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BROMIDE, IODIDE, AND BORON IN ALBERTA FORMATION WATERS

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CONTENTS

FIGURES

TABLES

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ABSTRACT

More than 860 formation waters from Alberta were analyzed for bromide, iodide, and boron. Bromide contents up to 2786 mg/l were found in high calcium and magnesium brines associated with evaporites in the Upper Devonian Beaverhill Lake Formation and Middle Devonian Elk Point Group. The most extensive regions of high-iodide formation waters are in the Cretaceous Viking, Bow Island, and basal Belly River Formations, with iodide contents generally in the range of 40 to 50 mg/l but reported up to 80 mg/l. Isolated occurrences of formation waters with iodide contents in the range of 47 to 59 mg/l were found in the Lower Jurassic Nordegg Member equivalent and Pennsylvanian-Permian strata, and are possibly geochemically and genetically associated with phosphate rocks. Boron contents up to 920 mg/l have been found in Alberta formation waters, possibly the highest concentration in any subsurface water.

INTRODUCTION

Bromide, iodide and boron* are present in essentially all formation waters and are occasionally found in amounts of economic importance. Iodide and, to a lesser extent, bromide have been shown to be petroleum indicators in formation waters from Alberta (Hitchon and Horn, 1974). For these reasons, bromide, iodide, and boron were determined by the authors in a suite of more than 860 formation waters from Alberta; the results are given in the appendix to this publication. This information complements that published by Hitchon and Holter (1971) on calcium and magnesium in Alberta brines, and is part of a continuing study of the economic aspects of formation waters from Alberta. Further, it supplements data used in the discriminant function study of Hitchon and Horn (1974), inasmuch as a portion of the data presented here was used in that statistical study. The chloride contents given in the appendix were determined by the Alberta Energy Resources Conservation Board, and these, together with locations and depths of the samples, may be used to locate the complete analyses in the files of the Board. It is the intention of this report to describe briefly the economically more interesting aspects of bromide, iodide, and boron in Alberta formation waters.

*Bromine and iodine are found in formation waters effectively only as bromide and iodide ions, respectively; boron is found mainly as borates. The two halogens were analyzed in the elemental form; boron was analyzed as a tetraborate complex. For convenience in this report these components of formation waters will be referred to as bromide, iodide and boron.

ACKNOWLEDGMENTS

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ANALYTICAL PROCEDURES

Bromide was determined by the X-ray fluorescence method of Dunton (1968) who concluded that in the concentration range 1 to 1000 ppm this method is as accurate as the most commonly used chemical methods. A similar X-ray fluorescence procedure for the determination of bromide in waters was described by Deutsch (1974). Our working curve was prepared using synthetic standards and formation waters previously analyzed by the Alberta Energy Resources Conservation Board (Table 1) and The Dow Chemical Company (Table 2).

Iodide was determined by the sodium thiosulfate titrimetric method, as modified by D. R. Shaw, Chief Chemist, Alberta Energy Resources Conservation Board, and our results compared favorably with analyzed formation waters supplied by The Dow Chemical Company and the Alberta Energy Resources Conservation Board.

Table 1. Comparison of analyses of bromide in duplicate samples made by the Alberta Energy Resources Conservation Board and the University of Calgary

Sample Number	The Alberta Energy Resources Conservation Board	The University of Calgary (A. A. Levinson)
W5	219	212
W13	296	318
W17	466	508
W20	193	215
W26	20	8
W28	35	5
W30	375	392
W32	820	950
W38	996	955
W45	961	917
W50	1121	1080
W52	13	0
W58	74	85
W66	89	103
W68	81	95
W70	trace	0
W79	459	420
W81	76	100
W85	2	0
W88	trace	0
W90	516	470
W92	267	248

Table 2. Comparison of analyses of bromide in duplicate samples made by The Dow Chemical Company and the University of Calgary

Sample Number	The Dow Chemical Company	The University of Calgary (A. A. Levinson)
DC 633	186	215
DC 628	1112	1155
DC 622	2251	2225

Boron was determined spectrophotometrically using the methylene blue — boron tetrafluoride method which was modified from that described by Pasztor, Bode, and Fernando (1960) and Schleicher and Heck (1970). Specifically, the procedure is:

> From 1 to 10 ml of formation water (which has been diluted 1/10 to 1/20 of the original formation water) is pipetted into a 100 ml polyethylene bottle. Add 10 ml of 2.5 N H_2SO_4 and dilute with distilled water to 20 ml. Add 5 ml of 5 percent HF, and let stand for at least 2 hours. Dilute to 50 ml and add 10 ml of 0.001 M methylene blue. Add 25 ml ethylene dichloride, stopper, and shake vigorously for at least 1 minute. Let the organic layer separate, and from the organic layer pipet 5 ml and transfer to a 25 ml volumetric flask which is made up to 25 ml with ethylene dichloride. Measure the absorbance at 660 mμ (we used a Beckman DU-2 spectrophotometer). A blank was run with each series of analyses. Chlorine, when present in large amounts, has been reported to interfere with this colorimetric procedure; specifically, chlorine will result in apparently higher values for boron. Several experiments were carried out in which we found that because it was necessary to dilute the original formation water to keep the color complex formation within the range of the standard working curve, chlorine did not interfere to any measurable degree.

COMPOSITION OF COMMERCIAL BRINES

Sea water, formation waters, and brines from saline lakes are exploited commercially for a variety of components, including bromine, iodine and boron, at several places throughout the world. Analyses of sea water and some of these commercial brines are shown in table 3.

BROMINE PRODUCTION

All methods of bromine production depend on the oxidation of the bromide ion which is found naturally only in relatively low concentrations in sea water (67 mg/l), formation waters, and brines from saline lakes. In the commercial isolation of bromine from these natural sources, there are four essential steps:

(1) oxidation of bromide to bromine
(2) removal of bromine vapor from the solution
(3) condensation of the vapor or fixation in some chemical form
(4) purification of the product.

Chlorine is the only oxidizing agent employed commercially in step (1) although other agents and techniques have been used in the past. Step (2) involves driving out the bromine vapor with a current of air or steam. Steam is suitable when the raw brine is relatively rich in bromine (1000 mg/l or more), but air is more economical when the bromine is extracted from very dilute solutions, such as sea water. Simple condensation of the vapor yields crude bromine which is subsequently purified. If alkali or alkaline earth bromides or bromates are to be manufactured, step (3) involves reaction of the vapor with the appropriate metal carbonate or hydroxide, followed by suitable purification of the metal salt. Further details of these and other processes related to the recovery of bromine may be found in Downs and Adams (1973).

The United States produces and consumes about three fourths of the world bromine supply, and of this production over three fourths comes from Jurassic Smackover Formation brines in Arkansas, which contain over 5000 mg/l bromide (Table 3). Until this relatively very recent production from Arkansas, effectively the only source of bromine production in the United States was from Midland, Michigan, where the brines contain about 2900 mg/l bromide (Table 3), with only very minor production from the Searles Lake brines as a byproduct of potassium chloride production (Ryan, 1951). Next to the United Kingdom, Israel is now the world's third largest producer of bromine with virtually unlimited resources in the Dead Sea, estimated by Neev and Emery (1967) at 0.694 x 10^9 metric tons. According to Kenat (1966) the brines in the solar evaporation ponds contain about 12,000 mg/l bromide when they are drawn off for bromine production during the carnallite crystallization stage. The United Kingdom, Japan, and Italy continue to produce bromine from sea water, but in France, bromine is recovered as a coproduct at the potash mines in Mulhouse in the Alsace area, although apparently production from these mines is limited by law to prevent excessive damage to the environment (Klingman, 1974). The USSR produces bromine at Nebit-Dag in Turkmenia from formation waters and from the Kara Bogaz. There is no Canadian production of bromine. If the plans reported in financial papers materialize, then Israel would be second only to the United States in world bromine production by the end of this decade, accounting for one sixth of the world production. The significance of this, and the recent preeminence of Arkansas as a source of bromine in the United States, to potential bromine production in Alberta suggests that formation waters should contain at least 3000 mg/l and preferably 5000 mg/l bromide before they can be considered a potential economic source of bromide, all other factors being equal.

IODINE PRODUCTION

Iodine may be recovered by one of several possible processes, including a process resembling that for the recovery of bromine from sea water in which the brine is acidified with sulfuric acid and treated with a slight excess of chlorine to liberate iodine. The liquor is subsequently stripped of its iodine by a current of air which then passes to a tower where the iodine is absorbed by a solution of hydriodic and sulfuric acids into which sulfur dioxide is passed continuously to reduce the iodine to iodide. When sufficiently concentrated, this solution is again chlorinated; the iodine precipitates and is then filtered off. Two alternate recovery processes involve the precipitation of insoluble metal iodides. In one process,

Table 3. Analyses of sea water and commercial brines

Sample Details	Chemical Constituents (mg/l)											
	Na	K	Ca	Mg	Cl	Br	I	B	SO_4	HCO_3	Total Dissolved Solids	Reference
Sea water (standard salinity of 35‰)	10,760	387	413	1,294	19,353	67	0.06	4	2,712	142	35,000	Culkin, 1965 (Table 1)
Midland, Michigan (Lower Devonian Sylvania Sandstone)	22,500	9,120	74,800	9,960	208,000	2,910	40	380	40	**	331,000[1]	White, Hem, and Waring, 1963 (Table 13, No. 8)
Columbia County, Arkansas (Jurassic Smackover Formation)	70,850	6,380	44,851	3,841	210,715	5,249	10	288	174	191	346,139[2]	A. G. Collins (pers. comm.)
Searles Lake, California	111,000	23,900	*	*	117,000	704	27	3,420	37,800	**	330,000[3]	Y. K. Kharaka (pers. comm.)
Dead Sea, Israel	39,150	7,260	16,860	40,650	212,400	5,120	< 1	~ 20	470	220	322,130	Neev and Emery, 1967 (Tables 6 and 9)
Japan	9,800	337	141	399	16,450	96	95	13	0	920	28,446[4]	Marsden and Kawai, 1965 (Table 11)
Woodward County, Oklahoma (Pennsylvanian Morrow Formation)	7,210	37	649	5	16,563	438	696	31	938	334	27,313[5]	A. G. Collins (pers. comm.)

* below detection limits

** no data available

1 includes Sr 2,650; NH_4 506; Li 70; Fe 22; Mn 2.

2 includes Sr 2,470; NH_4 170; Li 391; Ba 20; Mn 46; Fe 10; Zn 2; Cu 1.

3 includes CO_3 32,300; SiO_2 85; As 102; F 23; PO_4 536.

4 includes NH_4 195.

5 includes NH_4 36; Sr 27; Li 1.

a silver nitrate solution is added in sufficient quantity to precipitate only silver iodide, which is filtered off and treated with clean steel scrap to form metallic silver and a solution of ferrous iodide. The former is processed for recycling and the ferrous iodide solution is treated with chlorine to liberate the iodine. In another process, the brine is treated with chlorine gas to liberate free iodine and is then passed over bales of copper wire with which the iodine reacts to form insoluble cuprous iodide, which is filtered, dried, and stored or transported as such. Recently developed ion-exchange techniques have been reported to give a new, more economical extraction process for producing iodine of exceptionally high purity. The process used by the Chilean nitrate industry differs from all other processes because the iodine occurs as an iodate in caliche. Downs and Adams (1973) provide more details of these and other processes related to the recovery of iodine.

Commercial iodine sources include caliche deposits in Chile (for many years the world's major source of iodine), formation waters associated with shallow gas deposits, and deep saline formation waters. The very low content of iodine in sea water has so far generally precluded its use as a commercial source, although there is an unconfirmed report (Wang, 1974) that iodine has been produced at the Haifang seawater salt processing plant in Amoy, Fukieh Province, People's Republic of China. Prior to 1964, The Dow Chemical Company extracted iodine from California oilfield brines with iodine contents reported at 60 to 70 mg/l (Anonymous, 1964). Since 1964, The Dow Chemical Company has recovered iodine from formation brines at Midland, Michigan, using improved technology so that the process is economic at an iodide content of 40 mg/l (Table 3). The Midland brines also offer an advantage in that they are free of oil, and the crude iodine is recovered as a coproduct with bromine, calcium and magnesium compounds, and potash. This operation will shortly cease to be the only iodine producer in the United States. Although the United States continues to import much of its iodine supply, formerly mainly from Chile but more recently almost solely from Japan, plans call for an iodine extraction plant at Woodward, Oklahoma, which will recover iodine from formation waters at a rate sufficient to supply about one quarter of the United States' consumption within one year; other plants in Oklahoma may follow. No analyses of formation water feedstocks from Oklahoma have been published but Collins and Egleson (1967) and Collins (1969) have reported iodide contents up to 1400 mg/l in comparable Oklahoma formation waters. Collins, Bennett, and Manuel (1971) have demonstrated an association between these high-iodide brines and the presence of algae in adjacent sedimentary rocks. There is no Canadian production of iodine.

Japan has been the world's primary producer of iodine since the late 1960's, with production coming from brackish formation waters associated with shallow gas deposits and with iodide contents reported in the range 80 to 100 mg/l. Many of the gas fields are of the "suiyōsei-ten'nengasu" type, which translates as "natural gas which is dissolved in formation water" (Marsden and Kawai, 1965). An analysis of the brackish formation water from the important Mobara gas field is given in table 3. The close genetic relation between iodine and natural gas has been observed by several authors who have studied these Japanese occurrences, and Motojima (1963, 1964) has evaluated the various geochemical criteria for prospecting for these gas fields, and for their related iodine resources (Motojima, 1971). Plans have been made for the development, by joint Japanese-Indonesian interests, of comparable brackish waters in Indonesia with iodide contents of more than 70 mg/l. In the USSR, iodine apparently is produced at the Neftechlinski field near the Black Sea and at a plant in the Baku area (Wang, 1974), as well as at Kopet-Dag in Turkmenia, where Kudel'skii (1970) has reported iodide contents of up to 462 mg/l. With respect to potential iodide resources in Alberta, it seems likely that formation waters with iodide contents greater than 40 mg/l may be of interest.

BORON PRODUCTION

Unlike bromide and iodide, which are effectively only recovered from aqueous solutions, boron is principally mined from deposits of borax ($Na_2B_4O_7.10H_2O$), kernite ($Na_2B_4O_7.4H_2O$), or colemanite ($Ca_2B_6O_{11}.5H_2O$). However, at Searles Lake, San Bernardino County, California, a brine in equilibrium with shallow deposits of trona ($Na_3H(CO_3)_2.2H_2O$) is extracted for processing of the dissolved salts, including borates. Evaporation of the brine results in the precipitation of sodium chloride and burkeite ($Na_6(CO_3)(SO_4)_2$), whereby the liquor becomes increasingly concentrated with respect to potassium chloride and sodium tetraborate. Following crystallization of potassium chloride by cooling to 100° F, and its subsequent removal through settling and filtration, the liquor is further cooled to about 80° F at which temperature crude borax is precipitated and thickened. The crude borax filter cake is brine-leached to remove soluble phosphate impurities and then recrystallized and refined. Ryan (1951) provides more details of the entire operation at Searles Lake. Because of the abundance of mineable borax deposits and the fact that boron is only recovered as a by-product of processing the Searles Lake brine, it seems highly unlikely that any formation water with less than several thousand mg/l boron could be considered a potential source of this element.

BROMIDE IN ALBERTA FORMATION WATERS

Bromide contents greater than 1000 mg/l are found only in formation waters from the Upper Devonian Winterburn Group, Woodbend Group, and Beaverhill Lake Formation; the Middle Devonian Elk Point Group; and the Granite Wash. The computer-contoured maps in figures 1 to 4 show the distribution of bromide in formation waters from the four

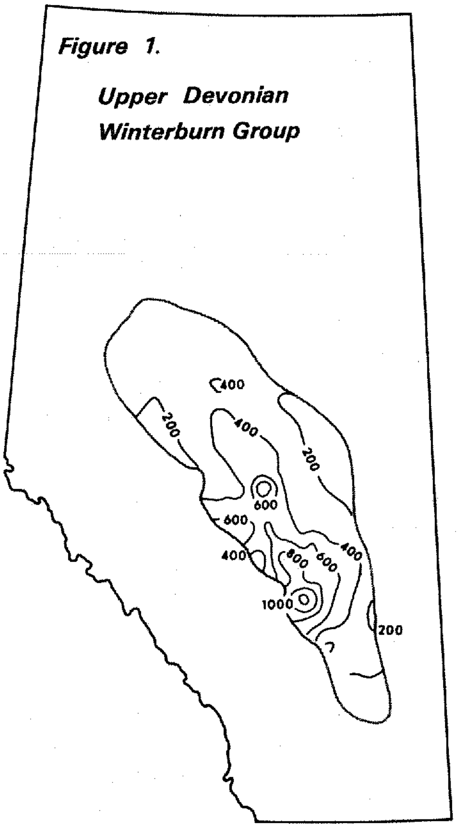

Figure 1.
Upper Devonian Winterburn Group

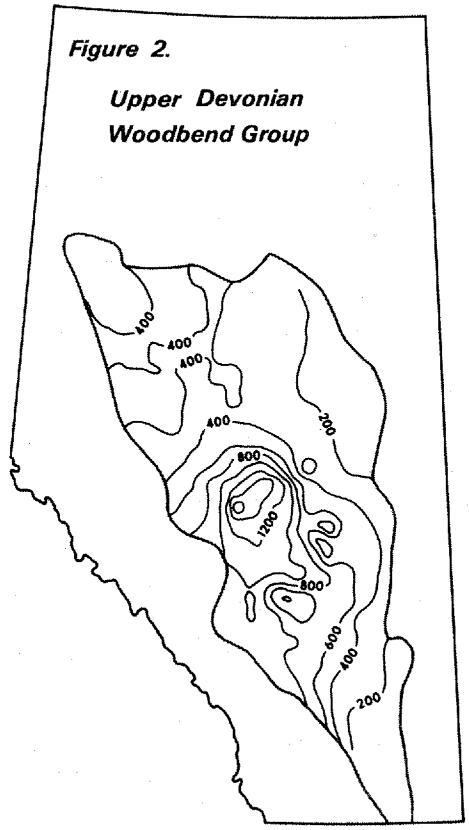

Figure 2.
Upper Devonian Woodbend Group

Bromide (mg/l) in formation waters, Alberta

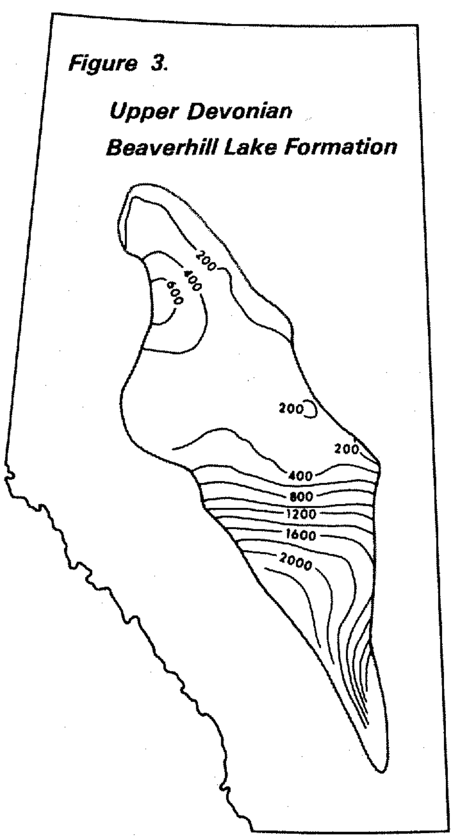

Figure 3.
Upper Devonian Beaverhill Lake Formation

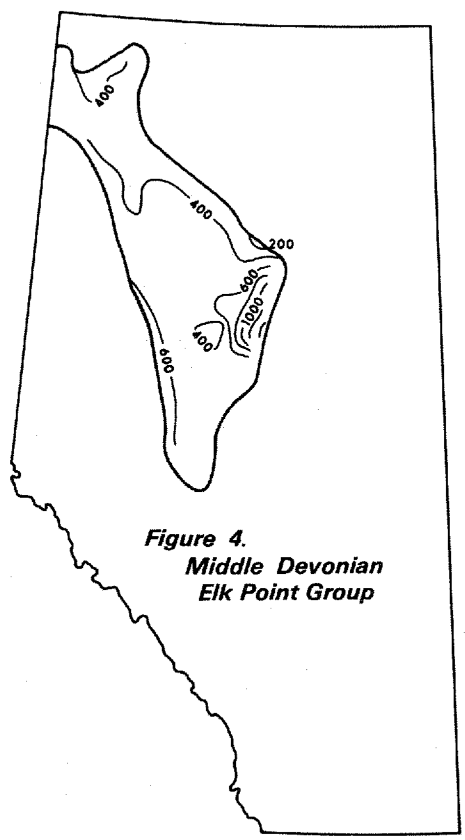

Figure 4.
Middle Devonian Elk Point Group

cited Devonian stratigraphic units, respectively. The computer data bank includes information from Shaw (1962), Hitchon, Billings and Klovan (1971), Hitchon and Holter (1971), Hitchon and Horn (1974), the files of the Alberta Energy Resources Conservation Board, the appendix of this report, and unpublished analyses in the files of the senior author. All formation waters from producing oil and gas fields have bromide contents less than 1500 mg/l. The highest recorded amount is 2786 mg/l from a wildcat well in the Beaverhill Lake Formation of southern Alberta. These observations suggest that formation waters with high bromide contents from so-called dry holes may have the greatest potential for the production of bromide. They have the further economic and technical advantage of not requiring the clean-up of the coproduced formation water from entrained crude oil. Table 4 provides details of formation waters with 1250 mg/l or more bromide from wildcat wells in Alberta. The information in the maps, table 4, and the computer data bank, indicates three areas of interest. The most important is the Beaverhill Lake Formation of southern Alberta with formation waters from four locations having bromide contents greater than 1500 mg/l. This is approximately the same region which has formation waters with high contents of calcium and magnesium (Hitchon and Holter, 1971). Absence of iodide from some of these high-bromide samples suggests a genetic geochemical association with the evaporites which are present within the Beaverhill Lake Formation of southern Alberta and in nearby underlying Middle Devonian Elk Point Group rocks. A second area of interest comprises a small, isolated portion of the Cooking Lake Formation carbonate platform in central Alberta, south of Edmonton and east of the Homeglen-Rimbey reef trend of the Leduc Formation, where the formation waters contain up to 1650 mg/l bromide. The third region of interest is the Keg River Formation of north central Alberta which is only sparsely drilled and for which only one high bromide formation water is available. However, the association of high calcium and magnesium brines (Hitchon and Holter, 1971) and evaporites in the area make it worthy of exploration for high bromide formation waters.

From the previous comments on commercial brines, it is clear that no Alberta formation water contains as much bromide as the Midland, Michigan brines, and all are far below the 5000 mg/l of the now dominant sources in Arkansas and the Dead Sea. On this basis alone it seems highly unlikely that any of the Alberta formation waters discovered so far would be an economic source of bromide. This conclusion should not preclude analyzing all formation waters for bromide and iodide, especially those recovered from areas that may contain potentially valuable brines.

Table 4. Formation waters from Alberta wildcat wells with 1250 mg/l or more bromide

	Location								
Lsd	Sec	Tp	R	Mer	Depth (ft)	Sampling Conditions	Stratigraphic Unit	Br (mg/l)	I (mg/l)
10	21	13	11	W4	5205-5225	Drillstem Test: 350 ft sw	Beaverhill Lake Formation	2786	0
4	17	30	20	W4	6960-7070	Drillstem Test: 860 ft sw	Beaverhill Lake Formation	2115	27
4	34	37	26	W4	7405-7462	Drillstem Test: 2500 ft sw	Leduc Formation	2115	2
11	7	36	23	W4	7650-7700	Drillstem Test: 4450 ft sw	Beaverhill Lake Formation	1900	0
13	16	50	24	W4	5620-5650	Drillstem Test: 670 ft sw	Cooking Lake Formation	1650	31
15	16	44	13	W4	4272-4316	Drillstem Test: 125 ft sw, 122 ft mud	Beaverhill Lake Formation	1590	25
4	3	88	25	W4	4278-4316	Drillstem Test: 3620 ft sw	Keg River Formation	1475	18
7	30	50	22	W4	5408-5431	Drillstem Test: 1260 ft gsw	Cooking Lake Formation	1470	34
12	14	12	12	W4	5120-5202	Drillstem Test: 518 ft sw	Beaverhill Lake Formation	1375	0
13	30	48	22	W4	5610-5650	Drillstem Test: 60 ft sw, 150 ft mud	Cooking Lake Formation	1250	21

IODIDE IN ALBERTA FORMATION WATERS

There is an ill-defined stratigraphic dichotomy between those formation waters with economically interesting bromide contents and other formation waters with potentially productive iodide concentrations. As noted previously, the former are confined to Devonian and Granite Wash strata. If we arbitrarily define the latter as formation waters with iodide contents 40 mg/l, the same concentration as the Michigan brines (Table 3), then formation waters with potentially productive iodide concentrations are effectively found only in Lower Cretaceous lower Colorado Group (Viking and Bow Island Formations) and Upper Cretaceous post-Colorado Supergroup (basal Belly River Formation) strata. Isolated examples of formation waters with more than 40 mg/l iodide are recorded from four stratigraphic units — Upper Cretaceous Medicine Hat Sandstone, Lower Jurassic Nordegg Member equivalent, Pennsylvanian-Permian strata, and Upper Devonian Slave Point Formation. Table 5 provides details of formation waters with 40 mg/l or more iodide and has been compiled using data from Shaw (1962), Hitchon and Horn (1974), the files of the Alberta Energy Resources Conservation Board, the appendix of this report, and unpublished analyses in the files of the senior author.

The map in figure 5 shows the distribution of iodide in formation waters from the Viking and Bow Island Formations. In four regions the formation waters contain more than 40 mg/l iodide, although subsequent data may show the two northern regions to be contiguous. Contents range up to 80 mg/l, though most are in the order of 40 to 50 mg/l. Many of the formation water samples are from drillstem tests, with all the uncertainties to which that method of sampling is prone, but nevertheless a sufficient number are from producing wells, so there can be little doubt about the broad regional pattern. The northwest orientation of some of the potentially productive iodide regions is probably related to the depositional environment of the Viking and Bow Island Formations as reflected in the total sandstone isoliths (Rudkin, 1964), an observation which may be of interest in subsequent exploration for economic iodide concentrations.

Iodide contents up to 54 mg/l have been found in formation waters from sandstones near the base of the Belly River Formation, with most samples from the Pembina field. Figure 6 shows the regional variations in the iodide concentration of formation waters from this stratigraphic unit. In addition, formation waters in the basal sandstones are distinguished from those elsewhere in the formation because of an incompletely confirmed tendency for higher iodide contents to occur in the formation waters from the basal sandstones. Paucity of data precludes the determination of a relation between high-iodide trends and lithology, such as was tentatively cited for the Viking and Bow Island Formations.

Isolated examples of formation waters with more than 40 mg/l iodide have been discovered in the Permian Belloy Formation and the subjacent Pennsylvanian Kiskatinaw Formation, in adjacent townships close to the border between Alberta and British Columbia. Details of the samples are provided in table 5 and their location with respect to the regional variations in iodide content of formation waters from Pennsylvanian-Permian strata is shown in figure 7. Study of the relations between the iodide content of formation waters from Pennsylvanian-Permian strata and those of the overlying Triassic and underlying Mississippian rocks reveals generally higher contents of iodide in the former compared to the latter, for any given salinity. These relations are illustrated in figure 8. Goldschmidt (1954) has observed that marine phosphate sediments contain surprisingly large amounts of iodine, and thus the presence of phosphates in Permian rocks and their absence from Triassic and Mississippian strata may explain the relations shown in figure 8. In this regard, it is interesting to observe that the single sample of formation water with a high iodide content from the Lower Jurassic is from the Nordegg Member equivalent. According to Springer, MacDonald, and Crockford (1964), the lithology of Sinemurian rocks, of which the Nordegg Member forms a distinct facies, changes from region to region and consists of phosphatic shale, coquina and conglomerate, or an impure, cherty, phosphatic limestone known as the Nordegg Member. The iodine-rich single sample is from thick shales equivalent to the Nordegg Member. Any search for high-iodide formation waters in Lower Jurassic or Pennsylvanian-Permian rocks should be cognizant of the geochemical relation between iodine and phosphate.

Two other stratigraphic units have yielded formation waters with iodide contents of 40 mg/l or more. They are an isolated sample from the Medicine Hat Sandstone in the Medicine Hat field and two samples from the Slave Point and Beaverhill Lake Formations in the Swan Hills reef trend, which have iodide contents of 41 and 40 mg/l respectively, in a region in which the iodide content of adjacent oil field and gas field waters is in the range 18 to 39 mg/l.

To summarize the occurrence of economically interesting high-iodide formation waters in Alberta: the most extensive regions are in the Viking, Bow Island, and basal Belly River Formations with iodide contents generally in the range 40 to 50 mg/l. Isolated occurrences of formation waters with iodide contents in the range 47 to 59 mg/l are found in the Lower Jurassic Nordegg Member equivalent and Pennsylvanian-Permian strata, and are possibly geochemically and genetically associated with the presence of phosphate rocks. The only other potentially interesting sample is an isolated example from the Medicine Hat Sandstone. The obviously wide diversity of occurrence of iodide-rich formation waters and paucity of data in certain regions suggests that a special exploratory effort should be made to determine the source and regional limits of these iodide occurrences in Alberta.

Table 5. Formation waters from Alberta with 40 mg/l or more iodide

Lsd	Location Sec	Tp	R	Mer	Depth (ft)	Sampling Conditions	Stratigraphic Unit	I (mg/l)	Br (mg/l)
10	33	10	18	W4	2517-2542	Drillstem Test: 1910 ft sw, 60 ft mud	Bow Island Formation	80	122
11	14	12	2	W4	1516-1536	Gas well	Medicine Hat Sandstone	62	87
10	21	74	18	W5	3164-3180	Drillstem Test: 435 ft sw, 100 ft mud	Nordegg Member Equivalent	59	14
-	-	48	3/4	W5	3206-3326	Oilfield battery	Basal Belly River Formation	54	139
6	19	40	16	W4	1490-1576	Drillstem Test: 1076 ft sw	Basal Belly River Formation	53	105
8	2	11	17	W4	2210-2314	Drillstem Test: 1600 ft sw	Bow Island Formation	53	88
7	20	23	18	W4	3404-3423	Gas well	Viking Formation	51	117
11	5	40	19	W4	3873-3933	Drillstem Test: 900 ft sw, 20 ft mud	Viking Formation	49	235
4	7	42	22	W4	4197-4244	Drillstem Test: 1680 ft sw	Viking Formation	49	206
10	14	29	20	W4	3549-3595	Drillstem Test: 1960 ft sw	Viking Formation	49	180
14	35	47	3	W5	3309-3317	Oil well	Basal Belly River Formation	49	143
11	10	80	12	W6	7914-7935	Drillstem Test: 874 ft sw, 92 ft mud	Kiskatinaw Formation	47	166
10	13	81	13	W6	6500-6590	Drillstem Test: 4700 ft sw	Belloy Formation	47	160
6	5	27	7	W4	3436-3448	Drillstem Test: 2665 ft sw	Viking Formation	47	113
10	23	35	12	W4	3035-3135	Drillstem Test: 1620 ft sw, 90 ft mud	Viking Formation	47	81
1	12	52	27	W4	3590-3605	Drillstem Test: 2295 ft sw, 30 ft mud	Viking Formation	46	310
7	18	41	23	W4	4401-4419	Drillstem Test: 180 ft oc sw, 100 ft mud	Viking Formation	46	230
10	8	20	14	W4	2837-2870	Drillstem Test: 1750 ft sw	Bow Island Formation	46	205
11	4	23	14	W4	2553-2600	Drillstem Test: 210 ft sw, 60 ft mud	Bow Island Formation	46	170
14	5	49	22	W4	3425-3445	Drillstem Test: 1765 ft sw	Viking Formation	45	290

Table 5. (continued)

Location					Depth			I	Br
Lsd	Sec	Tp	R	Mer	(ft)	Sampling Conditions	Stratigraphic Unit	(mg/l)	(mg/l)
7	34	41	19	W4	3500-3550	Drillstem Test: 900 ft sw, 80 ft mud	Viking Formation	45	260
11	3	20	16	W4	3032-3040	Drillstem Test: 420 ft sw, 60 ft mud	Bow Island Formation	45	203
10	12	25	23	W4	4201-4226	Drillstem Test: 270 ft sl m sw, 180 ft mud	Viking Formation	45	150
6/3	30	48	6	W5	3608-3742	Oilfield battery	Basal Belly River Formation	44	160
6	9	48	2	W5	2990-3021	Drillstem Test: 600 ft sl m sw	Basal Belly River Formation	44	100
-	7/18	35	9	W4	2900-3000	Oilfield battery	Viking Formation	44	90
13	16	50	24	W4	3350-3385	Drillstem Test: 1375 ft sw, 186 ft gc sw, 465 ft gc mud	Viking Formation	43	350
4	25	48	5	W5	3170-3176	Oil well	Basal Belly River Formation	43	95
10	11	46	25	W4	4083-4163	Drillstem Test: 2300 ft sw, 300 ft mud	Viking Formation	42	179
14	21	48	2	W5	2908-2925	Drillstem Test: 180 ft sw, 230 ft o mud	Basal Belly River Formation	42	105
4	2	63	10	W5	8119-8205	Drillstem Test: 2100 ft gc sw, 110 ft oc sw, 300 ft frothy oc mud	Slave Point Formation	41	365
7	18	43	20	W4	3525-3536	Drillstem Test	Viking Formation	41	224
7	14	27	21	W4	3920-3950	Drillstem Test: 780 ft sw	Viking Formation	41	180
10	27	19	16	W4	2800-2815	Drillstem Test: 300 ft mud	Bow Island Formation	41	160
-	-	47	4	W5	-	Oilfield battery	Basal Belly River Formation	41	106
4	30	65	13	W5	9372-9379	Oil well	Beaverhill Lake Formation	40	291
16	14	48	3	W5	3046-3075	Oil well	Basal Belly River Formation	40	104
-	7/18	48	2	W5	-	Oilfield battery	Basal Belly River Formation	40	89
6	30	10	17	W4	2384-2422	Drillstem Test: 535 ft mc sw, 100 ft mud	Bow Island Formation	40	80
-	-	56	25	W4	avg. 2822	Oilfield battery	Viking Formation	40	60

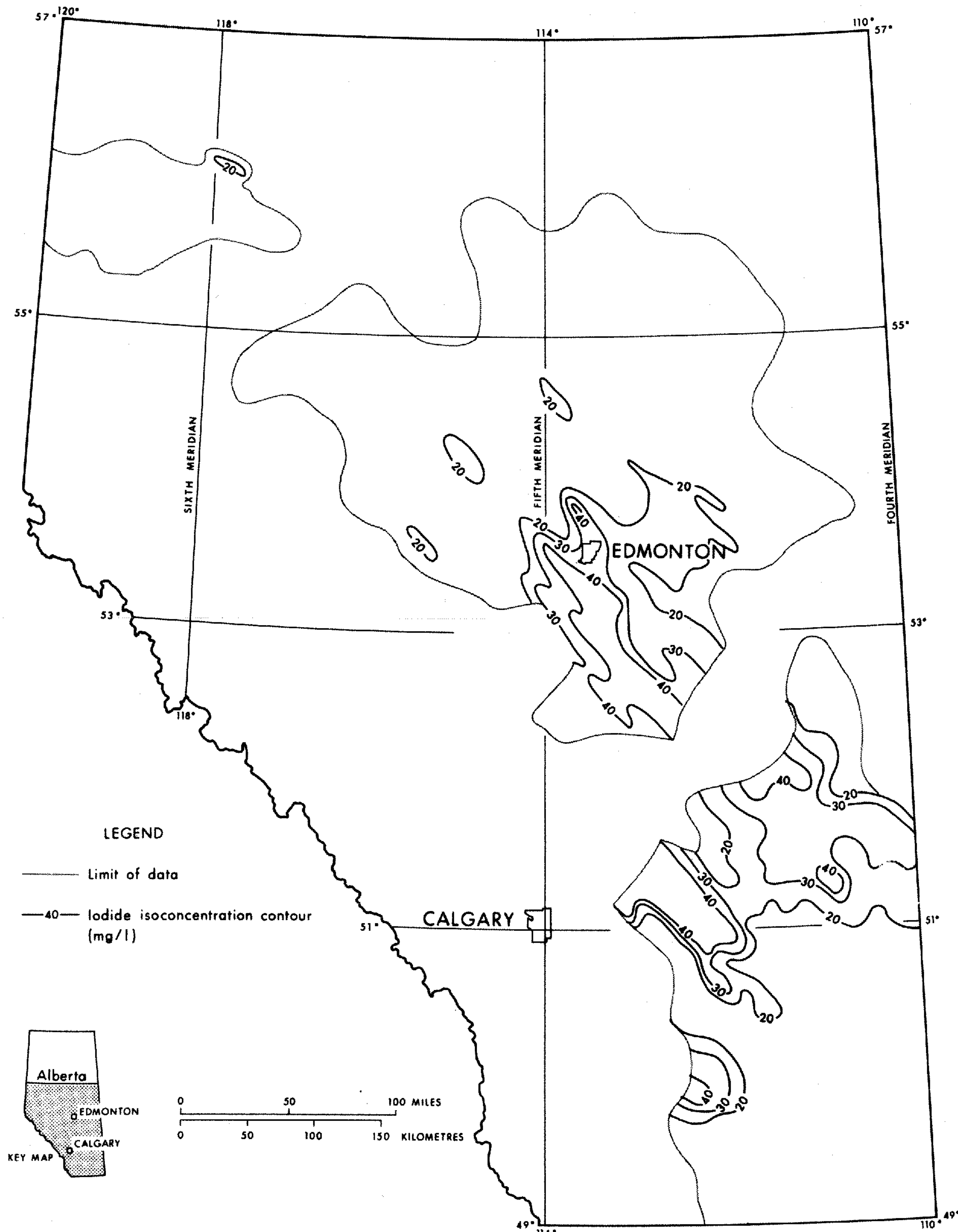

Figure 5. Iodide (mg/l) in formation waters, Lower Cretaceous lower Colorado Group, Viking and Bow Island Formations, Alberta

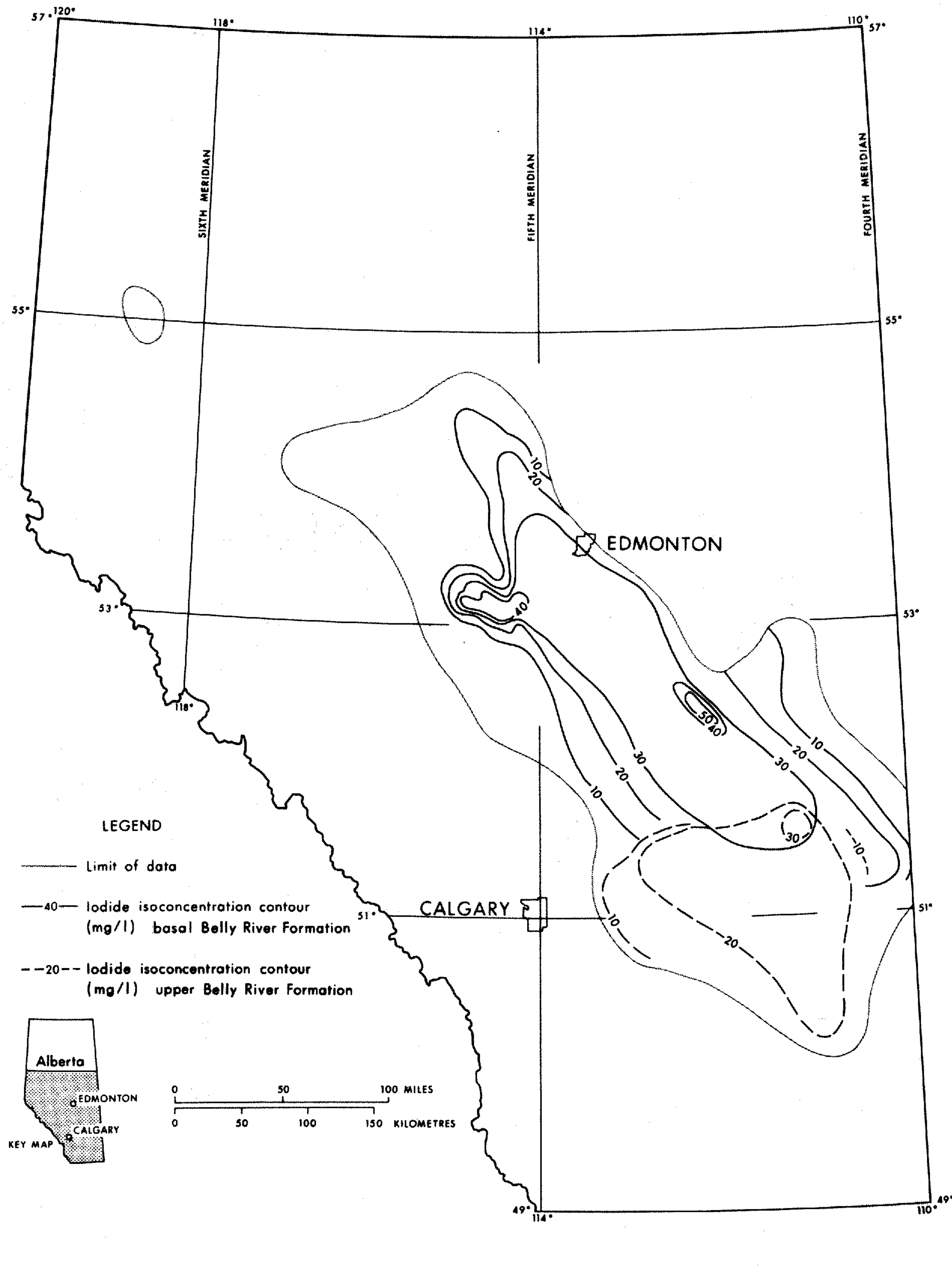

Figure 6. Iodide (mg/l) in formation waters, Upper Cretaceous post-Colorado Supergroup, Belly River Formation, Alberta

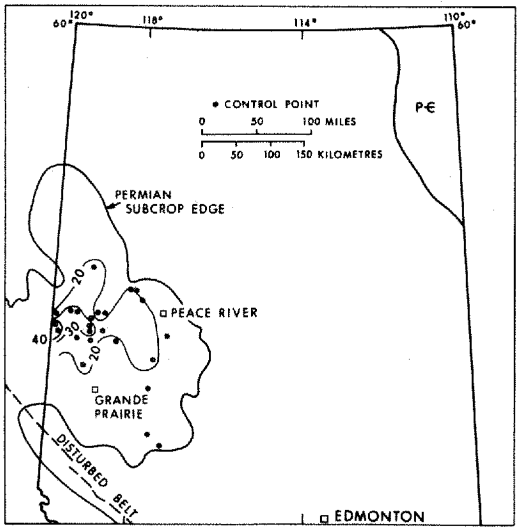

Figure 7. Iodide (mg/l) in formation waters, Pennsylvanian-Permian strata, Alberta

BORON IN ALBERTA FORMATION WATERS

The only published data on boron in Alberta formation waters are Hitchon, Billings and Klovan (1971) and the appendix of this report. Contents of boron range up to 86 mg/l and average 15.7 mg/l in formation waters from Mesozoic strata. In formation waters from Paleozoic strata the average content of boron is 101 mg/l with one sample from the Upper Devonian Beaverhill Lake Formation of north central Alberta containing 920 mg/l. A thorough, but by no means exhaustive, survey of the literature shows this latter value to be the maximum boron reported in a formation water (Hitchon, in press). All these boron concentrations are definitely not commercial at this time, nor is it very likely that commercial concentrations will be found. Nevertheless, the boron values cited in the appendix of this report may be of interest to those seeking to use boron as an indirect petroleum indicator, as suggested by several authors including Sivan (1972) and Gutsalo (1974). However, it is our opinion that until a statistical study is available on the importance of boron as a petroleum indicator, such as was reported for Alberta by Hitchon and Horn (1974), the merits of using boron as a petroleum indicator must remain equivocal.

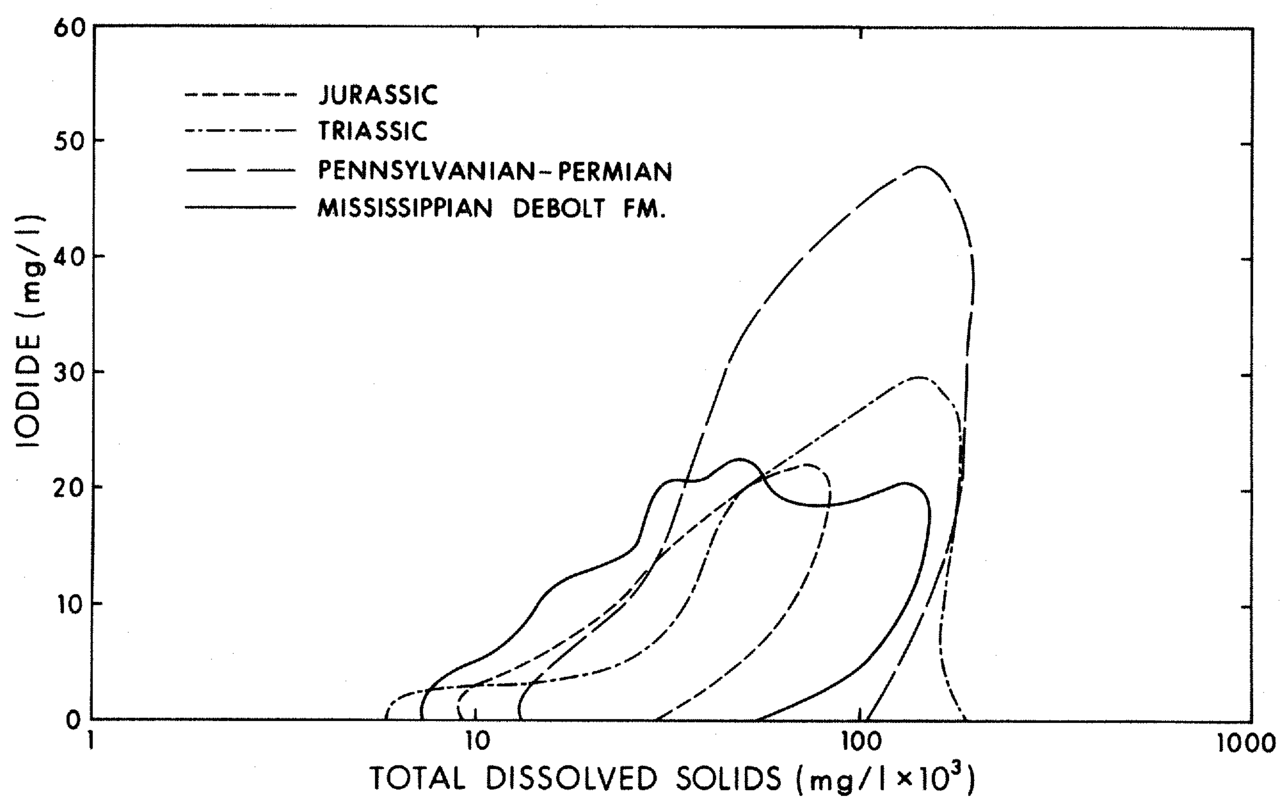

Figure 8. Scatter diagram of iodide and total dissolved solids in formation waters from Jurassic, Triassic, Pennsylvanian-Permian and Mississippian strata, northwestern Alberta

CONCLUSIONS

(1) Bromide contents up to 2786 mg/l have been reported in high calcium and magnesium brines of Alberta associated with evaporites in the Upper Devonian Beaverhill Lake Formation and the Middle Devonian Elk Point Group. This concentration is close to that at Midland, Michigan, but below the 5000 mg/l for the now dominant commercial sources in Arkansas and the Dead Sea. It seems highly unlikely that Alberta formation waters will be discovered which would be a separate economic source of bromide, although the recovery of bromide together with, say, calcium and magnesium, might prove economically viable.

(2) Iodide contents up to 80 mg/l have been reported in Alberta formation waters. The most extensive regions of high-iodide formation waters are in the Cretaceous Viking, Bow Island, and basal Belly River Formations with iodide contents generally in the range 40 to 50 mg/l. Isolated occurrences of formation waters with iodide contents in the range 47 to 59 mg/l are found in the Lower Jurassic Nordegg Member equivalent and Pennsylvanian-Permian strata, and are possibly geochemically and genetically associated with the presence of phosphate rocks. These concentrations are greater than that at Midland, Michigan, but less than Japanese and Oklahoma iodide resources. It seems likely that Alberta formation waters with iodide contents greater than 40 mg/l may be of economic interest.

(3) Boron contents up to 920 mg/l have been reported in Alberta formation waters but no commercial exploitation is likely at this time in view of other major world sources of boron.

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Appendix

BROMIDE, IODIDE AND BORON CONTENTS OF FORMATION WATER SAMPLES

Upper Cretaceous, Post-Colorado Supergroup

Location	Interval	Cl	Br	I	B
10 12 10 11 W.4	786- 830	550	0	3	
8 10 11 13 W.4	600- 700	1199	0	1	7
6 25 13 17 W.4	940- 941	4188	70	32	4
7 15 22 7 W.4	508- 518	2765	35	21	3
7 15 22 7 W.4	600- 635	3154	65	20	
12 19 22 22 W.4	1602- 1603	1706	15	15	
7 23 27 21 W.4	1020- 1240	3264	40	21	3
10 19 29 4 W.4	820- 870	458	0	3	4
11 23 40 15 W.4	1000- 1120	6363	50	26	
6 19 40 16 W.4	1490- 1576	8142	105	53	5
4 21 47 26 W.4	2512- 2660	5281	105	39	7
14 5 49 22 W.4	1760- 1800	8253	90	35	5
16 32 41 6 W.5	4498- 4503	1731	11	2	2
8 6 42 5 W.5	4629- 4632	11855	80	9	6
6 30 47 1 W.5	2934- 3014	3891	65	20	
6 9 48 2 W.5	2990- 3021	4692	100	44	
14 21 48 2 W.5	2908- 2925	6395	105	42	
10 27 48 2 W.5	2875- 2895	5965	100	39	6
16 6 48 4 W.5	3102- 3128	5258	80	20	
4 30 48 4 W.5	3187- 3224	5848	90	32	
33 48 7 W.5	1000- 2280	24	0	0	4
14 15 49 7 W.5	3298- 3305	4319	55	22	
9 35 50 9 W.5	3072- 3095	1537	0	3	5

Upper Cretaceous, Upper Colorado Group

Location	Interval	Cl	Br	I	B
11 14 12 2 W.4	1516- 1536	7401	95	59	6
4 18 65 23 W.5	3897- 3935	4511	110	30	12
13 12 78 13 W.6	1400- 1435	907	0	5	2
10 9 75 8 W.6	2360- 2430	2098	35	7	4

Lower Cretaceous, Lower Colorado Group

Location	Interval	Cl	Br	I	B
4 7 1 5 W.4	2432- 2462	1036	0	1	
4 7 1 5 W.4	2795- 2863	1962	0	1	
6 35 1 7 W.4	2451- 2453	994	2	2	5
1 6 1 9 W.4	2234- 2457	948	9	4	2
10 9 1 10 W.4	2131- 2148	1909	0	1	
10 13 1 13 W.4	1910- 1931	557	0	1	6
6 18 1 13 W.4	1422- 1430	164	0	1	
10 12 1 14 W.4	1365- 1423	2430	0	1	
11 21 2 9 W.4	1963- 1973	227	0	1	
11 7 3 7 W.4	2165- 2169	844	6	1	4
6 1 3 9 W.4	1911- 1926	1023	0	2	5
7 30 3 9 W.4	2187- 2214	2335	5	4	
10 21 4 6 W.4	2333- 2360	1963	0	4	
3 17 5 5 W.4	2520- 2523	1897	35	17	7
7 6 5 8 W.4	2235- 2284	1352	0	2	
10 9 6 8 W.4	2232- 2266	2608	15	5	6
11 32 6 9 W.4	2320- 2350	1439		1	
11 6 6 11 W.4	2074- 2092	1493	15	14	6
7 21 6 12 W.4	2264- 2275	1202	0	1	
7 21 6 12 W.4	2264- 2275	1227	0	1	
10 25 6 12 W.4	2040- 2055	1816	15	4	
10 25 6 12 W.4	2042- 2086	1791	20	9	
10 32 7 15 W.4	2580- 2794	11266	130	8	
10 16 7 16 W.4	2550- 2590	1938	100	9	
10 12 10 11 W.4	2250- 2300	2705	15	5	

Lower Cretaceous, Lower Colorado Group
(cont.)

Location	Interval	Cl	Br	I	B
10 11 11 14 W.4	2120- 2325	3112	15	6	5
10 18 12 10 W.4	2105- 2175	3750	30	13	
6 25 13 17 W.4	2520- 2521	9440	110	36	
4 30 14 13 W.4	2452- 2473	4592	45	7	
10 25 14 14 W.4	2280- 2300	5331	95	20	
10 1 15 18 W.4	2823- 2840	9285	100	22	
10 2 16 13 W.4	2323- 2350	4733	105	19	
6 20 16 19 W.4	3328- 3338	13613	105	12	
6 20 16 19 W.4	3328- 3338	13348	105	11	
10 9 17 13 W.4	2688- 2713	11448	160	20	
2 14 19 14 W.4	2754- 2774	12262	135	22	
10 25 19 14 W.4	2872- 2902	12898	95	10	
10 25 19 14 W.4	2872- 2902	15766	120	12	
10 27 19 14 W.4	2750- 2776	12105	135	28	
6 14 19 16 W.4	2806- 2831	10684	100	30	
10 27 19 16 W.4	2800- 2817	11649	160	41	
10 29 20 13 W.4	2572- 2590	17293	240	1	
10 8 20 14 W.4	2837- 2870	14489	205	46	
11 3 20 16 W.4	3032- 3040	14918	203	45	
11 32 20 16 W.4	2888- 3060	12999	105	4	
6 14 21 2 W.4	2403- 2523	5663	60	17	13
10 10 21 8 W.4	2520- 2590	5121	55	13	
4 20 21 9 W.4	2835- 2858	10386	75	5	
10 25 21 10 W.4	2890- 2927	15035	125	2	
11 27 21 13 W.4	2818- 2819	18833	145	15	
7 13 22 8 W.4	2480- 2521	4782	60	15	
7 15 22 8 W.4	2563- 2593	5073	50	16	
7 15 22 8 W.4	2838- 2878	5962	45	9	12
7 15 22 8 W.4	2612- 2617	4843	45	15	15
11 8 22 11 W.4	2771- 2810	17325	190	15	
11 4 23 14 W.4	2605- 2611	12991	155	30	
11 4 23 14 W.4	2553- 2600	12454	170	46	
10 6 24 12 W.4	2945- 2955	14488	120	18	11
6 15 25 5 W.4	2680- 2740	8439	115	28	
10 4 25 11 W.4	2795- 2815	9185	85	30	
16 23 25 12 W.4	3042- 3066	10543	190	21	
10 12 25 23 W.4	4201- 4226	7157	150	45	10
10 3 26 3 W.4	2419- 2427	8419	85	20	
11 21 26 3 W.4	2449- 2457	9195	115	22	
6 32 26 3 W.4	2468- 2478	9245	110	25	
11 15 26 6 W.4	2629- 2640	11102	115	31	
6 22 26 11 W.4	2813- 2891	8015	90	23	
11 24 26 11 W.4	2740- 2770	7329	75	17	
11 24 26 11 W.4	2740- 2770	9796	115	26	
10 7 26 14 W.4	3030- 3088	12125	90	23	
6 9 26 14 W.4	3014- 3069	12327	135	28	
6 9 26 14 W.4	3274- 3291	12401	140	17	
10 16 26 14 W.4	3236- 3256	12538		15	
11 18 27 3 W.4	2500- 2513	9555	85	15	
11 4 27 4 W.4	2462- 2485	10192	140	29	
6 22 27 13 W.4	3100- 3130	8416	110	27	
6 22 27 13 W.4	3110- 3140	8413	80	22	
6 15 27 15 W.4	3525- 3555	13173	110	13	
10 1 27 21 W.4	4150- 4180	5997	135	33	
10 12 27 21 W.4	4045- 4075	6800	145	33	
7 14 27 21 W.4	3920- 3950	6412	180	41	
10 5 28 5 W.4	2615- 2680	11520	100	29	12
10 27 28 7 W.4	2670- 2697	10570	125	30	
6 34 28 9 W.4	2852- 2877	9596	130	35	
6 31 29 4 W.4	2525- 2533	9016	175		
10 14 29 20 W.4	3549- 3600	7730	180	49	11
11 5 40 19 W.4	3873- 3933	19711	235	49	
7 34 41 19 W.4	3500- 3550	22361	260	45	
7 18 41 23 W.4	4401- 4419	21984	230	46	
11 25 42 19 W.4	3158- 3200	12408	150	35	

Lower Cretaceous, Lower Colorado Group (cont.)

Location	Interval	Cl	Br	I	B
7 31 44 17 W.4	2930- 2946	34221	280	28	
7 31 44 17 W.4	2887- 2915	36078	340	34	12
6 17 45 19 W.4	3135- 3170	42180	320	30	
7 12 45 20 W.4	3200- 3284	43552	330	28	
14 11 46 20 W.4	3231- 3234	39732	335	32	
9 15 46 20 W.4	3245- 3248	38592	300	32	
4 23 46 20 W.4	3251- 3255	36315	300	27	
10 2 47 20 W.4	3228- 3231	39050	360	29	
10 2 47 20 W.4	3228- 3231	39732	330	28	
16 9 47 20 W.4	3227- 3229	36531	315	34	
9 21 47 20 W.4	3210- 3216	37445	335	30	
6 33 47 20 W.4	3196- 3206	47180	300	27	
7 28 47 21 W.4	3351- 3365	31140	245	28	
7 28 47 21 W.4	3370- 3405	36112	275	33	
11 6 48 20 W.4	3215- 3218	32839	275	33	
12 7 48 20 W.4	3217- 3220	36201	305	30	
6 27 48 21 W.4	3252- 3260	34385	260	29	
3 33 48 21 W.4	3320- 3324	31390	280	32	
5 35 48 21 W.4	3265- 3270	35660	300	29	
3 20 49 21 W.4	3267- 3272	34110	320	33	
14 5 49 22 W.4	3425- 3445	30978	290	45	
1 22 49 27 W.4	3900- 3930	23297	250	38	6
11 33 50 18 W.4	2544- 2550	42629	280	21	
7 11 50 22 W.4	3282- 3289	32535	270	30	
11 14 50 22 W.4	3292- 3293	40169	310	28	
2 23 50 22 W.4	3279- 3283	40838	295	25	
1 27 50 22 W.4	3294- 3299	36388	280	28	
7 30 50 22 W.4	3282- 3302	27180	275	37	7
13 16 50 24 W.4	3350- 3385	41347	350	43	7
6 4 51 22 W.4	3254- 3265	29690	255	28	
6 6 52 15 W.4	2125- 2170	36584	230	21	5
10 36 52 21 W.4	2823- 2840	45418	310	30	
3 32 52 26 W.4	3445- 3483	33905	310	39	
1 12 52 27 W.4	3590- 3605	32810	310	46	7
10 14 53 21 W.4	2776- 2786	47958	300	24	
10 15 53 21 W.4	2742- 2756	39659	270	23	
10 15 53 21 W.4	2742- 2756	44235	275	25	
10 15 53 21 W.4	2742- 2756	45752	265	25	
6 23 55 25 W.4	2850- 2870	42152	330	35	8
10 10 59 20 W.4	1875- 1938	31910	245	30	5
10 28 68 13 W.4	805- 825	14996	80	11	13
7 2 69 13 W.4	815- 850	16470	85	10	
10 22 74 25 W.4	1230- 1262	908	0	1	9
7 3 61 7 W.5	3100- 3185	21010	145	21	
12 28 63 16 W.5	5065- 5155	7406	70	12	12
4 15 65 24 W.5	5560- 5600	3103	30	7	
4 15 65 24 W.5	5525- 5560	4274	45	8	10
4 15 70 2 W.5	1225- 1480	15024	110	11	13
10 7 77 23 W.5	1291- 1344	10813	55	10	10
6 8 82 25 W.5	1404- 1420	12252	130	21	17
10 9 75 8 W.6	3790- 3825	14118	80	12	8
6 33 77 11 W.6	3141- 3171	9483	20	5	4
10 1 78 12 W.6	3329- 3342	12353	50	11	
10 1 78 12 W.6	3292- 3307	12705	55	10	
6 11 78 13 W.6	3147- 3273	8400	45	7	
6 11 78 13 W.6	3147- 3273	8084	95	15	
2 12 78 13 W.6	3130- 3158	10667	50	8	
13 12 78 13 W.6	3355- 3373	11406	85	12	
13 12 78 13 W.6	3380- 3390	11937	45	10	
13 12 78 13 W.6	3455- 3466	11353	45	8	
12 23 79 9 W.6	2622- 2636	8072	35	7	
11 24 79 9 W.6	2642- 2652	13548	105	20	
11 24 79 9 W.6	2576- 2586	13878	90	17	
13 21 79 11 W.6	2473- 2479	10506	230	19	18
10 9 80 9 W.6	2705- 2740	12573	65	13	
10 9 80 9 W.6	2780- 2897	10884	45	10	
10 30 80 10 W.6	2590- 2607	11683	85	18	
10 30 80 10 W.6	2676- 2680	11068	100	22	
6 32 80 10 W.6	2821- 2825	10625	80	15	
11 6 80 12 W.6	2381- 2391	3527	5	2	
11 6 80 12 W.6	2336- 2356	3707	10	15	
10 11 80 13 W.6	2355- 2372	2575	5	3	
10 11 80 13 W.6	2251- 2261	3740	10	4	
10 13 80 14 W.6	2232- 2246	2411	5	3	
10 13 80 14 W.6	2215- 2225	5471	45	10	
10 13 80 14 W.6	2270- 2285	5150	30	5	
10 13 80 14 W.6	2251- 2265	5402	45	11	

Lower Cretaceous, Mannville Group

Location	Interval	Cl	Br	I	B
1 6 1 9 W.4	3008- 3029	1369	13	0	5
1 6 1 9 W.4	2694- 2704	117	0	0	
12 5 1 11 W.4	2474- 2496	4106	0	1	
6 18 1 13 W.4	2330- 2350	1370	0	1	
10 12 1 14 W.4	2272- 2300	855	0	0	
6 15 1 16 W.4	2520- 2570	1653	0	0	
12 3 1 17 W.4	2760- 2780	735	0	1	
12 9 1 17 W.4	2991- 3005	649	0	0	
7 16 1 20 W.4	3720- 3800	3129	0	1	
7 29 2 8 W.4	2830- 2850	685	4	0	7
11 21 2 9 W.4	2230- 2309	443	0	0	
11 9 3 8 W.4	2750- 2785	2786	5	1	5
10 18 4 5 W.4	3307- 3315	1016	0	0	
10 21 4 6 W.4	3016- 3040	3558	0	1	
2 23 4 17 W.4	3060- 3085	872	0	0	
4 13 6 3 W.4	4100- 4115	2916	0	3	11
6 9 7 8 W.4	3008- 3058	7395	50	7	
6 9 7 8 W.4	3016- 3064	1628	0	3	
10 14 7 8 W.4	3040- 3067	5286	0	3	
6 11 7 10 W.4	3002- 3025	2344	0	1	
8 18 7 16 W.4	3300- 3322	2731	0	1	
10 25 7 16 W.4	3217- 3241	1013	0	1	
4 18 9 17 W.4	3241- 3249	861	0	0	
16 14 10 16 W.4	3150- 3170	1028	0	1	5
16 32 12 16 W.4	3382- 3455	1981	0	1	
6 29 12 18 W.4	3568- 3612	3912	0	2	
11 32 12 18 W.4	3615- 3633	4571	5	3	15
4 30 14 13 W.4	3231- 3250	1566	0	1	
4 30 14 13 W.4	3234- 3310	1576	0	1	
10 28 15 11 W.4	3205- 3230	2234	0	1	
10 14 15 18 W.4	3674- 3705	11038	105	9	
4 26 16 12 W.4	3190- 3245	2946	0	2	
4 26 16 12 W.4	3165- 3180	3074	0	2	
12 26 16 12 W.4	3184- 3190	2937	0	2	
8 9 16 13 W.4	3365- 3404	3353	0	1	
8 9 16 13 W.4	3404- 3442	2935	0	1	
4 10 16 13 W.4	3252- 3300	3031	0	2	
2 11 16 21 W.4	4409- 4421	10022	30	3	
14 3 17 12 W.4	3280- 3372	3697	0	1	
10 4 17 12 W.4	3214- 3255	7018	0	2	

Lower Cretaceous, Mannville Group

(cont.)

Location	Interval	Cl	Br	I	B
4 21 17 12 W.4	3213- 3266	3219	0	1	
10 26 17 13 W.4	3258- 3264	6771	30	1	
13 36 17 13 W.4	3245- 3246	13333	75	3	45
12 5 18 12 W.4	3333- 3345	6104	20	3	
6 13 18 13 W.4	3282- 3322	8389	60	1	
12 23 18 13 W.4	3259- 3261	8090	30	3	
10 30 18 13 W.4	3342- 3346	9466	30	4	24
12 34 19 9 W.4	3360- 3400	5784	0	2	
11 20 19 13 W.4	3293- 3319	7560	40	4	
11 20 19 13 W.4	3292- 3293	6925	40	2	27
8 1 19 14 W.4	3343- 3359	9348	55	4	
12 28 20 8 W.4	2841- 2866	3003	0	1	
14 32 20 8 W.4	3047- 3059	3971	13	2	
2 10 20 9 W.4	3207- 3213	8021	30	3	23
8 10 20 9 W.4	3290- 3322	8219	20	3	
14 10 20 9 W.4	3280- 3350	7495	60	1	
10 29 20 9 W.4	3345- 3400	7853	40	3	
2 11 20 12 W.4	3235- 3287	12704	160	7	
12 21 20 18 W.4	3916- 3966	17044	90	7	
12 21 20 18 W.4	3920- 3929	17107		7	
6 5 21 8 W.4	3226- 3281	4563	0	1	
8 6 21 8 W.4	3138- 3192	3088	50	3	
10 10 21 8 W.4	3162- 3195	3332	0	3	
11 17 21 9 W.4	3200- 3275	13752	125	11	
10 36 21 9 W.4	3206- 3297	7698	40	2	20
10 36 21 9 W.4	3169- 3202	5105	19	2	
10 25 21 10 W.4	3297- 3375	11657	150	7	
10 5 21 13 W.4	3370- 3417	9902	75	4	
10 15 21 14 W.4	3435- 3493	17469	155	11	
10 21 21 14 W.4	3438- 3453	17554	85	6	
11 1 22 8 W.4	3290- 3360	4252	10	3	
7 15 22 8 W.4	3191- 3202	4034	0	3	
12 32 22 8 W.4	2917- 2947	6147	55	7	
6 6 22 14 W.4	3320- 3356	14730	105	9	
6 1 22 15 W.4	3430- 3460	8938	50	3	
6 1 22 15 W.4	3430- 3460	10564	90	6	
6 12 22 15 W.4	3419- 3434	15671	60	5	
6 4 23 19 W.4	4275- 4295	12821	60	10	
2 15 24 14 W.4	3427- 3438	14074	75	5	
11 10 25 10 W.4	3135- 3167	4147	0	3	
11 21 26 3 W.4	2990- 3010	8256	65	17	
11 15 26 6 W.4	3190- 3265	9539	70	12	
10 13 26 10 W.4	3315- 3326	6710	20	6	
10 4 26 11 W.4	3335- 3352	5315	10	3	
6 22 26 11 W.4	3423- 3440	5970	10	3	
11 24 26 11 W.4	3340- 3350	7286	35	6	
11 24 26 11 W.4	3351- 3359	8094	35	4	
10 29 26 15 W.4	3856- 3878	969	75	13	
10 28 27 20 W.4	4430- 4447	7068	50	15	16
10 1 27 21 W.4	4604- 4610	9785	55	11	
11 12 27 21 W.4	4494- 4568	8275	50	12	
10 18 29 22 W.4	4566- 4586	15667	90	12	
10 10 29 23 W.4	4865- 4895	16788	35	4	
3 35 31 22 W.4	4866- 4868	12191	50	7	
10 27 33 4 W.4	2722- 2920	3343	35	19	8
6 24 39 19 W.4	4100- 4172	12918	55	3	
4 27 40 11 W.4	3042- 3072	34067	165	13	
16 29 40 11 W.4	3073- 3078	47385	210	10	34
1 32 40 11 W.4	3095- 3098	44054	180	5	
12 12 40 13 W.4	3261- 3343	35681	160	14	33
11 23 40 15 W.4	3140- 3160	54285	330	11	
16 27 40 15 W.4	3422- 3476	50680	385	10	
6 35 40 15 W.4	3331- 3356	41567	310	19	
6 35 40 15 W.4	3371- 3400	54529	320	16	
6 35 40 15 W.4	3470- 3495	47735	370	10	

Lower Cretaceous, Mannville Group

(cont.)

Location	Interval	Cl	Br	I	B
7 7 40 16 W.4	3715- 3745	48608	310	11	
6 17 40 16 W.4	3635- 3678	65942	350	18	
6 17 40 16 W.4	3735- 3765	68801	480	8	
6 19 40 16 W.4	3695- 3725	57231	385	18	
6 19 40 16 W.4	3800- 3825	65153	485	9	
6 20 40 16 W.4	3740- 3750	53908	375	7	
6 20 40 16 W.4	3740- 3750	61176	430	7	
6 20 40 16 W.4	3630- 3657	60375	330	16	
6 20 40 16 W.4	3740- 3750	63165	430	10	
6 20 40 16 W.4	3630- 3657	54547	320	15	
10 13 40 17 W.4	3723- 3755	57125	330	16	
10 13 40 17 W.4	3840- 3855	65225	540	9	
7 34 40 17 W.4	3710- 3740	58758	435	15	
6 19 40 18 W.4	4050- 4070	39407	315	11	
6 19 40 18 W.4	4150- 4185	65327	520	9	
11 5 40 19 W.4	4343- 4373	41227	285	4	
10 3 40 23 W.4	4772- 4792	90027	545	14	
1 5 41 11 W.4	3090- 3116	43876	195	13	
16 28 41 12 W.4	2965- 2985	52720	280	13	20
4 28 41 13 W.4	3043- 3053	48859	315	8	
10 20 41 17 W.4	3770- 3870	64335	375	9	
11 19 41 18 W.4	3853- 3878	30210	195	8	
10 21 41 18 W.4	3730- 3785	30558	175	5	
7 10 41 25 W.4	5310- 5328	49724	230	6	
4 11 43 1 W.4	2003- 2007	51886	205	9	
10 22 43 11 W.4	2642- 2674	38605	300	14	
10 22 43 11 W.4	2766- 2803	44513	330	15	
7 2 43 19 W.4	3710- 3749	32203	195	12	
8 25 44 1 W.4	1819- 1828	79472	260	19	36
11 3 44 13 W.4	3018- 3034	43054	205	9	
10 20 44 14 W.4	3022- 3057	42794	350	21	
10 20 44 14 W.4	3105- 3120	45082	345	16	
11 3 44 17 W.4	3447- 3472	57874	380	10	
11 30 44 17 W.4	3379- 3389	27999	325	15	
11 30 44 17 W.4	3421- 3439	26778	305	14	
11 30 44 17 W.4	3522- 3547	58487	455	12	
11 30 44 17 W.4	3420- 3422	58918	310	7	
7 31 44 17 W.4	3358- 3368	41597	280	9	
7 31 44 17 W.4	3430- 3440	54526	360	7	
10 13 44 23 W.4	4510- 4550	74014	385	0	
2 25 45 6 W.4	2056- 2064	110776	515	24	76
7 32 45 6 W.4	2252- 2257	61513	370	16	55
1 34 45 6 W.4	2109- 2114	85539	470	24	41
1 34 45 6 W.4	2109- 2114	52860	280	8	
7 12 45 20 W.4	3803- 3855	62401	355	13	
10 30 46 20 W.4	3948- 3982	63164	395	13	
10 30 46 20 W.4	4005- 4020	63835	305	8	
6 14 46 22 W.4	4064- 4084	51877	260	7	
1 5 47 5 W.4	2209- 2215	137265	620	30	
8 5 47 5 W.4	2194- 2200	131573	730	38	86
11 5 47 5 W.4	2182- 2207	53180	265	21	
4 4 47 21 W.4	4050- 4092	36939	190	7	
7 28 47 21 W.4	4055- 4065	67756	360	17	
7 28 47 21 W.4	3973- 3985	53579	255	10	
7 28 47 21 W.4	3829- 3872	34313	180	7	
10 11 47 26 W.4	4790- 4826	28743	135	5	
10 10 48 6 W.4	1855- 1880	49737	320	13	
10 28 48 6 W.4	1829- 1840	46700	345	18	
13 30 48 22 W.4	4170- 4227	66999	300	12	
13 30 48 22 W.4	4100- 4115	64299	285	13	
1 33 48 26 W.4	4480- 4513	42269	205	6	
7 30 49 6 W.4	1897- 1923	50428	300	16	
3 31 49 6 W.4	2112- 2134	51047	250	10	
3 31 49 6 W.4	1810- 1820	22316	110	7	
11 36 49 17 W.4	2963- 2981	57404	260	15	

Lower Cretaceous, Mannville Group
(cont.)

Location	Interval	Cl	Br	I	B
11 36 49 17 W.4	2576- 2620	22442	145	8	
10 9 49 18 W.4	3314- 3336	52486	345	2	
11 26 50 1 W.4	1870- 1874	69604	385	2	
16 15 50 2 W.4	1984- 1988	53825	550	23	
6 4 50 14 W.4	2730- 2770	46473	410	29	
11 33 50 18 W.4	2920- 2950	49734	255	16	
7 32 50 20 W.4	4026- 4042	65140	340	15	
16 13 50 21 W.4	3560- 3576	58102	290	18	
16 13 50 21 W.4	3072- 3090	36280	305	16	
11 19 50 22 W.4	3868- 3902	54697	250	15	
11 19 50 22 W.4	3902- 3969	53892	405	12	
11 19 50 22 W.4	3962- 3984	54105	275	14	
11 19 50 22 W.4	3992- 4021	58120	250	14	
7 30 50 22 W.4	3812- 3838	51711	245	13	
7 30 50 22 W.4	4010- 4026	25656	115	6	
10 36 50 23 W.4	3800- 3838	51297	235	12	
10 36 50 23 W.4	3855- 3882	30851	260	13	
10 36 50 23 W.4	3947- 3972	61281	145	9	
13 16 50 24 W.4	3958- 3978	73124	315	15	
11 8 50 25 W.4	4080- 4130	55526	285	9	
11 8 50 25 W.4	4190- 4235	62829	300	10	
10 31 51 24 W.4	3850- 3851	68929	340	20	65
6 32 51 24 W.4	3899- 3932	64200	290	16	42
10 10 51 25 W.4	4080- 4109	69657	235	11	
10 10 51 25 W.4	4080- 4118	68383	285	10	
16 28 51 26 W.4	4303- 4308	77280	385	15	58
10 30 52 23 W.4	3696- 3707	65264	280	15	42
2 30 52 25 W.4	4021- 4051	62629	320	17	50
10 19 52 26 W.4	4218- 4254	42417	285	10	
1 12 52 27 W.4	4335- 4345	65480	315	11	
14 17 53 23 W.4	3464- 3529	53099	270	15	
1 6 53 25 W.4	3960- 3964	67211	255	14	
2 29 53 25 W.4	3857- 3877	52608	360	14	
7 22 54 26 W.4	3775- 3815	41400	240	13	
7 22 54 26 W.4	3990- 4051	63739	285	16	
16 17 55 20 W.4	3347- 3348	55296	185	15	37
10 19 55 24 W.4	3569- 3579	51961	220	12	
6 23 55 25 W.4	3615- 3641	54790	240	14	
10 31 56 25 W.4	3432- 3444	35308	285	17	
10 31 56 25 W.4	3551- 3606	48046	240	16	31
6 16 56 27 W.4	3810- 3830	56884	265	12	29
11 21 57 5 W.4	1350- 1355	33423	170	16	17
10 34 57 5 W.4	1397- 1412	33572	130	8	
4 3 57 20 W.4	2595- 2607	48338	210	10	
4 3 57 20 W.4	2592- 2630	42387	255	12	
14 30 57 20 W.4	2811- 2825	26745	120	3	
11 7 58 5 W.4	1634- 1800	27074	105	9	
7 18 58 19 W.4	2521- 2586	36866	125	9	
10 10 59 20 W.4	2460- 2520	34658	215	13	
10 13 61 6 W.4	1024- 1036	24113	85	9	
7 9 62 19 W.4	2270- 2300	9804	30	2	
10 9 62 21 W.4	2265- 2300	31777	165	9	
12 12 63 3 W.4	904- 908	18504	70	10	9
10 26 63 21 W.4	2397- 2465	29997	120	10	
10 26 63 21 W.4	2468- 2498	32115	125	11	
10 26 63 21 W.4	2573- 2600	30651	135	11	
9 22 64 3 W.4	1128- 1140	18330	60	8	
10 8 66 19 W.4	1459- 1501	16320	45	8	12
6 25 66 23 W.4	1632- 1661	15793	75	7	
6 25 66 23 W.4	1946- 1957	21983	105	12	
6 8 66 25 W.4	2610- 2730	28798	100	12	
11 26 67 23 W.4	1415- 1460	17389	130	13	
6 6 67 24 W.4	1972- 1977	25793	95	8	
7 2 69 13 W.4	1475- 1563	12701	35	6	
7 2 69 13 W.4	965- 980	14518	70	10	

Lower Cretaceous, Mannville Group
(cont.)

Location	Interval	Cl	Br	I	B
11 5 69 13 W.4	1386- 1396	14043	40	15	12
16 22 82 4 W.4	747- 930	7435	0	0	5
6 13 91 18 W.4	549- 677	494	0	0	2
10 26 29 2 W.5	7980- 8038	34091	95	5	
6 17 37 3 W.5	7605- 7635	9365	20	4	
6 17 37 3 W.5	7525- 7617	15567	45	6	
4 35 38 4 W.5	7423- 7459	25759	110	21	
6 7 39 3 W.5	7110- 7148	19659	145	13	
4 32 39 3 W.5	7108- 7111	25660	110	11	
6 13 39 4 W.5	7117- 7145	23511	90	12	
2 21 48 1 W.5	5102- 5110	55522	210	11	
2 21 48 1 W.5	5102- 5110	55663	230	10	
2 21 48 1 W.5	5102- 5110	55011	220	10	
2 21 48 1 W.5	5102- 5110	54588	200	10	
2 21 48 1 W.5	5102- 5110	55240	205	9	
10 3 51 7 W.5	5755- 5819	27847	120	7	
10 3 51 7 W.5	5755- 5819	26755	110	6	
7 35 52 9 W.5	6216- 6420	35958	115	14	
7 35 52 9 W.5	6216- 6420	33089	110	15	
10 23 56 1 W.5	3885- 3892	60283	275	12	33
10 23 56 1 W.5	3885- 3892	55902	280	10	
4 13 57 12 W.5	6095- 6134	38440	95	13	
4 13 57 12 W.5	6095- 6134	40385	100	12	
12 20 60 15 W.5	6142- 6165	53751	190	12	
9 22 63 15 W.5	5701- 5813	28486	70	8	
12 28 63 16 W.5	5945- 6040	35866	95	11	
10 21 63 19 W.5	5831- 5963	35300	155	17	18
2 2 63 22 W.5	7030- 7060	36617	130	18	
2 8 63 22 W.5	7131- 7161	36224	110	17	
4 13 65 24 W.5	6780- 6815	32321	115	20	
10 2 66 24 W.5	6698- 6748	33272	140	23	
4 7 68 7 W.5	3905- 3935	31960	95	13	
12 21 71 16 W.5	3505- 3680	2010	0	9	
6 34 71 24 W.5	4597- 4618	25915	110	20	17
3 26 72 24 W.5	4438- 4487	21482	70	13	
3 26 72 24 W.5	4510- 4590	13649	40	11	
10 35 72 24 W.5	4481- 4521	21736	60	5	
10 35 72 24 W.5	4430- 4470	14666	40	10	
10 3 73 22 W.5	3816- 3835	13705	25	8	
10 3 73 22 W.5	3931- 4050	21607	55	8	
2 27 74 23 W.5	3473- 3539	9837	15	5	
10 7 77 23 W.5	2550- 2598	11640	10	5	
10 11 77 23 W.5	2802- 2814	19662	85	16	
12 15 78 11 W.5	1382- 1397	982	0	0	
10 36 83 23 W.5	2140- 2190	3527	0	1	
9 28 87 20 W.5	860- 890	16074	90	28	18
10 23 71 1 W.6	4449- 4547	18505	130	20	
11 28 77 11 W.6	4938- 4942	1013	0	2	
12 23 79 9 W.6	4401- 4405	851	0	0	
11 24 79 9 W.6	4381- 4385	931	0	0	
11 24 79 9 W.6	4326- 4330	370	0	0	
10 30 80 10 W.6	4422- 4426	1216	0	0	
10 30 80 10 W.6	4376- 4380	967	0	0	3
10 30 80 10 W.6	4029- 4033	9762	25	15	
6 32 80 10 W.6	4629- 4633	999	0	1	6
6 32 80 10 W.6	4235- 4239	10182	35	16	5
10 13 81 13 W.6	3639- 3694	10690	30	20	
10 13 81 13 W.6	2531- 2588	494	0	1	3
10 13 81 13 W.6	4155- 4187	533	0	1	4
2 11 82 2 W.6	2824- 2940	66311	175	18	53
10 29 96 3 W.6	2053- 2108	7992	35	12	6

Jurassic

Location	Interval	Cl	Br	I	B
4 7 1 5 W.4	3500- 3534	1324	0		
10 21 4 6 W.4	3260- 3300	530	0	0	
2 34 5 16 W.4	3186- 3196	3983	5	3	
4 13 6 3 W.4	4122- 4300	2441	50		42
4 13 6 3 W.4	4303- 4370	695	0	1	
11 32 6 9 W.4	3140- 3160	2702	5	3	
10 32 7 15 W.4	3259- 3286	814	0	0	
10 16 7 16 W.4	3320- 3330	725	0	0	
8 6 9 16 W.4	3178- 3190	1120	0	0	
10 3 9 19 W.4	3644- 3700	1879	0	1	13
11 14 10 16 W.4	3202- 3223	1144	7	1	5
7 10 11 13 W.4	3035- 3037	1019	0		
7 10 11 13 W.4	3035- 3037	985	0	4	
4 13 11 14 W.4	2975- 3007	1843	0	1	
1 8 13 13 W.4	3130- 3139	1428	6	1	4
6 7 39 3 W.5	7179- 7190	21741	105	12	
6 7 39 3 W.5	7216- 7240	14589	65	12	
12 26 56 13 W.5	6188- 6210	36503	190	25	
2 18 57 13 W.5	6392- 6427	41446	195	21	
10 22 59 13 W.5	5708- 5770	16583	65	6	

Triassic

Location	Interval	Cl	Br	I	B
12 28 63 16 W.5	6250- 6319	59758	150	17	46
9 24 68 22 W.5	5066- 5088	91410	230	26	
6 15 68 23 W.5	5815- 5858	82169	195	14	
8 21 69 19 W.5	4890- 4925	88014	230	19	
14 27 69 19 W.5	4989- 5039	73788	270	35	
4 29 69 19 W.5	4774- 4799	69168	195	8	
14 29 69 19 W.5	4760- 4763	87859	215	18	
5 8 69 21 W.5	4915- 4933	91315	220	20	
3 26 72 24 W.5	4974- 5054	65793	180	12	
10 3 73 22 W.5	4201- 4260	86706	250	15	
10 30 80 10 W.6	4801- 4805	36260	65	6	48
6 24 87 1 W.6	2710- 2795	21614	595		
6 25 87 7 W.6	3293- 3304	72350	190	22	

Permian

Location	Interval	Cl	Br	I	B
2 2 63 22 W.5	7550- 7600	80157	200	19	
4 13 65 24 W.5	7405- 7450	70729	120	13	
3 26 72 24 W.5	5360- 5395	89607	230	19	
10 7 77 23 W.5	3283- 3353	79507	190	24	38
10 9 75 8 W.6	7313- 7380	88947	210	28	128
12 23 79 9 W.6	6477- 6507	108216	215	20	
10 13 81 13 W.6	6500- 6690	89859	160	47	199
6 24 87 1 W.6	2878- 2882	22167	90	18	
6 24 87 1 W.6	2830- 2900	34344	145	34	30

Carboniferous, Rundle Group

Location	Interval	Cl	Br	I	B
6 10 1 9 W.4	2813- 2914	1251	0	0	
6 22 1 9 W.4	3314- 3341	973	0	0	
10 7 1 10 W.4	3266- 3309	133	0	0	
7 9 1 10 W.4	3148- 3179	59	0	1	
10 9 1 10 W.4	3190- 3215	63	0	0	

Carboniferous, Rundle Group (cont.)

Location	Interval	Cl	Br	I	B
12 24 1 10 W.4	3202- 3230	333	0	0	
12 5 1 11 W.4	2800- 2825	110	0	7	
2 23 1 12 W.4	2806- 2866	167	0	0	
6 15 1 16 W.4	2760- 2800	212	0	0	
10 3 1 17 W.4	2920- 2934	1259	0	1	
12 3 1 17 W.4	2897- 2910	757	0	0	
13 3 1 17 W.4	3101- 3108	773	0	0	
11 5 1 17 W.4	3091- 3100	791	0	1	
11 1 1 18 W.4	3295- 3332	904	0	0	4
11 21 2 9 W.4	2830- 2880	886	0	0	
10 13 3 10 W.4	2934- 3000	1394	0	7	
10 18 6 16 W.4	3270- 3301	732	0	1	
10 27 6 16 W.4	3300- 3320	853	0	0	
10 31 7 15 W.4	3280- 3300	763	0	0	
10 16 7 16 W.4	3366- 3376	757	0	0	
2 3 9 17 W.4	3360- 3390	2590	0	1	
8 26 9 17 W.4	3233- 3358	3074	5	1	
4 13 11 14 W.4	3011- 3031	1042	0	0	
11 35 13 17 W.4	3342- 3350	12190	58	5	14
7 17 16 18 W.4	3905- 3925	19472	170	7	
6 10 16 26 W.4	6843- 6920	15161	80	3	
6 10 16 26 W.4	6896- 6921	15409	80	4	
4 21 17 12 W.4	3300- 3342	3385	5	1	
6 34 19 9 W.4	3332- 3362	7107	25	2	3
3 8 19 11 W.4	3302- 3311	8783	40	4	
7 8 19 11 W.4	3345- 3346	10201	50	7	30
14 14 19 14 W.4	3394- 3464	12452	70	2	
10 14 19 14 W.4	3415- 3437	9501	50	3	
10 10 20 9 W.4	3304- 3324	8798	35	4	
10 16 21 15 W.4	3527- 3567	10968	170	8	
6 15 21 16 W.4	3675- 3713	8661	35	5	
16 32 31 24 W.4	5220- 5358	33093	130	20	28
11 27 30 3 W.5	8340- 8500	42364	195	16	
12 32 33 5 W.5	9470- 9500	31868	220	13	
12 32 33 5 W.5	9475- 9495	35962	420		
12 32 33 5 W.5	9475- 9495	36094	220	19	
3 9 34 5 W.5	9198- 9208	39306	275	18	
6 16 35 5 W.5	9070- 9083	45245	200	19	
4 2 35 6 W.5	9633- 9643	26675	265	16	
4 2 35 6 W.5	9633- 9643	32490	295	12	
4 2 35 6 W.5	9643- 9665	27534	330		
10 27 35 6 W.5	9440- 9460	42429	170	15	
4 27 36 3 W.5	7580- 7795	7668	30	5	
8 15 37 3 W.5	7435- 7467	17813	60	13	
12 20 37 3 W.5	7555- 7580	27268	110	15	
10 29 37 7 W.5	9515- 9556	39530	220	11	
10 20 38 5 W.5	8135- 8175	35294	250	18	
4 4 40 3 W.5	7105- 7113	22750	90	14	
8 5 40 3 W.5	7091- 7095	34260	95	15	
6 30 44 4 W.5	7126- 7185	31214	120	12	
11 4 45 5 W.5	7153- 7205	16166	60	7	
6 22 45 5 W.5	6976- 7015	62919	260	13	
11 10 49 16 W.5	10180-10240	28078	100	2	152
10 18 50 17 W.5	10022-10152	34108	225	10	
10 21 51 9 W.5	6500- 6570	62849	265	18	
10 21 51 9 W.5	6495- 6521	61223	250	17	
4 29 55 19 W.5	9470- 9494	60383	180	15	
10 25 56 9 W.5	5116- 5121	60035	230	13	
4 29 60 19 W.5	7720- 7800	74409	200	11	
4 2 63 10 W.5	4872- 4920	59672	60	10	

Carboniferous, Rundle Group (cont.)

Location	Interval	Cl	Br	I	B
10 25 63 10 W.5	5081- 5136	26754	80	8	
6 5 63 22 W.5	7751- 7811	84003	180	19	
2 16 64 11 W.5	5462- 5559	38543	125	16	64
3 9 70 13 W.5	3836- 3856	44925	170	14	
10 21 72 13 W.5	3137- 3289	19699	65	9	
4 31 73 13 W.5	2699- 2756	27287	95	16	
4 31 73 13 W.5	2699- 2756	18313	170	32	40
9 7 78 15 W.5	2600- 2616	22894	35	17	20
10 27 81 9 W.5	1690- 1711	4309	15	8	
13 8 81 19 W.5	2792- 2827	39800	150	20	
10 15 101 8 W.6	2545- 2590	10991	55	12	10

Carboniferous, Banff Formation

Location	Interval	Cl	Br	I	B
10 4 19 11 W.4	3752- 3800	11593	20	3	
10 10 20 9 W.4	3600- 3680	12442	50	3	
11 31 23 9 W.4	3399- 3440	3292	5	3	14
6 15 25 5 W.4	3390- 3440	5430	40	3	
11 21 26 3 W.4	3070- 3110	7421	55	6	
10 20 26 5 W.4	3220- 3255	9714	75	7	
11 15 26 6 W.4	3310- 3357	9816	65	8	
7 9 27 4 W.4	3190- 3210	10187	85	10	
10 19 29 4 W.4	2925- 2970	10303	80	17	13
6 31 29 4 W.4	3028- 3052	5753	90	16	
11 35 55 4 W.5	4281- 4291	47174	350	10	
12 20 56 5 W.5	4351- 4390	40978	150	9	
10 14 59 7 W.5	4230- 4277	27282	110	11	
2 21 60 7 W.5	4415- 4445	40757	170	21	
2 14 82 8 W.5	1742- 1872	1624	0	1	1

Upper Devonian, Wabamun Group

Location	Interval	Cl	Br	I	B
11 22 41 18 W.4	3840- 3875	24884	170	9	
4 28 42 22 W.4	4790- 4835	40797	250	6	31
5 29 47 14 W.4	2928- 3012	35983	215	10	
1 12 52 27 W.4	4596- 4612	83614	460	11	
10 10 59 20 W.4	2596- 2613	34818	180	11	
7 34 62 20 W.4	2325- 2350	27790	135	12	18
6 6 67 24 W.4	2625- 2650	19868	90	6	
7 34 31 1 W.5	8549- 8572	78490	170	3	315
2 21 60 7 W.5	4928- 5063	96333	320	15	
2 21 60 7 W.5	5428- 5505	101027	320	20	110
10 2 66 24 W.5	9670- 9710	166358	425	20	140
4 32 68 8 W.5	5440- 5488	93392	220	10	
4 21 69 22 W.5	7900- 7942	188952	350	20	
4 15 70 2 W.5	3004- 3038	39240	185	20	
4 15 70 2 W.5	2302- 2350	20212	160	23	
4 15 70 2 W.5	2287- 2296	33616	150	34	33
4 15 70 2 W.5	2232- 2242	29858	110	14	
10 35 73 4 W.5	2377- 2511	6918	220	5	
10 31 76 6 W.5	3136- 3235	1195	20	1	63
13 8 81 19 W.5	5821- 5871	148694	440	12	
11 31 82 1 W.5	1412- 1425	5709	15	3	
6 13 82 3 W.5	1565- 1625	7950	20	1	
12 29 86 7 W.5	2450- 2540	3388	0	1	
6 28 85 3 W.6	6210- 6410	122856	410	20	31

Upper Devonian, Winterburn Group

Location	Interval	Cl	Br	I	B
10 4 19 11 W.4	4132- 4162	3275	5	1	18
10 21 19 17 W.4	4860- 4880	7773	10	2	23
10 14 29 20 W.4	5300- 5320	36161	320	6	
10 25 29 20 W.4	5419- 5424	28100	210	5	71
4 35 29 20 W.4	5423- 5440	28572	210	2	
10 13 29 21 W.4	5530- 5640	41520	340	7	
1 36 29 21 W.4	5559- 5575	61401	500	8	117
2 12 30 20 W.4	5379- 5394	40400	335	5	
4 17 30 20 W.4	5670- 5745	62095	455	7	
10 11 33 17 W.4	4990- 5015	113090	200	15	
10 11 33 17 W.4	4982- 5008	100055	540	9	
14 22 33 23 W.4	6200- 6260	139137	1040	18	
15 27 34 20 W.4	5459- 5509	81642	730	15	
5 26 34 21 W.4	5680- 5715	104363	935	13	
2 1 35 20 W.4	5530- 5551	82869	705	13	
12 25 35 22 W.4	6037- 6087	140957	1245	24	
10 14 35 25 W.4	6985- 7065	141315	1010	23	
6 26 36 20 W.4	5160- 5161	69116	615	12	
4 8 37 20 W.4	5400- 5423	40223	360	6	
4 8 37 20 W.4	5400- 5423	62353	530	9	
4 8 37 20 W.4	5400- 5423	70342	580	12	
2 18 37 20 W.4	5407- 5420	75315	910	19	
13 17 37 23 W.4	5890- 5894	103443	775	17	
6 3 38 20 W.4	5229- 5276	121115	830	17	
14 29 39 23 W.4	5945- 5980	132229	980	13	
14 29 39 23 W.4	6025- 6045	130146	975	19	
1 15 39 26 W.4	6842- 6897	91908	580	9	
6 35 40 15 W.4	3700- 3791	63648	450	13	86
9 10 40 24 W.4	6205- 6207	125527	1000	12	
11 22 41 18 W.4	4360- 4560	69425	480	12	
2 10 44 22 W.4	4967- 4976	99808	535	13	
4 14 44 22 W.4	5108- 5117	95921	535	10	
10 23 44 28 W.4	6890- 6975	108159	550	16	
7 1 45 22 W.4	4662- 4667	83224	490	16	101
5 29 47 14 W.4	3168- 3200	35405	180	11	22
1 33 48 26 W.4	5465- 5482	119066	515	14	
10 34 49 25 W.4	4955- 5025	76513	210	11	
10 22 49 26 W.4	5301- 5323	108018	645	16	
15 22 49 26 W.4	5305- 5318	106842	520	16	
6 33 49 26 W.4	5190- 5224	155269	1180	22	
3 2 49 27 W.4	5526- 5546	106530	595	23	
11 13 49 27 W.4	5413- 5440	107083	465	16	
4 23 49 27 W.4	5428- 5445	107734	425	12	
7 30 50 22 W.4	4375- 4435	57348	375	15	75
7 30 50 22 W.4	4433- 4445	50386	325	10	
10 36 50 23 W.4	4400- 4460	61281	355	12	
13 16 50 24 W.4	4650- 4670	65098	405	12	
2 12 50 26 W.4	5038- 5084	85430	435	14	
1 16 50 26 W.4	5059- 5394	106733	695	17	
12 28 50 27 W.4	5250- 5280	85389	460	12	
5 9 51 26 W.4	4988- 5002	113654	595	24	
15 34 51 27 W.4	5105- 5107	131922	955	24	
5 18 52 21 W.4	4030- 4065	62337	310	16	
5 18 52 21 W.4	4065- 4075	56747	280	12	
7 26 52 26 W.4	4640- 4648	69430	390	8	
1 12 52 27 W.4	5100- 5150	62904	400	11	
14 18 54 25 W.4	4632- 4688	62036	400	12	
4 19 54 25 W.4	4437- 4463	66040	400	14	
10 31 56 25 W.4	4197- 4252	73704	420	14	
15 29 58 24 W.4	3682- 3710	57615	375	16	

Upper Devonian, Winterburn Group (cont.)

Location	Interval	Cl	Br	I	B
6 13 60 17 W.4	2049- 2090	25474	95	10	
10 26 63 21 W.4	2670- 2700	27694	105	12	21
12 28 67 18 W.4	1838- 1910	14196	350	11	26
9 23 43 2 W.5	7407- 7465	120190	660	30	167
16 16 50 2 W.5	5985- 6025	100251	435	19	144
4 20 50 2 W.5	6085- 6135	118419	495	20	
2 21 60 7 W.5	5628- 5672	94921	425	27	144
10 26 62 17 W.5	8300- 8358	68688	160	12	
10 18 63 19 W.5	8605- 8695	76923	210	13	
6 5 63 22 W.5	9890- 9950	108929	280	12	
4 15 70 2 W.5	3195- 3220	41559	245	15	
4 15 70 2 W.5	3245- 3275	65920	255	12	53
6 34 71 24 W.5	8385- 8440	157082	425	25	148
10 36 76 8 W.5	3830- 3910	44939	165	13	

Upper Devonian, Woodbend Group

Location	Interval	Cl	Br	I	B
6 18 1 13 W.4	4180- 4194	310	0	4	
6 18 1 13 W.4	4219- 4233	105	0	2	2
7 17 16 18 W.4	5050- 5090	17664	135	7	122
11 31 23 9 W.4	3777- 3820	11032	5	1	13
10 13 29 21 W.4	5680- 5788	70138	530	11	
2 12 30 20 W.4	5517- 5534	49163	555	9	
4 29 31 18 W.4	5437- 5490	56539	470	7	
2 5 31 20 W.4	6116- 6156	123143	820	14	
5 26 34 21 W.4	6354- 6358	129375	1190	26	142
2 1 35 20 W.4	6095- 6146	106364	865	18	147
13 31 36 17 W.4	5107- 5122	78481	570	13	126
8 4 38 20 W.4	5376- 5396	76288	620	12	
10 1 38 21 W.4	5370- 5400	83000	1060	18	
4 14 38 26 W.4	7110- 7160	141530	1060	25	348
4 13 39 21 W.4	5374- 5385	127230	950	17	
16 23 39 21 W.4	5875- 5913	140636	995	16	
6 35 40 15 W.4	3846- 3861	57846	460	18	92
10 9 40 22 W.4	5545- 5561	125564	1010	17	
16 16 40 24 W.4	6277- 6279	128418	1045	24	337
3 21 40 24 W.4	6294- 6297	131464	996	21	224
2 34 40 25 W.4	6477- 6493	71090	615	4	
7 10 41 25 W.4	6422- 6438	112388	910	7	
16 8 43 22 W.4	5389- 5399	142138	1035	18	
15 10 44 22 W.4	5210- 5217	115038	865	20	
16 10 44 22 W.4	5252- 5282	122235	660	26	145
10 36 44 22 W.4	4938- 4950	79090	500	11	
2 1 45 22 W.4	4882- 4885	75415	505	16	143
8 1 45 22 W.4	4885- 4889	79450	470	12	
8 1 45 22 W.4	4885- 4889	75406	460	12	
8 24 46 28 W.4	7084- 7086	151864	1240	12	
3 19 47 27 W.4	7076- 7092	150827	1285	27	
3 19 47 27 W.4	7076- 7092	162207	848	26	130
13 30 48 22 W.4	5610- 5650	100253	1250	21	110
1 22 49 27 W.4	6280- 6310	150293	1150	23	
7 30 50 22 W.4	5408- 5431	141886	1470	34	120
13 16 50 24 W.4	5620- 5650	154808	1650	31	12
8 5 50 25 W.4	5777- 5780	162926	915	10	125
10 10 51 25 W.4	5732- 5749	144799	1165	22	123
11 26 51 27 W.4	5928- 5940	163282	1020	28	
7 34 51 27 W.4	5969- 5993	159346	1105	22	
5 18 52 21 W.4	5000- 5050	128342	610	20	90
7 34 52 26 W.4	5116- 5129	138095	935	24	135
1 12 52 27 W.4	6245- 6316	146200	925	29	142
7 22 54 26 W.4	5600- 5653	112815	1110	31	146
15 16 56 21 W.4	3218- 3261	58762	210	13	

Upper Devonian, Woodbend Group (cont.)

Location	Interval	Cl	Br	I	B
1 17 56 21 W.4	3177- 3195	61682	210	12	
7 18 56 22 W.4	3644- 3660	58731	240	13	
4 5 56 25 W.4	4495- 4515	70564	560	17	
2 6 57 20 W.4	3124- 3130	63457	220	24	
14 30 57 20 W.4	3921- 3950	137204	390	20	63
4 31 57 21 W.4	3186- 3187	57617	220	14	
3 4 58 21 W.4	3310- 3318	62559	275	15	
10 2 58 22 W.4	3196- 3254	60256	300	20	
5 20 58 22 W.4	3198- 3211	63343	250	13	
3 8 58 24 W.4	3930- 3960	41573	265	9	
3 8 58 24 W.4	3930- 3960	61065	380	18	79
10 26 63 21 W.4	3250- 3310	41220	200	12	25
10 26 63 21 W.4	3814- 4000	90870	240	16	44
6 6 67 24 W.4	3201- 3280	36961	185	9	26
11 5 69 13 W.4	1473- 1476	10718	50	10	14
11 5 69 13 W.4	1480- 1520	9180	10	4	8
16 12 33 2 W.5	9170- 9201	150043	1015	19	296
2 1 34 2 W.5	9140- 9165	164674	1015	21	
6 17 37 3 W.5	9445- 9464	130499	930	19	
6 17 37 3 W.5	9390- 9450	133015	920	11	
6 17 37 3 W.5	9464- 9484	127982	980	12	207
11 7 43 1 W.5	7852- 7854	149737	1120	23	235
6 32 56 20 W.5	12065-12085	133865	295	11	269
4 26 57 19 W.5	10840-11024	113248	280	20	205
10 22 60 17 W.5	9388- 9416	129413	480	22	360
10 22 60 17 W.5	9388- 9416	131885	480	17	
10 22 60 17 W.5	9388- 9416	127604	470	15	
11 6 63 25 W.5	11830-11831	154152	430	13	114
7 27 67 22 W.5	8708- 8712	171835	455	19	118
10 27 67 22 W.5	8707- 8742	149752	400	13	
13 24 68 22 W.5	8491- 8496	171849	385	15	
7 33 68 22 W.5	8608- 8622	154299	370	21	168
11 26 69 23 W.5	8766- 8771	145540	385	19	158
4 15 70 2 W.5	3687- 3715	40815	350	23	47
6 34 71 24 W.5	8451- 8482	151415	370	15	
6 34 71 24 W.5	8628- 8675	156585	385	16	
6 34 71 24 W.5	9052- 9100	163094	400	19	
10 35 73 4 W.5	3342- 3384	43577	330	23	64
11 9 79 22 W.5	6718- 6719	157987	516	12	47
13 8 81 19 W.5	6112- 6140	119273	390	16	27
13 8 81 19 W.5	6155- 6190	151250	370	16	
6 24 87 1 W.6	6490- 6538	119093	355	15	
2 16 87 2 W.6	6344- 6368	119537	395	15	59

Upper Devonian, Beaverhill Lake Formation

Location	Interval	Cl	Br	I	B
4 17 30 20 W.4	6960- 7070	195955	2115	27	305
15 16 44 13 W.4	4272- 4316	124178	1590	25	102
6 7 57 9 W.4	2921- 2922	49144	80	5	17
14 30 57 20 W.4	4489- 4509	63705	225	3	17
10 7 64 19 W.4	3679- 3784	90725	440	38	73
6 22 64 19 W.4	3757- 3790	71285	345		
6 36 58 19 W.5	11280-11305	134694	340	14	206
12 34 62 12 W.5	8578- 8644	111028	300	39	109
4 2 63 10 W.5	8119- 8205	128591	365	41	
2 31 63 12 W.5	9404- 9664	104317	260	26	
10 6 63 21 W.5	10890-10903	98375	155	24	920
2 2 63 22 W.5	11067-11077	164132	375	17	512
10 10 66 11 W.5	8660- 8686	109396	250	27	
14 29 69 19 W.5	8904- 8950	131301	260	22	144
4 3 70 18 W.5	8909- 8945	127086	265	17	
4 14 83 10 W.5	5412- 5484	76838	305	7	18
12 17 93 21 W.5	5190- 5240	100681	220	10	20

Middle Devonian, Elk Point Group

Location					Interval	Cl	Br	I	B
10	31	54	12	W.5	10006-10026	87975	460	12	143
10	22	60	17	W.5	10062-10094	206361	575	17	149
10	22	60	17	W.5	10062-10094	183312	740	22	210
4	8	71	4	W.5	6115- 6139	178088	720	3	38
4	8	71	4	W.5	6115- 6139	175047	700	3	38
4	8	71	4	W.5	6115- 6139	171581	720	3	28
10	11	71	12	W.5	7625- 7685	142474	465	7	71
2	9	73	4	W.5	5308- 5318	170530	670	3	30
2	6	73	5	W.5	5492- 5614	156156	530	5	37
2	10	73	18	W.5	8106- 8116	174213	580	8	79
4	10	75	6	W.5	5740- 5865	136680	560	4	35
10	31	76	6	W.5	6272- 6288	200334	1200	12	46
2	16	80	9	W.5	5649- 5660	105132	375	9	33
2	33	87	5	W.5	5012- 5075	116528	480	6	8
10	6	91	1	W.5	4020- 4080	182235	100	2	22
12	17	93	21	W.5	5402- 5447	116833	415	18	40
6	15	98	11	W.5	5326- 5354	116306	330	7	40
10	22	100	17	W.5	4806- 4916	204371	395		44
6	32	114	23	W.5	3770- 3805	51088	260	13	34
1	18	119	21	W.5	4040- 4150	59468	270	7	100
10	21	120	23	W.5	3720- 3750	87376	400	15	100
10	21	120	23	W.5	4316- 4345	72329	350	15	172
6	33	113	7	W.6	5425- 5513	87613	320	12	132
3	27	117	4	W.6	4802- 4812	73198	335	8	117
2	7	117	10	W.6	5380- 5407	56371	300	4	112
10	11	118	4	W.6	4936- 4941	89725	395	12	144

Lower Paleozoic

Location					Interval	Cl	Br	I	B
4	13	6	3	W.4	8190- 8210	27246	110	1	24
6	34	71	24	W.5	10033-10061	184801	455	8	29

Granite Wash

Location					Interval	Cl	Br	I	B
4	15	70	2	W.5	6422- 6464	205952	125	14	21
10	23	81	9	W.5	5668- 5734	147996	680	11	41
12	26	81	9	W.5	5675- 5736	147402	700	12	25
12	27	81	9	W.5	5668- 5674	157469	720	13	41
4	34	81	9	W.5	5713- 5737	161662	690	11	38
2	6	88	21	W.5	6287- 6315	122955	510	17	38
6	15	98	11	W.5	5541- 5574	126052	400	14	35
6	15	98	11	W.5	5541- 5574	123227	400	14	55