly trending faults that cut Coast Range Plutonic rocks and roof pendants of Mesozoic sedimentary and volcanic rocks. Secondary faults diverge from the main northwesterly trend and cut across a mountainous upland on either side of the main valley. All of the springs are believed to be discharging meteoric water that has circulated to sufficient depth along this fault system to become heated by the natural geothermal temperature increase. A difference in elevation of 5,000 to 7,000 feet between the springs and recharge area in the adjacent mountains provides for extremely deep circulation of water.

The largest and best known of the group is Harrison Hot Springs, (24) at the south end of Harrison Lake near the TransCanada highway. It has been developed as a tourist resort and the water, which is moderately radioactive, is reputed to have curative powers. Two main springs, a sulphur spring (24A) and a potash (24B), spring have been developed. Despite their close proximity the chemical character of water from the two springs is different, and probably reflects the great variety of rocks that are cut by the controlling fault system.

None of the other springs in the group has been developed, although the Skookumchuck spring (21) is considered by local inhabitants to have therapeutic value. It is depositing a hard yellow precipitate of calcium, magnesium, and sodium sulphates with minor sodium chloride and silica.

Water from all the Lillooet springs is of the lightly mineralized sulphur type with a moderate content of alkali chlorides, and about 8 ppm. hydrogen sulphide.

Dean Channel Group (13 to 18) — This group of six widely separated springs is clustered around the head of Dean and Burke Channels, part of a system of narrow fiords that extend into the centre of the Coast Range. All of the springs are near sea-level and all of them discharge from fissures in quartz diorite of the Coast Crystalline complex. In general, they fall within a broad northwesterly trending zone of migmatite, gneiss and schist that forms nearly vertical pendants within the more uniform granitic rock. The metamorphic rocks tend to be more porous and more highly fractured than the surrounding quartz diorite and this may account for the localization of hot springs in the area. The largest spring and only one of the group on which quantitative data are available (Table 1) is on the shore of Eucott Bay (14) on the west side of Dean Channel. The water is of the calcium sulphate-- calcium bicarbonate type, quite unlike the sodium sulphate water that is characteristic of most springs in the Coast Range. This difference is probably due to solution of minerals such as calcite and pyrite which are abundant in the screens of metamorphic rocks but absent in other parts of the Coast Crystalline complex.

Gardner Canal Group (8 to 12) — This group of springs, like the Dean Channel group, is located in the central part of the Coast Range. Four of the springs issue from fractures in quartz diorite and one (9) from fractures in a large pendant of schist. The temperature of all five springs is remarkably similar, varying from 110° to 112 °F. Water from four of the springs is of the sodium sulphate type with 300 to 1,200 ppm. total dissolved solids. The fifth spring (12), at the head of Klekane Inlet, discharges sodium chloride water with 9,384 ppm. total dissolved solids. Comparison of the Klekane Inlet water with sea water shows a close similarity in ratios of the major components.

All of the springs in this group are believed to be discharging meteoric water that has circulated to great depth along fractures in the quartz diorite. The high salinity of the Klekane Inlet spring is probably due to contamination at depth by sea water.

Lakelse Hot Springs (7) — In 1958 the Lakelse Hot Springs were developed into bathing facilities at a resort hotel which has become a major tourist attraction in northern British Columbia. There are nine springs with an average temperature of 186 °F.

The springs are situated in a broad northerly trending valley on the eastern margin of the Coast Range mountains. The valley is part of a major fault-controlled lineament that, at Lakelse, cuts granitic rocks of the Coast Crystalline complex and extends northward into sedimentary and volcanic rocks of the Interior System. Thirty-five miles north of Lakelse the lineament is occupied by a basaltic cinder cone and flow that are reported to be about 300 years old.

The water is of the sodium sulphate type with a total of 1,109.6 ppm. dissolved mineral salts. It differs from other Canadian thermal springs in the relatively high content of lithium.

Stikine River Springs (42) — The Stikine River Springs comprise eighteen flows issuing from joints in granitic rocks at the edge of the valley floor. Water from the separate springs combines to form a slow moving stream with an estimated flow of 700 gallons a minute. The water is clear and odorless with only 880 ppm. dissolved solids, chiefly sodium-chlorides and calcium-

Table 1 — Thermal springs

No. on Fig. 1	Name and location	Temp. °F	Flow 1 gpm.	Total diss. solids (ppm.)	Chemical constituents (ppm.)	Gaseous constituens	Associated rocks	References
1	Portage Brule Spring two miles below mouth of Coal River	90—112	5—10	814	Ca(125), K(34), Mg(77), Fe(1), Na(41), Mn(.08), HCO_3(725), SO_4(77), F(. 33), Cl(64), Si(40)		Silurian dolomite	24, 20 5
2	Liard R., 1 mile N. W. of bridge on Alan Road	121—125	75	1195	Cl(23), SiO_2(57), CaO(292), MgO(68), SO_3(505),	CO_2		24, 20, 5
3	Toad R. 1.5 miles above junction with Racing R.	Hot						24, 20
4	Lepine Creek	Warm	small			CO_2; SO_2	Sedimentary rocks	20
5	Prophet River	Hot	small			CO_2		24, 20
6	Peace R. at Hudson Hope	Hot	large			CO_2		24, 20
7	Lakelse Hot Springs, southeast corner of Lakelse Lake	185		1109.6	Ca(46.6), Mg(50.2), Na(320.6), HCO_3(43.6), CO_3(2.3), SO_4(457.2), Cl (215.9),F(3.3) SiO_2(5.6), Fe(18.2) P(8.2), Li(10.2)		Quartz diorite	24, 12
8	West side of Bishop's Cove on Ursula Channel	112		400	SO_4(179),Na(92),CO_3 (7), SiO_2(65), HCO_3(4), Cl(32), Mg(0.3), Ca(18), FeO + Al_2O_3(5)		Fissured quartz diorite	24, 10, 15
9	Near Gardner Canal	112	small	1229	SO_4(546), Na(259), Cl(60), HCO_3(167), K(29), SiO_2(90), Mg(5), Ca(67), FeO+Al_2O_3(5)		Chloritic schist	24, 10, 15

10	Near Southeast bank of Brim R., 200 yd. above mouth	100		281	SO_4(78), Cl(52), Ca(17), Na(43), Mg(12), HCO_3(40), FeO + Al_2O_3(3), SiO_2(36)		Fissured quartz diorite	24, 10, 15
11	Shore of Ursula Channel 2-3/4 mi. north of Fisherman Cove	112	small	395	SO_4(174), Ca(22), Na(81), CO_3(10), SiO_2(59), HCO_3(2), Cl(24), Mg(.3), FeO + Al_2O_3(23)		Quartz diorite	24, 10, 15
12	Head of Klekane Inlet off Fraser reach	112		8640	Cl(4600), Mg(179), Na(2523), K(82), SO_4(717), HCO_3(58), Ca(385), FeO + Al_2O_3(58)		Quartz diorite	24, 10, 15
13	Shore of Nacall Bay	Warm					Quartz diorite	24,
14	Shore of Eucott Bay west side of Dean Channel	130		192	SO_4(80), Na(16), Ca(35) Cl(8), HCO_3(33), Mg(Trace), SiO_2(17), FeO + Al_2O_3(3)		Quartz diorite	24, 10, 15
15	Shore of Brynildsen Inlet on Labourchere Channel	Warm					Granodiorite	24
16	Northwest of Bella Coola	Warm						24
17	Shore of South Bentinck Arm 25 mil. south of Bella Coola	Warm	large		Sodium sulphate waters		Fissured quartz diorite	24, 20
18	Head of South Bentinck Arm	Warm						24

(continued)

No. on Fig. 1	Name and location	Temp. °F	Flow 1 gpm.	Total diss. solids (ppm.)	Chemical constituents (ppm.)	Gaseous constituents	Associated rocks	References
19	1 mile from Fair Harbour on Kyuquot Sound Vancouver Is.	Hot						24, 8
20	Sharp Point, between Sydney Inlet & Refuge Cove, west side Vancouver Island	125	100	483	Cl(217), Ca(20), Na(137), Mg(1), SiO_2(59), K(2), SO_4(47)	H_2S	Fractured diorite	24, 8
21	Skookumchuck, 20 miles of Douglas	130	small	1280	SO_4(413), Ca(163), Cl(338), Na(119)			24, 7, 15
22	Bank of August Jacob's Creek, 11 miles northwest of Douglas	120	small	367	SO_4(162), HCO_3(36), SiO_2(54), Ca(32), Mg(41), Na(3), Cl(39)	H_2S	Metasediments between large bodies of granodiorite	24, 7, 15
23	Bank of Sloquet Creek, 10 mi. above junction with Lillooet River	160	large	742	SO_4(360), Cl(63), Na(108), Ca(94)	H_2S	Sedimentary strata (Jurassic)	24, 7
24A	Harrison, near S. end of Harrison Lake (Sulphur)	145		1332	NaCl(473), Na_2SO_4(452), $CaSO_4$(278), SiO_2(59), $Ca(HCO_3)_2$(28), KCl(28), $MgSO_4$(13)	H_2S	Fractured sedimentary rocks	24, 7, 15
24B	Harrison, near S. end of Harrison Lake (Potash)	140		1279	NaCl(478), Na_2SO_4(402) $CaSO_4$(278), SiO_2(74), $Ca(HCO_3)_2$(32), $MgSO_4$(15)	N_2, CO_2 H_2S, CH_4	Fractured sedimentary rocks	24, 15, 7

25	Halcyon on east shore of Upper Arrow Lake	120—128	33	788	SO_4(433), Na(161), Ca(57), HCO_3(48)	N_2, CO_2 H_2S, CH_4	Crystalline schist	24, 15
26	Near Nakusp on the east side of Upper Arrow Lake	Warm		510	$CaSO_4$, NaCl, $MgHCO_3$			15
27	Radium Hot Springs	114—116	330	696	SO_4(306), HCO_3(216), Ca(140)	N_2, CO_2 CH_4, H_2S	Fractured Jubilee Formation (Cambrian)	24, 15
28	Fairmont, 1.5 mi. northeast of Columbia Lake	86—113		1218	SO_4(570), HCO_3(230), Ca(228), Mg(75)	CO_2, N_2	Fractured Jubilee Formation (Cambrian)	24, 15
29	Kootenay River 9.5 miles NW of Canal Flats	Warm	small				Fractured Jubilee Formation (Cambrian)	24
30	East shore of Columbia Lake	Warm	small				Fractured Jubilee Formation (Cambr.)	24
31	Lussier River, 11 miles east of Canal Flats	108				H_2S	Beaverfoot Limestone (Upper Devonian)	24, 15
32	Bank of Ram Creek, 13 miles southeast of Canal Flats	90—100				CO_2	Jubilee Formation (Cambrian)	24, 19
33A	Miette Hot Spring, Jasper, Alberta	70—120		503	HCO_3(281), SO_4(115), Cl(45), Ca(86), Mg(22), Na(50), K (trace), SiO_2(9)			24, 15, 3
33B	Miette Hot Springs, Jasper, Alberta	70—120		1825	SO_4(45), CO_3(116), Mg(65), Na(13), K(17.3), SiO_2(116)			24, 15, 3

(continued)

No. on Fig. 1	Name and location	Temp. °F	Flow 1 gpm.	Total diss. solids (ppm.)	Chemical constituents (ppm.)	Gaseous constituents	Associated rocks	References
34	Bank of Fortymile Creek, 4 mi. northwest of Banff	Warm	small			CO_2, H_2S	Upper Banff Shale (Mississippian)	24, 17
35	Stoney Squaw Mountain, 2 miles north of Banff	Warm	small			CO_2, H_2S	Pennsylvanian Strata	24, 17
36	Vermillion Lake, 3 miles northwest of Banff	67	100	434	HCO_3(115), SO_4(147), Ca(95), Cl(42), Mg(23)		Upper Banff Limestone (Mississippian)	24, 17
37	Upper Hot Spring, northeast flank of Sulphur Mtn.	115	130	1098	SO_4(634), Ca(239), HCO_3(133), Mg(40)	CO_2, H_2S	Upper Banff Limestone (Mississippian)	24, 17, 15
38	Middle Spring, northeast flank of Sulphur Mtn.	92	100	1059	SO_4(610), Ca(228), HCO_3(128), Mg(39)	CO_2, H_2S	Upper Banff Limestone (Mississippian)	24, 17
39	Kidney Spring, northeast flank of Sulphur Mountain	101	20	1064	SO_4(587), Ca(230), HCO_3(154), Mg(39)	CO_2, H_2S	Upper Banff Limestone (Mississippian)	24, 17
40	Sulphur Mountain, cave near valley floor	85	250	1107	Ca(217), HCO_3(140), Mg(39)	N_2, CO_2, H_2S	Upper Banff Limestone (Mississippian)	'24,-77
41	Banff Basin Spring Sulphur Mnt., near valley floor	94	150	1905	SO_4(1,120), Ca(400), HCO_3(175), Mg(71)	N_2, CO_2, H_2S	Triassic strata faulted against Devonian Limest.	24, 17
42	East side of Stikine R. opposite Great Glacier	120–150	700	880	NaCl(423), $CaSO_4$(202), Na_2SO_4(154)		Fractured schist and granite	24, 18

43	Roche-qui-trempe-à-l'eau, east bank of Mackenzie R. 2 miles below Wrigley	70— 88	2—20	12556	Cl(5226), F(3), SO_4(2810), NO_3(1), HCO_3(184), Si(24)		Devonian limestone and shale	5
44	Old Fort Island, at Mile 336, Mackenzie River	53	300	1180	SO_4(683), F(3), HCO_3(182), NO_3(3), Si(52), Cl(19)		Devonian limestone and shale	5
45	Bank of the South Nahanni R. upstream from Clausen Creek	95— 98	300	4942	Cl(2277), NO_3(4), SO_4(660), F(1), HCO_3(271), Si(26)	H_2S	Devonian limestone of the Nahanni Formation	5
46	Lower part of O'Donnel R. valley south of Atlin	48— 80	60—300	226	HCO_3(253), Cl(1), Si(14), F(0), SO_4(11), NO_3(0)		Cache Creek limestone (Permo-Carboniferous)	5
47	Takhini Hot Spring, 6 miles west of Dawson Road	116	50	2559	SO_4(1721), F(5), CO_3(132), Cl(2), Si(41), NO_3(8)		Limestone and greywacke	5
48	McArthur Hot Springs	128	500	177	SO_4(50), Cl(2)	H_2S	Shale intruded by granite	5
49	Cantung Hot Springs	102—119				H_2S	Tertiary granite pluton	5, 1
50	Rabbitkettle Hot Springs	69					Lower Paleozoic limestone and shale	1
51	Caesar Lake Spring	38— 44					Precambrian calcareous gneiss	1
52	Upper Flat River	79				CO_2	Lower Paleozoic limestone and shale	1

(continued)

No. on Fig. 1	Name and location	Temp. °F	Flow 1 gpm.	Total diss. solids (ppm.)	Chemical constituents (ppm.)	Gaseous constituents	Associated rocks	References
53	Ainsworth Hot Spring	101.5	60	1766.2	HCO_3(1144), SO_4(37.6), Cl(62.5), Na(290.1), Ca(150), Mg(13.8), FeO(1.3), SiO_2(66.9)	CO_2	Metamorphosed sedimentary and volcanic rocks	24, 22
54	Elwyn Creek Hot Springs	120	Large			CO_2	Tertiary granite	
55	Tawah Creek Hot Spring	170	Large			CO_2	Jurassic shale	
56	Mess Lake Hot Spr.	50	Small			CO_2	Triassic andesite	
57	Raspberry Cr. Spring	55	Small			CO_2	Triassic andesite	
58	Southern Queen Charlotte Island	Hot	Large			H_2S	Granodiorite	

-sulphate. Bubbles of carbon dioxide issue from the main spring which is also the hottest of the group with a temperature of 150 °F. The springs are in area of extensive Tertiary plutonic activity and Kerr (1948) states that "the water is probably of magmatic origin and associated in some way with recent igneous activity".

Interior System

Selkirk Mountain Springs (25, 26, 53) — The Selkirk Mountains comprise a number of north-trending ranges in the southern interior of British Columbia. They are underlain by metamorphic and sedimentary rocks that range in age from late Precambrian to Mesozoic and are intruded by plutons of early Tertiary age. All of the thermal springs known in the area lie along north-trending lineaments that are believed to be controlled by major fault systems. Halcyon (25) and Nakusp (26) springs rise from fissures on the east side of Upper Arrow Lake, and the Ainsworth Spring (53) is situated on the west side of Kootenay Lake.

A sanitarium was built at Halcyon Hot Spring (25) in 1888 and for many years its waters were used in the treatment of tuberculosis patients. The buildings were later destroyed by fire and the spring has since returned to its natural state. The water, which varies from 120° to 128 °F, is moderately radioactive and liberates large quantities of hydrogen sulphide gas. The Halcyon and Nakusp spring waters are lightly mineralized sodium, calcium-sulphate waters with small amounts of alkali chlorides whereas water from the Ainswort spring is of the calcium bicarbonate type and it has built large terraced deposits of travertine. This difference is attributed to extensive beds of limestone and calcareous shale in the mountains of the recharge area immediately east of Ainsworth and these absence ox calcareous rocks in the recharge area of Halcyon and Nakusp springs. All of the springs are near Tertiary plutons which are undoubtedly surrounded by a relatively high thermal aura.

Mount Edziza Group (54—57) — The four springs of this group are the only hot springs known in Canada that appear to be associated with recent volcanic activity. They occur along the western side of Mount Edziza, a large composite volcano in northern British Columbia that has been active within the last 1,000 years. Both hot springs and recent cinder cones are aligned in a north-south direction, parallel with major faults in the subvolcanic basement. Two of the springs are within a graben-like depression bounded by north-south faults that have post-Pleistocene movement. The water varies in temperature from 60° to 170 °F due mainly to varying degrees of dilution by cold surface water. All of the springs give off large quantities of carbon dioxide but no hydrogen sulphide. An extensive deposit of tufa has been precipitated by each of the four hot springs and similar tufa deposits are formed by at least six cold mineral springs that emerge from the base of the Mount Edziza pile.

No analyses of this water were available at the time of writing, but it is probably of the calcium bicarbonate type with a high iron content. The tufa is slightly radioactive.

Yukon Plateau (46 to 48) — Three widely separated hot springs in the Yukon Plateau of northern British Columbia and southwestern Yukon have been described by Brandon (1965). O'Donnel River valley (46) contains several warm springs with temperatures of 48° to 80 °F and a low mineral content, chiefly calcium bicarbonate. The water issues from carboniferous limestone and is believed to be meteoric water that has entered solution channels in high ground a short distance north of the springs.

Takhini Hot Springs (47) rise in a natural pool formed by glacial drift that rests on steeply dipping beds of limestone and greywacke that have been extremely faulted. Water in small lakes on a upland north of the spring is believed to be the source. The spring water with a temperature of 116 °F is of the calcium sulphate type. It is piped into an open swimming pool and was formerly used to heat a commercial greenhouse.

McArthur Hot spring (48) with a temperature of 128 °F and an estimated flow of 500 gpm. issues from slate that has been intruded and pyritized by a younger granite pluton. The spring is probably recharged by meteoric water that enters joints in the granite and flows through the highly pyritized slate. The waters are of the lightly mineralized sodium sulphate type and liberate hydrogen sulphide gas. It has been suggested that oxidation of the pyritiferous slates generates the heat acquired by the spring water.

Nahanni Group (49—52) — Four groups of hot springs have been described by Atchison (1964) in the upper reaches of Nahanni and Flat Rivers. They occur in an area of late Precambrian carbonate-bearing schists and gneisses and Palaeozoic limestone and shale, intruded by Tertiary granitic plutons. — Three of the springs issue from fractures in the sedimentary rocks and are notable for their large deposits of travertine. One of them, Rabbitkettle Spring (50), has built a series of beautifully terraced pools on a circular mound 225 feet in diameter that rises 90 feet above the valley floor. The fourth spring of the group, Cantung Hot Spring (49) issues directly from joints in a Tertiary granite pluton. It is the hottest spring of the group, 119 °F, and the only one that is not depositing tufa; a difference that suggests it stems from a flow system that is restricted entirely to the plutonic rock. Atchison concludes that the springs are discharging meteoric water that has circulated through a relatively high thermal aura surrounding nearby Tertiary plutons.

Eastern System

Southern Rocky Mountain Trench (27 to 32) — All the springs in this group occur either within or very close to the Rocky Mountain Trench, a great northwest-trending rift valley that separates lower Palaeozoic sedimentary rocks on the east from Proterozoic rocks on the west. Five of the hot springs issue from fractures in Cambrian limestone of the Jubilee Formation, the sixth (31) issues from Devonian limestone of the Beaverfoot Formation. The best known springs, Radium (27) and Fairmont (28) Hot springs, are the only ones for which quantitative data are available, and both have been developed as tourist and health resorts.

Radium Hot Spring, with a temperature of 125 °F and a flow of 330 gpm. issues from a prominent fault zone that can be traced through a vertical distance of 4,000 feet into mountains above the springs. Rock adjacent to the fault are hydrothermally altered and stained bright red. The water is of the sulphated calcium bicarbonate type with a total of 69,6 parts per million dissolved solids.

The Fairmont Springs comprise six main springs that range in temperature from 86° to 113 °F and have a combined flow of about 1,000 gpm. The water contains 1,640 ppm. dissolved solids, chiefly calcium and magnesium bicarbonate which are deposited as the water looses carbon dioxide.

Both Radium and Fairmont springs are notable for the strong radioactivity of their waters, about 4000 units ($4000 \cdot 10^{-12}$g Ra).

Banff Hot Springs (34—41) — The springs at Banff, Alberta in the southwestern Rocky Mountains are probably the most widely known of all Canadian hot springs. Surrounded by lofty, snow capped mountains the springs provide a major attraction for visitors to Banff National Park. Although developed mainly for recreational bathing the water is also used for medical purposes, particularly the treatment of rheumatism.

The springs are located along the sides of Bow River valley in a line that closely approximates the trace of the Sulphur Mountain thrust fault which dips to the west and brings Cambrian carbonate beds over Triassic shale of the Spray River Formation. The hottest spring is Upper Hot Spring (37) which discharges 120 gallons of water a minute at a temperature of 115 °F. It is also the highest of the springs, with an elevation of 5,195 feet on the northheastern slope of Sulphur Mountain, nearly 700 feet above the floor of the valley and considerably higher than any of the nearby rivers and streams. According to Haites (1959) the source of the spring water is Sundance Creek on the opposite, southwest, side of Sulphur Mountain (Fig. 3). The bed of this creek is higher than Upper Hot Spring and water from it is believed to travel down a secondary thrust that intersects the Sulphur Mountain thrust at a depth of 21,000 feet. Assuming a thermal gradient of 1 °F

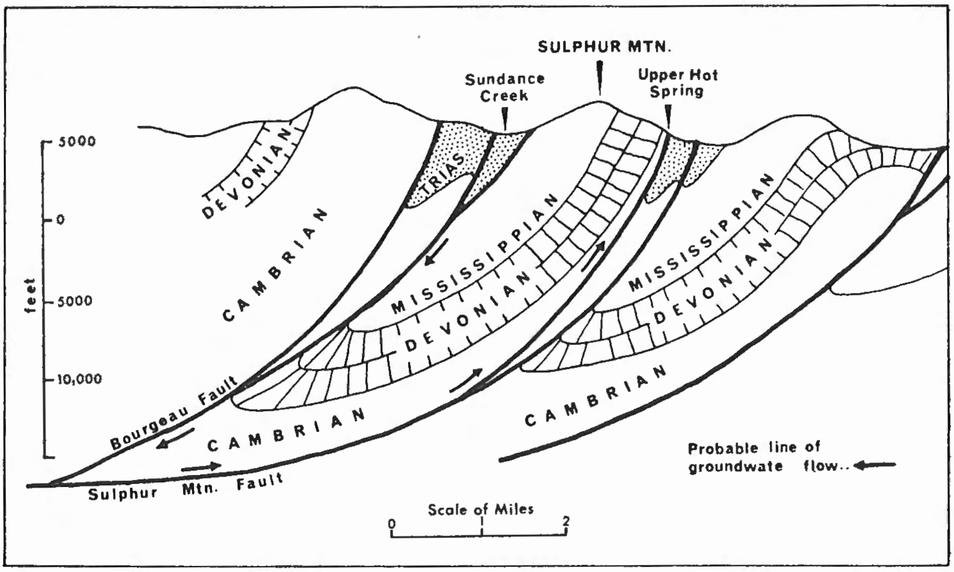

Fig. 3 — Diagrammatic section illustrating the geology and flow system of the Sulphur Mountain hot springs, Banff. (Adapted from Haites, 1959)

per 100 feet the Sundance Creek water sould attain a temperature of 210 °F before ascending along the Sulphur Mountain thrust. A water-cycle period of at least two and one-half months is suggested by the fact that the Upper Hot Spring ceased to flow from March 12 to May 11, 1923 following a severe drought the previous summer.

The waters of all the Banff Springs are similar and contain about 1,000 parts per million total dissolved solids, chiefly calcium and magnesium sulphates and calcium bicarbonate. Gasses evolved from the springs consist mainly of nitrogen and minor amounts of carbon dioxide, hydrogen sulphide and methane. Tufa deposits around the orifices of springs that have been kept in their natural state are too large to have been formed by the present output, suggesting a diminishing supply of water during the history of the springs.

Miette Hot Springs (33) — Miette Hot Springs, near the resort town of Jasper, Alberta, have been developed for recreational bathing. Six main springs occur in the narrow canyon of Sulphur Creek which flows along steeply dipping Palaeozoic limestone beds in the faulted axis of a large anticline. The springs have a combined flow of 85 gpm. and the hottest has a temperature of 126 °F. The water contains from 500 to 1,800 parts per million dissolved solids, chiefly calcium and magnesium sulphate, probably dissolved from the enclosing limestone and dolomite. Gasses liberated from the water are mainly hydrogen sulphide and nitrogen with minor amounts of carbon dioxide.

Northern Rocky Moutain Springs (1—6) — Of this group of springs only the Liard Crossing Spring (1) and the Portage Brulé Spring (2) have been examined geologically. The others are reported to discharge hot water (above 90 °F) and to have built large deposits of calcareous tufa.

Liard Crossing Springs (1) consist of two main pools enclosed by small terraces of calcerous tufa. The water is discharged at a temperature of 118 °F and a rate of 75 gallons per minute. The area surrounding the springs supports a luxuriant vegetation and is known locally as "Tropical Valley". Although the springs are used for bathing by travellers on the Alaska Highway, they have not been developed commercially.

The springs are at an elevation of 1,500 feet at the foot of hills that rise to 3,000 feet. According to Brandon (1964) the recharge area is in the hills to the north where water enters bedding planes in Devonian limestone and flows along them to the discharge area in Liard Valley. The waters is of the calcium sulphate type.

Portage Brule Springs (2) comprise six small flows that issue from solution channels in dolomite on the bank of Liard River. They have a maximum temperature of 112 °F and the water is predominantly a calcium bicarbonate water. The relatively low mineral content (814 ppm.) is indicative of a short flow system.

Franklin Mountain Springs (43—45) — The Franklin Mounttains extend for 400 miles in a narrow arc that borders the northern Interior Plains and includes the most easterly ranges of the northern Cordillera. Clausen Creek Hot Spring (45) is situated in the Nahanni Range at the southern end of the Franklin Mountains and the Old Fort and Roche-qui-Trempe-a--l'eau springs are located 150 miles farther north in the McConnel Range. Both ranges are underlain by folded and faulted lower Palaeozoic carbonate rocks interbedded with shale, sandstone and lesser amounts of salt, gypsum and anhydrite.

The Clausen Creek Spring (45) emerges from alluvial sand and gravel that rests on Devonian limestone at the foot of the Nahanni Plateau escarpment. The water discharges at a temperature of 98 °F and accumulates in a natural pool about 30 feet in diameter, where it cools to an average temperature of 95 °F. It is moderately saline and has a strong odor of hydrogen sulphide. A tritium count analysis (Brandon, 1965) indicates an age of water of 30 ± 10 years. The recharge area is believed to lie in the Nahanni Plateau where meteoric water entres solution channels in the limestone and circulates to a depth of at least 5,000 feet before emerging at Clausen Creek.

The Roche-qui-trempe-à-l'eau (44) and Old Fort Springs (43) both issue from fractured Devonian limestone exposed in the bottom of Mackenzie River Valley, adjacent to the western edge of the McConnel Range. Water from the Old Fort Spring is only slightly mineralized and its temperature of 53 °F is

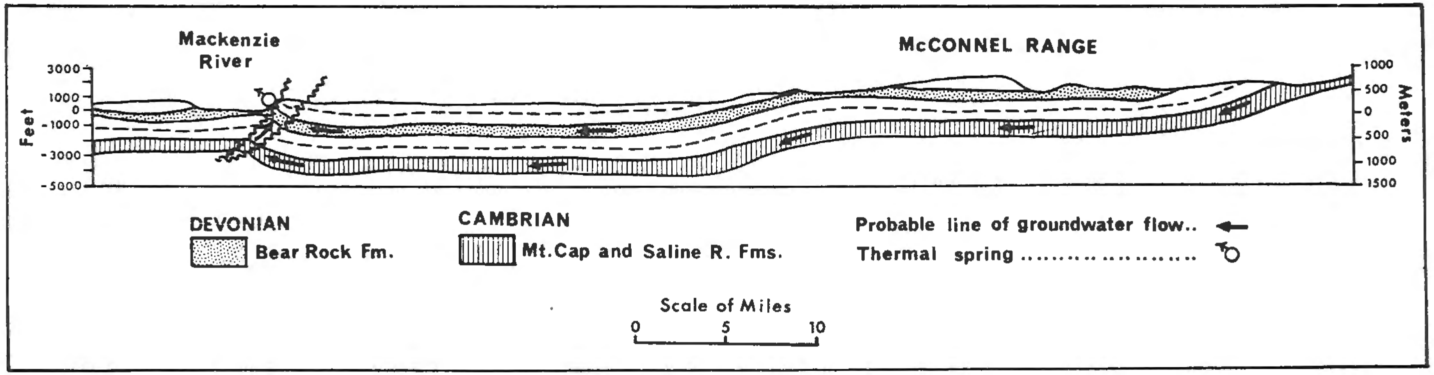

Fig. 4 —Diagrammatic cross-section of McConnel Range, illustrating the flow systems that give rise to the Old Fort and Roche-qui-trempe-à-l'eau thermal springs. (Adapted from Brandon, 1965)

not more than 15 °F warmer than the regional groundwater temperature. In contrast, the Roche-qui-trempe-à-l'eau water, with a temperature of 88 °F, is strongly saline and probably originates from a much deeper flow system.

The geological structure of the region is illustrated in the diagramatic cross section (Fig. 4). Westerly dipping strata of the McConnel Range are cut by a steeply west-dipping thrust fault, the trace of which passes through both springs. Meteoric water is believed to enter porous beds in the McConnel Range, then flows through favourable aquifers until it intersects and ascends the trust fault in Mackenzie Valley. Tritium counts on the Roche-qui-trempe-à-l'eau water suggest a water-cycle period of 30 ± 10 years. The relatively high temperature and salinity of water from the latter spring suggest that it travelled along a deep aquifer, probably the Cambrian Saline River Formation which contains salt and gypsum beds. Water from the Old Fort Springs is believed to have followed a shallower course, through solution channels in Devonian limestone, of the Bear Rock formation which accounts for its lower temperature and mineral content.

Nonthermal Mineral Springs of the Cordillera

Hundreds of small nonthermal springs in the Cordillera are precipitating deposits of calcareous tuffa or iron hydroxide. Few of them have been recorded in the literature and there is little or no chemical data on their waters. Those forming calcareous deposits are found mainly in limestone areas whereas the iron-bearing springs are commonly associated with pyritiferous shale or with local areas of mineralization. The vast areas of flat-lying lavas in central British Columbia provide a favourable environment for long shallow flow systems and escarpments bounding these areas are common sites for cold, highly mineralized springs.

Three nonthermal springs in the Cordillera warrant special mention. The Fernwood spring ((26) on Salt Spring Island discharges water with more than 71,900 ppm. dissolved solids and precipitates sodium chloride and sodium sulphate over an area about 300 feet in diameter. It is situated on a transverse fault that cuts Cretaceous marine sandstone and through which sea water may enter the flow system.

A salt spring seepage near Kwitnitsa (27) has impregnated about 100 feet of Pleistocene and Recent silty clays that occupy a basin at the confluence of the Kwitnitsa and Skeena Rivers. Sea water intrusion is probably the source of the salinity as the present Skeena River is tidal to a point three miles west of the Kwinitsa seeps. During 1913 about 15 tons of salt were extracted by means of boreholes drilled into the silty muds adjacent to the seeps.

Table 2 — Nonthermal mineral springs

No. on Fig. 1	Name or location	Temp. (°F)	Flow (I gpm.)	Total diss. solids (ppm.)	Chemical constituents (ppm.)	Gaseous constituents	Associated rocks	References
1	Fishells Brook and Saint Vintans, Nfld. (4 springs)			Relatively high	$NaCl$ $CaSO_4$	H_2S	Codroy group (Mississippian)	9, 6
2	Cape Breton Is. a) Whycocomagh, N. S. (3 springs)	43	100	3,300	Na Cl		Windsor group limestone	9
	b) Bucklaw, N. S.	56	35	58,300	Na Cl	H_2S odor	Windsor group limestone	9
3	Antigonish, N. S. (7 springs)	48	2—5	65,500	Na Cl	H_2S	Windsor group	9
4	Kemptown, N. S.		Small		Na Cl		Windsor group	9
5	Oxford District, N. S. (9 springs)	48	1/2—2	13,200	Na Cl		Windsor group	9
6	Windsor District, N. S. (6 springs)	47	15	21,400	Na Cl SO_4		Windsor group	9
7	Sussex, New Brunswick — Kings County	45	3	44,500	Na Cl		Windsor group	9, 16
8	Salina, New Brunswick	52	6	19,600	Na Cl SO_4		Windsor group	9
9	St. Geneviève De Batiscan, Quebec	47	8	29,260	Cl(16,850), Na(9,090), HCO_3(1,123), I(7), Br(34)	H_2S (trace)	Ordovician limestone	14, 21
10	Radnor Forges Spring, Champlain Co. Quebec	48	20	1,888	Cl(869), Na(478), HCO_3(224)	CO_2 (6.3 ppm.)		14, 21

11	St. Leon, Maskinonge Co. Quebec	48	1–1/2	13,988	Cl(17,215), Na(4,250), HCO_3(1,675)	H_2S (2 ppm.)	Chazy group	14, 21
12	Varennes Spring, Quebec	48		11,634	Cl(6,060), Na(3,858), HCO_3(1,285)		Chazy group	14, 21
13	Abenakis Springs, Que.	48	3–4	14,117	Cl(7,522), Na(4,285), HCO_3(1,228)	CO_2 (3 ppm.)	Chazy group	14, 21
14	Richelieu, Que.	49	1	2,077	Na(748), Cl(518)		Chazy group	14, 21
15	Caledonia Springs, Ont. (3 saline springs)	47	2	8,118	Cl(4,194), Na(2,691), HCO_3(930)	CO_2 (41 ppm.) H_2S (1 ppm.)	Carlsbad Form. (Ordovician)	14
16	Carlsbad Springs, Ont. (sulphur) (7 saline springs)	47	2	3,210	Cl(1,390), Na(1,065), HCO_3(657)	CO_2 (17 ppm.) H_2S (2 ppm.)	Carlsbad Form.	14
17	Borthwick Spring, Ont.	51	3	10,952	Cl(5,910), Na(3,740), HCO_3(954)	CO_2 (22 ppm.)	Ordovician limestone	14
18	Dominion Spring, Ont.	50		9,887	Cl(4,870), Na(3,044), HCO_3(1,410)	H_2S (1 ppm.)	Chazy Formation	14
19	Diamond Park Spring, Ont.	48	5	5,137	Cl(2,537), Na(1,640), HCO_3(708)			14
20	South end of Lake Winnipeg – Red Deer Peninsula, Manitoba	45		40,066	Na Cl		Devonian limestones	9, 6
21	Pine Creek, Man.	42	14.5	33,626	Na Cl		Devonian limestone	9, 6
22	Red Deer River – Dawson Bay, Manitoba	52	3.5	51,899	Na Cl		Devonian limestone	9, 6

(continued)

No. on Fig. 1	Name or location	Temp. (°F)	Flow (I gpm.)	Total diss. solids (ppm.)	Chemical constituents (ppm.)	Gaseous contituents	Associated rocks	References
23	Salt Point Dawson Bay Manitoba	44	45.5	59,297	Na Cl		Devonian Limestone	9, 6
24	La Saline, Alberta	40	7	70,000	Na Cl		Devonian Limestone	9, 6
25	Salt River, Alberta (6 springs)	40	4	260,000	Na Cl		Devonian	9, 6
26	Fernwood Salt Spring Island, B. C.	50	2	71,926	Cl(27,440), Na(25,240), SO_4(17,520)		Cretaceous shaly sandstones	9
27	Kwinista 45 miles east of Pr. Rupert, B. C. North bank of Skeena				Na Cl			9
28	Moore Creek, B. C.				MnO_2		Tertiary rhyolite	

An unusual spring on a tributary of Moore Creek (28) has formed terraced deposits of psilomelane and pyrolusite at least 8 feet thick and covering an area about 200 feet in diameter. The spring issues from fractures in a late Tertiary rhyolite stock which, at the surface, contains only trace amounts of manganese.

Interior Plains Region

The Canadian Interior Plains lie between the Cordillera and the Canadian Shield and extend from the American Great Plains to the Arctic Ocean. Pleistocene deposits covering the entire plains area are in turn underlain by nearly horizontal strata of Palaeozoic, Mesozoic and Tertiary age. Regional shallow flow systems, in these rocks, provide groundwater that contains 1,000 to 2,500 ppm. total dissolved solids, chiefly calcium-magnesium sulphate or sodium sulphate. Discharge from these flow systems commonly accumulates as alkali and salt water that occupies shallow depressions in the surficial deposits. Numerous brine springs (20—25) occur along the edge of the Precambrian Shield and issue from the Palaeozoic strata along Lake Winnipegosis and Lake Manitoba. The Palaeozoic springs (Fig. 5) fall into two groups separated by a 40,000 ppm. isochlor, the direction of which coincides with the strike of the strata. Springs on the east side of the 40,000 ppm. isochlor discharge water with an even greater concentration of sodium chloride derived from a lower member of Devonian limestone whereas elsewhere in the area upper Devonian strata are believed to be the source of brine springs (I. C. Brown).

Temperature measurements along the western shore of Dawson Bay, Lake Winnipegosis carried out by Cole (1930) suggest that the brines originate in an even larger stratigraphic interval. There is a ten-degree difference in average brine temperatures east and west of the 40,000 ppm. isochlor which at this location would indicate a difference in depth of origin of about 500 feet.

The few springs that issue from the Jurassic rocks near Lake Manitoba have total dissolved solids in the order of 10,000 ppm. but the dominant ions are also sodium and chloride.

In the Slave River district (25) a number of brine springs rise from the Silurian rocks at the base of the escarpment west of Fort Smith. The flow of the springs is not more than 4 gpm. and the total dissolved solids are in the order of 260,000 ppm. which is similar to the amount of total dissolved solids of waters in deep aquifers in the Swan Hills area of northern Alberta (I. C. Brown).

La Saline spring (24) discharges brine that contains more than 70,000 ppm. total dissolved solids, at a point 28 miles downstream from the junction of the

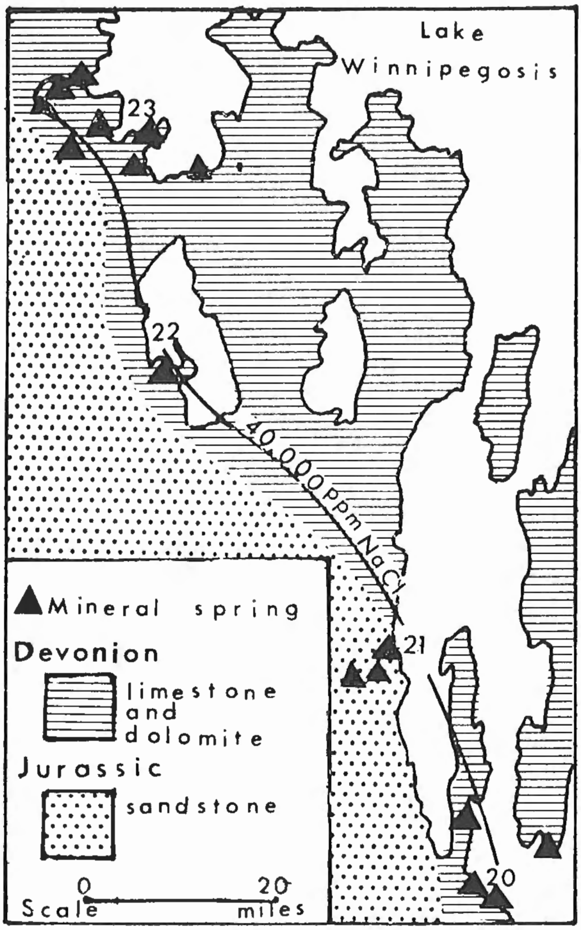

Fig. 5 — Map showing the bedrock geology, and the location and degree of mineralization of brine springs in northern Manitoba. (Adapted from Cole, 1930)

Mackenzie and Clearwater Rivers. Ninety per cent of the brine is sodium chloride which suggests a source in Devonian bedrock that underlies the river nearby.

The Canadian Shield and Innuitian Regions

The Canadian Shield is the largest physiographic subdivision of Canada. It is underlain almost wholly by granitic and metamorphic rocks that have formed a stable mass since Precambrian time. The porosity of the rocks is low and nearly all the groundwater occurs in fractures or in permeable surficial deposits. The chemistry of mine, well and spring water from the Shield is similar to the chemistry of surface waters, low in total dissolved solids, suggesting that groundwater flowsystems are relatively short.

The Innuitian Region lies entirely within the zone of continuous permafrost where groundwater circulation is restricted by a thick layer of permanently frozen ground. Although circulation of water below the permafrost is possible no thermal springs are known in the Innuitian Region. A circular pool of open water in the fast ice of Cambridge Fiord in northeast Baffin Island is attributed by Dunbar (1958) to springs issuing below the ice, however, it is not known whether the springs are hot or cold. Gypsum domes in the central Innuitian Region are associated with surface waters and small intermittent springs that contain over 1,000 ppm. calcium sulphate.

The Saint Lawrence Lowland

The Saint Lawrence Lowland is underlain by unfolded Palaeozoic sedimentary rocks overlain in most places by a thick cover of surficial deposits. The climate is humid to continental and precipitation totals 30 to 40 inches a year. All the mineral springs occur in the central part of the lowland which is a well defined synclinal basin of Cambrian and Ordovician rocks bounded on the west by the Frontenac axis, on the north by the Canadian Shield on the east by the Beauharnois axis and on the south by the Saint Lawrence River. The outcropping of Palaeozoic strata along the edge of the Canadian Shield provides a recharge or intake area for the meteoric water that moves downdip to the steeply dipping east-southeast trending faults along which the springs discharge mineral waters of the sodium-chloride-bicarbonate type. The Mid Ordovician Chazy Group of limestone, dolomite, shale and some sandstone beds are perhaps the principal host rocks for the groundwater flow systems as these strata constitue the most productive aquifer encountered elsewhere by drilled wells in the lowland area. Spring discharge is commonly less than 10 gpm. and total dissolved solids are less than 14,000 ppm. with one exception, the Saint Geneviève de Batiscan spring (9) at the eastern limit of the mineral spring area. The higher chloride concentration at this spring may be due to longer residence of the water in the flow system or local recharge from marine surficial deposits. All the mineral springs discharge carbon dioxide and some yield hydrogen sulphide believed picked up as the water migrates through shale facies of the Chazy Group.

The Carlsbad and Caledonia springs (15 and 16) were known as early as 1806 to the Ottawa valley settlers. These two groups of springs were developed as health spas and were well patronized in the early part of this century. The flow of the springs to the bathing pools was augmented by drilling flowing artesian wells up to depths of 240 feet into grey shale and interbedded limestones of the Carlsbad Formation of the Upper Ordovician rather than the Mid Ordovician Chazy Group.

The Appalachian Region

The Appalachian region is an upland sloping gently to the southeast, dissected by valleys and broken by lowland areas. Folded crystalline and sedimentary rocks occupy the uplands whereas flat lying sediments covered by thin surficial deposits occupy the lowland areas. Salt springs are associated with Carboniferous sediments that were deposited in a large basin that occupies parts of Newfoundland, Prince Edward Island, Nova Scotia and New Brunswick. The Carboniferous includes great thicknesses of conglomerate, sandstone siltstone, shale and limestone with local accumulations of gypsum, anhydrite and rock salt. Structurally the basin includes a series of folds with parallel and transverse faults. The distribution of the Carboniferous (Mississippian)

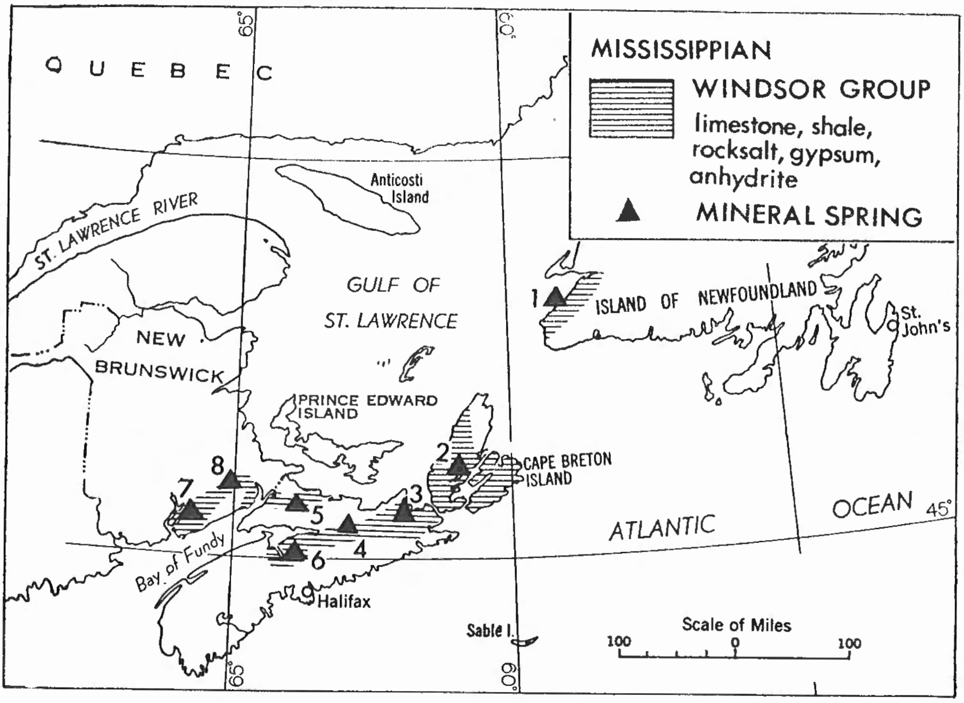

Fig. 6 — Map showing the close association of saline springs in the Appalachian region with salt-bearing strata of the Mississippian, Windsor Group

rocks and location of springs is shown in figure 6. The Carboniferous Codroy group, Windsor group and Albert formation are the locus of mineral springs of the sodium-chloride-sulphate type. Total dissolved solids range from 3,000 to more than 65,000 parts per million depending on the degree of brine dilution by circulating meteoric waters in the flow system.

On the west coast of Newfoundland at Fishells Brook and St. Fintans (1) brine springs issue from fault zones within the gypsum bearing Codroy group rocks. Similar springs at Flat Bay and Stinking Cove are sulphurous. In Nova Scotia, brine springs (2 to 6) occur in five areas underlain by Carboniferous rocks of the Windsor group that include limestone, gypsum, rock salt and anhydrite. The rock salt beds are up to 1,500 feet thick and occur at depths of 85 feet to 3,500 feet below the land surface. In general the springs discharge in seep areas covering a few acres of marshy ground but the Whycocomagh spring, Cape Breton Island, flows at the base of an escarpment in to St. Patrick channel at a rate of about 100 gallons a minute but the salinity is low. The best known springs in New Brunswick (7 and 8) occur in the Moncton basin and are related to anticlinal structures that appear to be the result of thrust faulting with salt accumulation and doming on the upthrow side (Fig. 7).

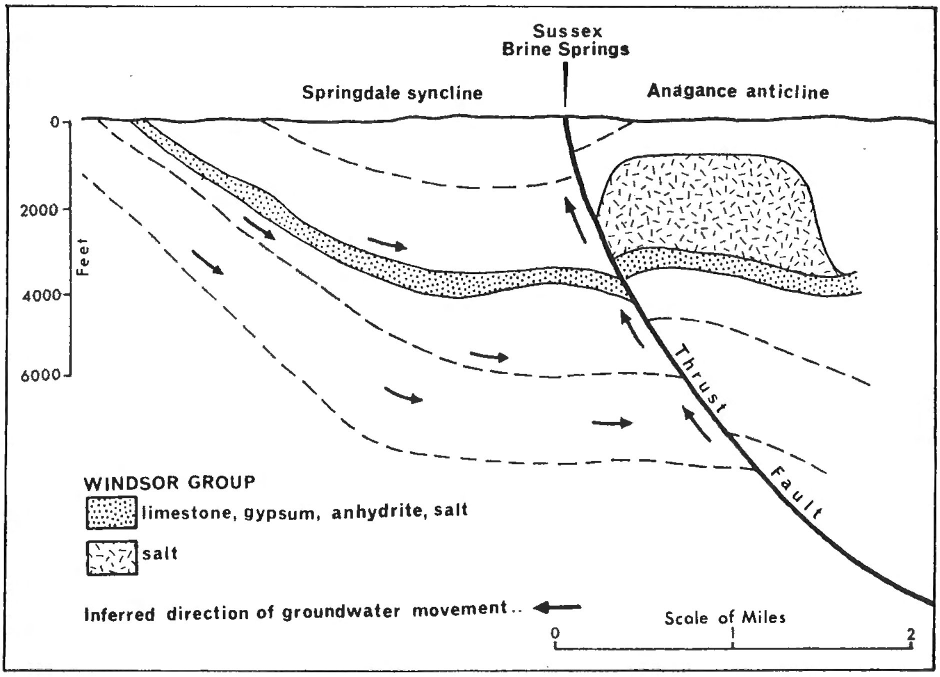

Fig. 7 — Diagrammatic cross-section near the Sussex brine springs, showing the relationship of the flow system to salt-bearing beds of the Windsor Group. (Adapted from Gussow, 1953)

Exploitation of Canadian Springs

Brine springs and seeps of the St. Lawrence Lowland and Appalachian regions were formerly the centres of Canada's salt Industry. The manufacture of salt by evaporation of brine from these springs was underway as early as 1887 with the production in that year of 150 barrels. After about 1900 with the discovery of salt beds in bore holes at or near the springs, the production of salt from flowing brines was discontinued in eastern Canada. The salt seeps at Kwinitsa, Cordilleran region, were developed in 1913 and 15 tons of salt extracted from bore holes adjacent to the seeps.

During the period 1900 to 1930 mineral springs in the St. Lawrence Lowland were developed for their therapeutic value and today the sale of bottled mineral water from these springs represents about 98.8 per cent of the total Canadian production. In 1962 the sale of bottled mineral waters in Quebec province amounted to $ 211,825. In recent years the use of mineral waters for medical purposes has declined.

Although a number of Canadian springs contain traces of rare elements the combined flow of such springs is too small to justify their extraction.

The power potential of Canadian thermal areas has not been explored. Preliminary data from a borehole drilled near the Mt. Edziza volcano indicates a relatively high thermal gradient and suggest that further exploration in the vicinity of the Edziza springs is justified.

The production of water for bathing at health spas and resorts is by far the most important use of thermal springs in Canada. Many springs that are still in their natural state have great potential as hot spring resorts and will undoubtedly be developed in the future.

Conclusions

The great majority of mineral and thermal springs in Canada are believed to be discharging meteoric water that has circulated through deep flow systems. The extent to which the temperature and chemistry of the original surface waters has changed is dependent on the depth and cycle-period of the flow-system, and on the lithology of the rocks the water encounters between recharge area and spring. In general the deeper the flow system the higher will be the temperature and mineral content of the water issuing from it, however, local variations in the geothermal gradient and the content of soluble minerals in the enclosing rocks may greatly influence the quality of the water.

Since the temperature of spring water is directly related to the depth of its parent flow system it is not surprising that all thermal springs in Canada are found in the Cordillera where high local relief provides the gravitational energy necessary for deep circulation. It is also significant that all of the 58 known thermal springs are at or near the bottom of valleys and 47 of these occur along major faults that provide channels for groundwater circulation. Thirty-two thermal springs occur in or near Tertiary plutons, suggesting that these young intrusive bodies are surrounded by a relatively high thermal aura in which groundwater may encounter high temperatures at moderate dephts. Surprisingly, there is little correlation between the occurrence of thermal springs and areas of recent volcanism. Although more than 130 centres of Pleistocene and Recent volcanic activity are known in the Canadia Cordillera, only the Lakelse and Edziza thermal springs are even remotely associated with volcanic features. In both of these cases the springs are situated on major north-south faults in the sub-volcanic basement. The presence of young cinder cones along these same faults suggests that the springs may be of volcanic origin, however, in the absence of similar relationships elsewhere it seems more likely that the cinder cones as well as the springs are related to fault systems which have provided conduits both for the eruption of lava and the deep circulation of meteoric water.

The mineral content of both thermal and nonthermal springs may be explained by solution of minerals contained in rocks through which the water has circulated. Carbonate waters are invariably discharged from springs in a terrain that includes limestone aquifers, whereas sulphate waters are commonly associated with rocks containing disseminated pyrite. The low mineral content of springs issuing from crystalline rocks of the Coast Range, including many thermal springs from deep flow systems, reflects the low solubility of minerals in the enclosing rocks. Saline springs are found in two different geological environments. In the Cordillera they are confined to the Coastal lowlands where the source of salt is probably due to intrusion of sea water into the flow system. Elsewhere saline springs are associated with Palaeozoic carbonate rocks that contain beds of salt and gypsum. The low temperature and high salinity of these springs suggest relatively shallow flow systems through salt-bearing aquifers.

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