RESEARCH COUNCIL OF ALBERTA

GEOLOGICAL DIVISION

Preliminary Report 58-5

SODIUM SULFATE DEPOSITS IN ALBERTA

by

G. J. S. GOVETT

Price 50 cents

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Research Council of Alberta
Edmonton, Alberta
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SODIUM SULFATE DEPOSITS IN ALBERTA

Introduction

Sodium sulfate is found as solid salt beds and brines in undrained or poorly drained basins in Manitoba, Saskatchewan, Alberta, and British Columbia. The salt waters generally give an alkaline reaction and they are commonly referred to as "alkali" lakes. Those of Saskatchewan are better known than the others as sodium sulfate has been extracted from them with varying degrees of economic success during the past 40 years. A reconnaissance investigation of naturally occurring sodium sulfate in Alberta was carried out during the summer of 1958 and, on the whole, the general character of the alkali lakes of Alberta seems to be similar to that of the Saskatchewan lakes originally described by Cole (1926) and recently reviewed by Tomkins (1954). The aim of the survey was to locate potentially economic deposits for subsequent more detailed investigation. To this end over 250 lakes were visited in the area from Edmonton eastwards to the Alberta-Saskatchewan border, and southwards to the Alberta-Montana border.

The concentration of sodium sulfate and other salts in lakes in Alberta shows great variation, some lakes are virtually fresh whilst others are saturated with various salts. Lakes containing high concentrations of salts were found to be present only in depressions in glacial drift within areas of rolling topography. The depth of brine in different lakes varies from a few inches to nearly seven feet, and some of the shallower lakes dry up completely during the summer.

According to Cole (1926) two types of crystal beds may be present in the Saskatchewan deposits: (1) a permanent bed which forms the source of the

sodium sulfate in most of the economic deposits, and (2) an intermittent bed which crystallizes or dissolves according to prevailing temperatures and moisture conditions. Intermittent crystal may even form during a cold night, and go back into solution consequent upon a rise in temperature the next day. An intermittent crystal bed was observed forming in several lakes in Alberta during the summer months, but in the absence of drilling data it is not possible to determine with certainty whether a permanent crystal bed is present in any of these lakes.

The methods adopted for the routine investigation of the lakes consisted of measuring the specific gravity and temperature of the lake waters with hydrometer and thermometer (all specific gravity results have been corrected to 15°C). Samples of brine – and in some cases salt – were collected from the lakes of high salt concentration for chemical analyses in the laboratory. In an effort to determine whether crystal beds were present, the bottom of some of the lakes was probed with a pipe.

Acknowledgment

The assistance of L. Bell in the field work necessary for the compilation of this report is gratefully acknowledged.

Forms of sodium sulfate and methods of extraction

Sodium sulfate generally crystallizes as mirabilite ($Na_2SO_4 . 10\ H_2O$) commonly called Glauber's salt. When exposed to the air, as at the margins of the lake, the mirabilite effloresces and collapses to a white powder of anhydrous sodium sulfate (thenardite).

The salt reaches the market in three forms: salt cake, anhydrous sodium sulfate, and Glauber's salt. Salt cake is a crude form of anhydrous sodium sulfate, containing at least 97 per cent of this salt. Anhydrous sodium sulfate is prepared by refining salt cake, and is required to contain at least 99.7 per cent sodium sulfate, and "no calcium or magnesium" (Tomkins, 1954, p. 11). Glauber's salt has purity specifications similar to those of the anhydrous form (Tomkins, 1954).

Extraction of sodium sulfate may be achieved either by mining the permanent crystal bed, or from the brine. In the latter method brine near saturation is pumped into open reservoirs during the summer. Sodium sulfate crystallizes as the temperature drops during the fall, and the remaining liquor is drained back into the lake. Tomkins (1954) stated that the brine method has replaced mining of the permanent bed to a large extent in Saskatchewan.

Subsequent treatment involves the removal of impurities and dehydration of the salt. The dehydration process is the most expensive stage in producing sodium sulfate, and commonly amounts to about half the total production costs (Tomkins, 1954).

Discussion of production methods is beyond the scope of this report but may be found in the report by Tomkins (1954).

Uses of sodium sulfate

The largest single use for sodium sulfate is in the production of kraft paper pulp. Kraft pulp is used largely for making brown paper and similar wrapping materials. The salt should contain at least 96 per cent Na_2SO_4, and

not more than 2 per cent NaCl and 0.5 per cent Fe_2O_3 (Johnstone, 1954, p. 474).

Sodium sulfate is also used extensively in the manufacture of plate and sheet glass. Purity specifications are more rigid than for the pulp industry; the product should contain 95 to 97 per cent Na_2SO_4, and not more than 1 per cent NaCl, 0.01 per cent Fe_2O_3 and 0.3 per cent Al_2O_3 (Johnstone, 1954, p. 474).

Other uses for sodium sulfate are for the manufacture of chemicals, such as sodium carbonate, sodium aluminum sulfate, sodium silicate and sodium sulfide; also in the processing of rayon, wool and other textile fibres, and in the manufacture of synthetic detergents and pharmaceutical goods.

Most of the sodium sulfate used in the world is produced as a by-product during the manufacture of other chemicals. The principal sources are in the manufacture of hydrochloric acid from common salt and sulfuric acid, and the preparation of nitric acid from sodium nitrate and sulfuric acid. Smaller amounts are recovered in a number of other chemical processes, for example, the manufacture of rayon, phenol, chromates, cellophane and boric acid.

Manufactured sodium sulfate is not at present a serious competitor with the natural product in Canada. Although complete figures for recent years are not available for publication, in 1953 by-product sodium sulfate accounted for only 0.2 per cent of the total Canadian production (table 1).

All natural sodium sulfate is at present produced by Saskatchewan, which would be a source of competition to any possible production of sodium sulfate in Alberta, particularly because the Saskatchewan plants are only working at just over half their capacity (Edmunds, 1957).

Table 1: Canadian production and exports of sodium sulfate, 1950-1957

Year	Production			Canadian Exports	
	Natural(1)		By-product(2)		
	Tons	Value $	Tons	Tons	Value $
1950	133,235	1,798,673	3,674	25,335	302,329
1951	192,371	2,383,770	3,297	56,410	735,902
1952	122,590	1,708,807	2,386	24,236	382,274
1953	115,565	1,681,258	2,395	17,975	298,374
1954	167,354	2,595,337	*	58,972	1,039,284
1955	178,888	2,799,715	*	76,894	1,263,911
1956	182,628	2,837,949	*	60,579	985,801
1957	157,789	2,488,333	*	37,023	593,390

(1) Supplied by Industrial Development Office, Saskatchewan
(2) After Edmunds, 1957
* Figures not available

Description of deposits of sodium sulfate in Alberta

Specific gravity readings for some of the lakes visited are shown on figure 1, and the sodium sulfate content of some of these lakes is given on figure 2. The course of crystallization of a natural brine is complex: concentrations of sodium and sulfate ions necessary for precipitation of sodium sulfate salt vary according to the presence of other ions and their concentrations; variation

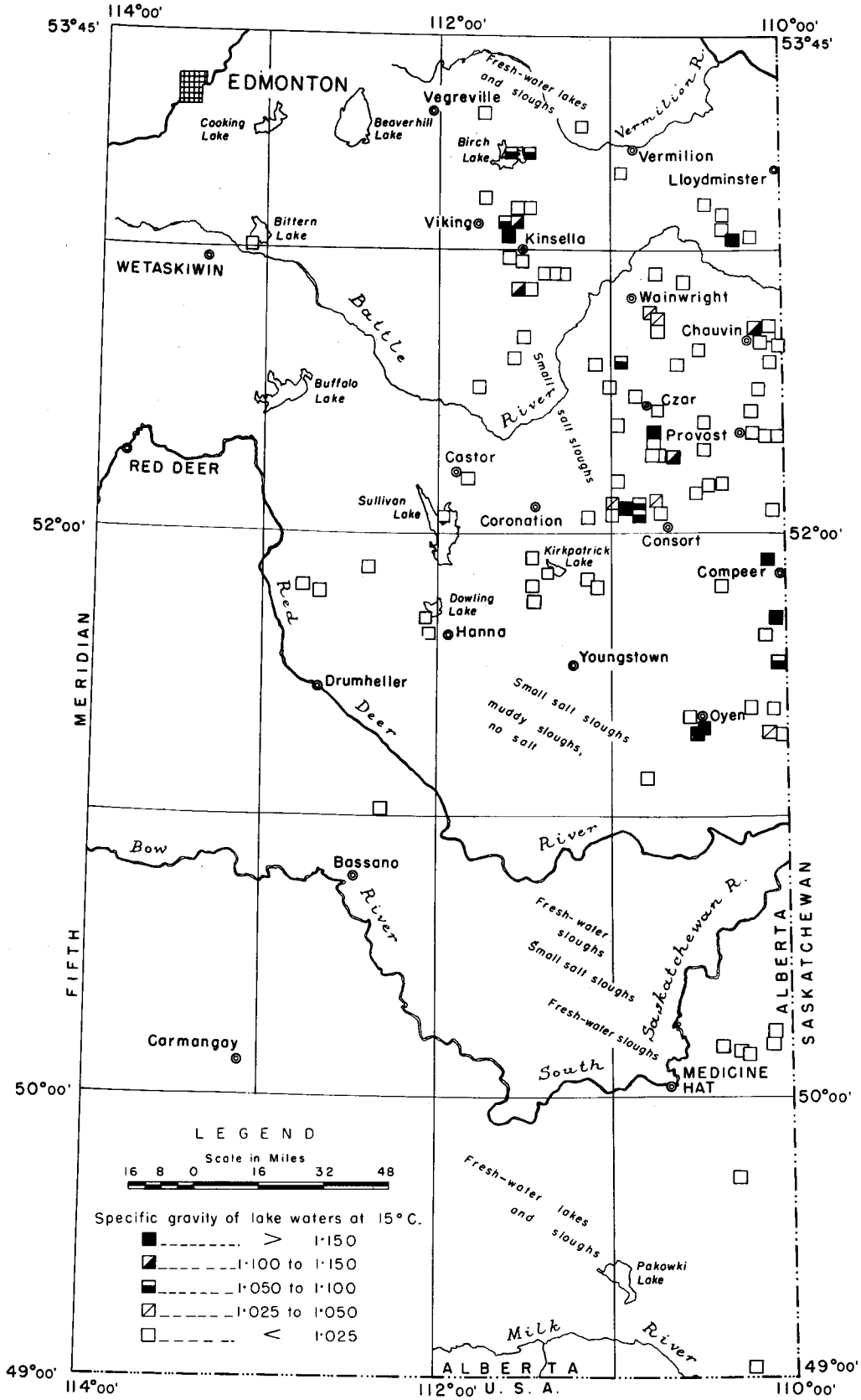

FIG.1 SPECIFIC GRAVITY OF SOME LAKES IN ALBERTA

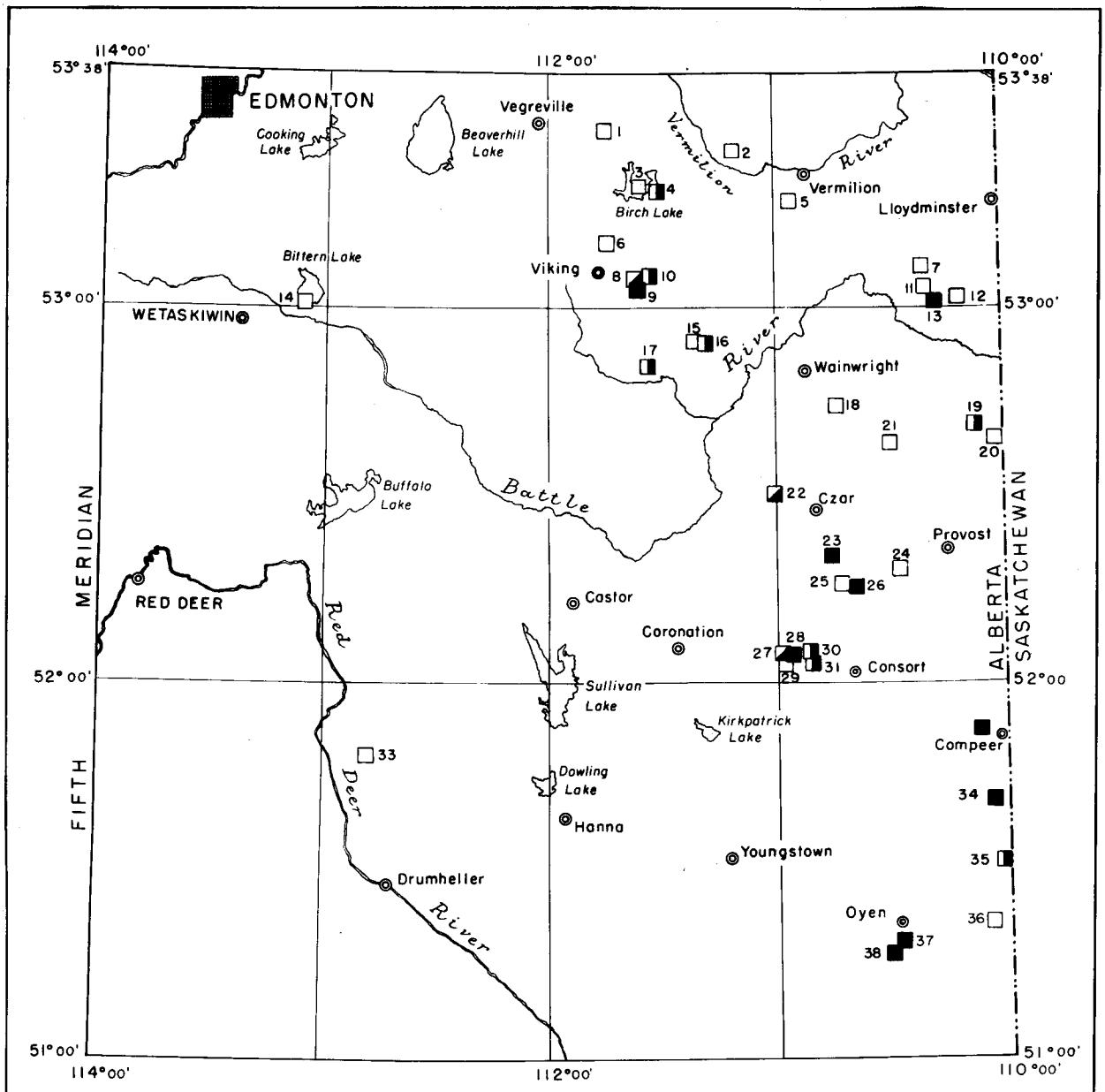

FIG. 2. SODIUM SULFATE CONTENT OF SOME LAKES IN ALBERTA

Scale in Miles

16 8 0 16 32 48

■	> 10 percent sodium sulfate
◨	5 to 10 " " " "
◪	2 to 5 " " " "
□	< 2 " " " "
□26	number of lake described in report

in temperature significantly affects the saturation concentration. Furthermore, a certain undetermined degree of variation in concentration between samples collected from the same lake at different times must be attributed to sampling error, but all variations reported are greater than the analytical error. For these reasons no attempt is made in this report to give a complete interpretation of observed variation in ion concentration. Percentages of compounds – such as sodium sulfate – which are reported here have been calculated on the assumption of complete evaporation of the brine, and the ions which were determined to be present have been combined in their most likely proportions to yield simple salts.

The samples were analysed for sodium, potassium, calcium, magnesium, bicarbonate, carbonate, chloride and sulfate. A brief summary of the analytical methods employed is given below. The sensitivity limits apply to results quoted in this report only; variation in aliquot of sample and strength of reagents permits the sensitivity of the test to be adjusted to suit any particular circumstances.

Sodium and potassium: These two ions were estimated by the internal standard method with a Perkins-Elmer flame-photometer. The lower limit of sensitivity for both sodium and potassium was 0.002 grams per litre.

Calcium and magnesium: Analysis of these two ions was accomplished by titration with standard versene solutions (Shapiro and Brannock, 1956). The lower limits of detection were 0.007 grams per litre for calcium and 0.006 grams per litre for magnesium.

Bicarbonate and carbonate: Both were determined together by titration with a standard solution of sulfuric acid, with phenolphthalein and methyl orange as indicators (Vogel, 1948, p. 302). The lower limit of detection for both bicarbonate and carbonate was 0.02 grams per litre.

Chloride: This determination was made by titration with standard silver nitrate solution with potassium chromate as an indicator (Vogel, 1948, p. 313). The lower limit of detection was 0.01 grams per litre.

Sulfate: Any bicarbonate and carbonate present in the sample was first neutralized with hydrochloric acid. A known excess of standard barium chloride solution was added to the sample and back-titrated with standard potassium sulfate with sodium rhodizonate as an indicator (Vogel, 1948, p. 332). The lower limit of detection was 0.1 grams per litre.

Brine samples were filtered before analysis. Crystal samples were dried at 105°C to constant weight, and then dissolved in distilled water to give a 1 per cent (weight/volume) solution. This solution was analyzed in the same manner as the brine samples. Insoluble matter in the crystal samples was determined gravimetrically.

Lake 8* (Oliva Lake), Lake 9, Lake 10 (Carrier Lake)

Because of their proximity, lakes 8, 9, and 10 are described together. Lake 8 has an area of 153 acres and is located in Sec. 30, Tp. 47, R. 11 W. 4th Mer., Lake 9 has an area of 96 acres and is located in Sec. 29, Tp. 47,

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* Numbers refer to location on figure 2

R. 11, W. 4th Mer., and Lake 10 has an area of 200 acres and is located in Secs. 28, 33, Tp. 47, R. 11, W. 4th Mer. (see figure 3 for detailed map. These lakes are 8 to 10 miles by road from Kinsella.

Lake 8, Oliva Lake, occupies a depression in hilly sandy drift-covered country. Several freshwater springs enter the lake. The lake bed is sandy and there was no evidence of either intermittent or permanent crystal beds. The brine varied from 4 to 6 feet deep in different parts of the lake in September and contained about 4 per cent sodium sulfate and about 2.6 per cent sodium carbonate (table 2).

Table 2: Analyses of brine from Lake 8 (Oliva Lake)

	grams per litre		
	August 5th	August 21st	September 4th
Na	26.52	27.79	29.49
K	n.d.*	n.d.	n.d.
Ca	n.d.	n.d.	n.d.
Mg	0.02	0.02	0.03
SO_4	32.5	33.9	34.4
CO_3	15.84	14.64	13.44
HCO_3	3.22	3.34	5.42
Cl	0.71	0.71	0.78
S.G. at 15°C	1.067	1.064	1.074
Temp. of lake, °C	23.0	24.0	24.0

* n.d. = not detected

Lake 9 is topographically lower than lakes 8 and 10, and is surrounded by sandy hills. The brine was about 2 feet deep in August, and contained about 11 per cent sodium sulfate and nearly 5 per cent sodium carbonate (table 3). Crystal was encountered on the floor of the central part of the lake, although it was mixed with large quantities of mud. Detailed traverses are required to establish the extent and nature of the crystal bed.

Table 3: Analysis of brine from Lake 9

	grams per litre
	August 5th
Na	70.77
K	n.d.
Ca	n.d.
Mg	0.03
SO_4	89.1
CO_3	31.92
HCO_3	7.81
Cl	2.69
S. G. at 15° C	1.165
Temp. of lake, °C	20.0

The brine of Lake 10, Carrier Lake, had a depth of 4 feet in September and contained about 5 per cent sodium sulfate. Sodium carbonate content was comparatively high, being 4.5 to 5 per cent (table 4).

Table 4: Analyses of brine from Lake 10

	grams per litre	
	August 21st	September 3rd
Na	48.83	46.76
K	n.d.	n.d.
Ca	n.d.	n.d.
Mg	0.03	0.06
SO_4	42.8	43.0
CO_3	28.80	31.44
HCO_3	5.12	4.88
Cl	1.30	1.30
S. G. at 15°C	1.106	1.186
Temp. of lake, °C	24.0	24.0

The lake margins and bottom are muddy. In the central part of the lake crystallized sodium sulfate is mixed with mud, but it is not known whether this represents a permanent or intermittent crystal bed. In either case, the crystal bed does not appear to be extensive, although further investigation is required to definitely establish this.

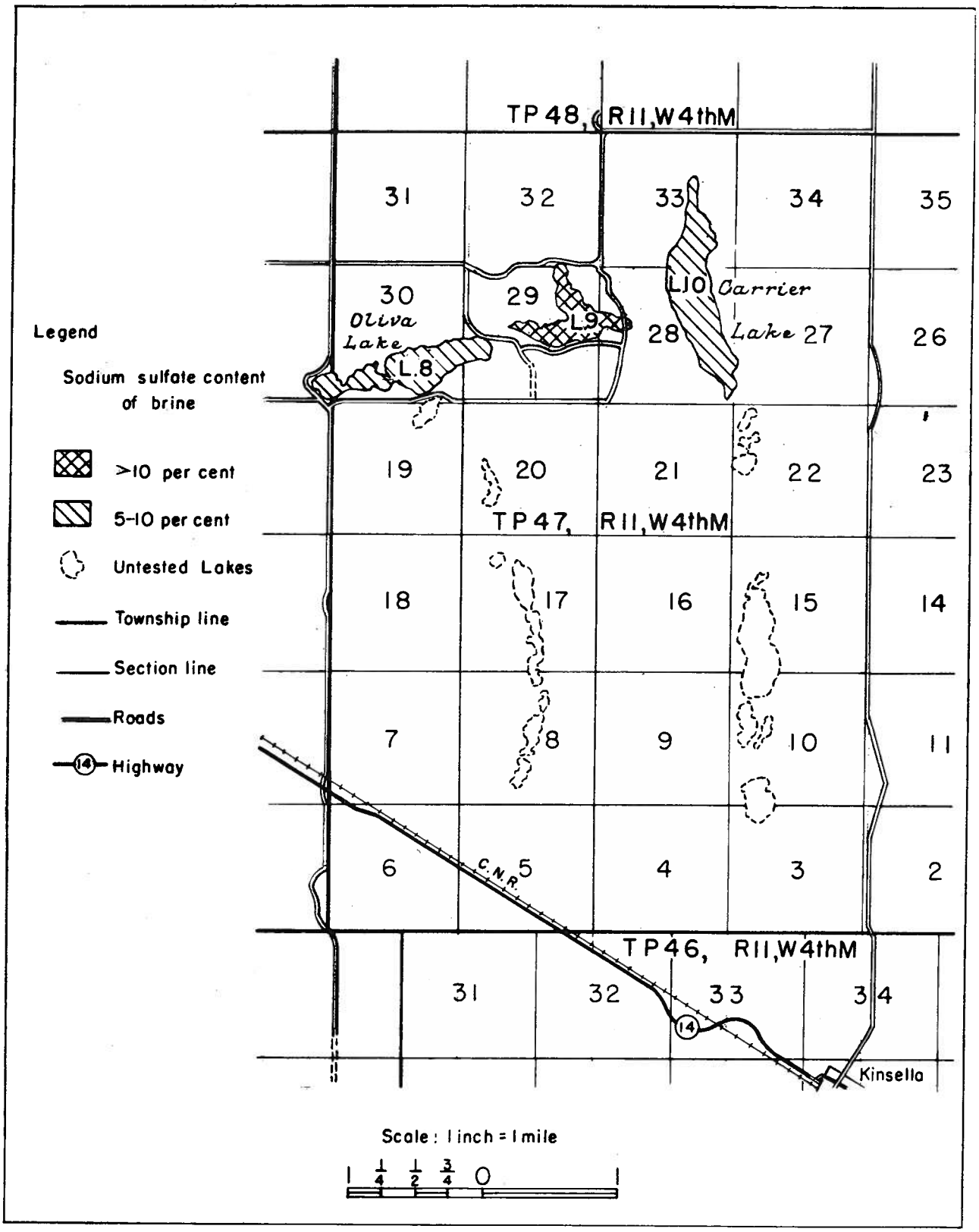

FIGURE 3 **SODIUM SULFATE CONTENT OF SOME LAKES IN THE AREA NORTH OF KINSELLA**

Lake 13

Lake 13 is about 0.5 miles northeast of the town of Paradise Valley and in Secs. 7 and 8, Tp. 47, R. 2, W. 4th Mer. This lake occupies a depression in rolling sandy drift and has a maximum area of about 320 acres.

When visited at the end of June about 160 acres were water-covered and the remaining brine contained about 15 per cent sodium sulfate (table 5).

Table 5: Analysis of brine from Lake 13

	grams per litre
	June 26th
Na	66.69
K	n.d.
Ca	n.d.
Mg	2.30
SO_4	129.7
CO_3	1.80
HCO_3	6.10
Cl	12.00
S. G. at 15°C	1.166
Temp. of lake, °C	24.5

At the end of August the lake was completely dry. The outer margins of the lake were composed of soft mud, overlain by about 0.5 inches of powdery sodium sulfate. The soft mud made it impracticable to traverse the lake, and it is not known whether a permanent crystal bed exists.

Another lake (Sec. 8, Tp. 47, R. 2, W. 4th Mer.), situated 0.25 to 0.75 miles east of Lake 13, has an area of about 128 acres. No sample was taken here, but it appears to have similar characteristics to those of Lake 13.

Lake 23 (Horseshoe Lake)

This crescent-shaped lake is situated 7 miles by road southwest of Metiskow in Secs. 11, 12, 13, 14, 24, Tp. 39, R. 6, W. 4th Mer., and covers an area of just over 640 acres (Fig. 4).

This lake has been fully described by Cole (1926) and received only a cursory examination during the current investigation. Consequently, the following account is derived largely from Cole's reports.

The lake occupies a depression within low rolling hills. The hills are composed largely of boulder clay except to the north where they are formed of sand. Four fresh-water springs enter the lake in the south.

The brine is shallow: Cole (1926) recorded 8 inches in 1924. Cole remarked that an unusual feature of this lake compared with Saskatchewan deposits is the presence of a very high percentage of sodium carbonate. An analysis of the brine made by Cole is shown in table 6.

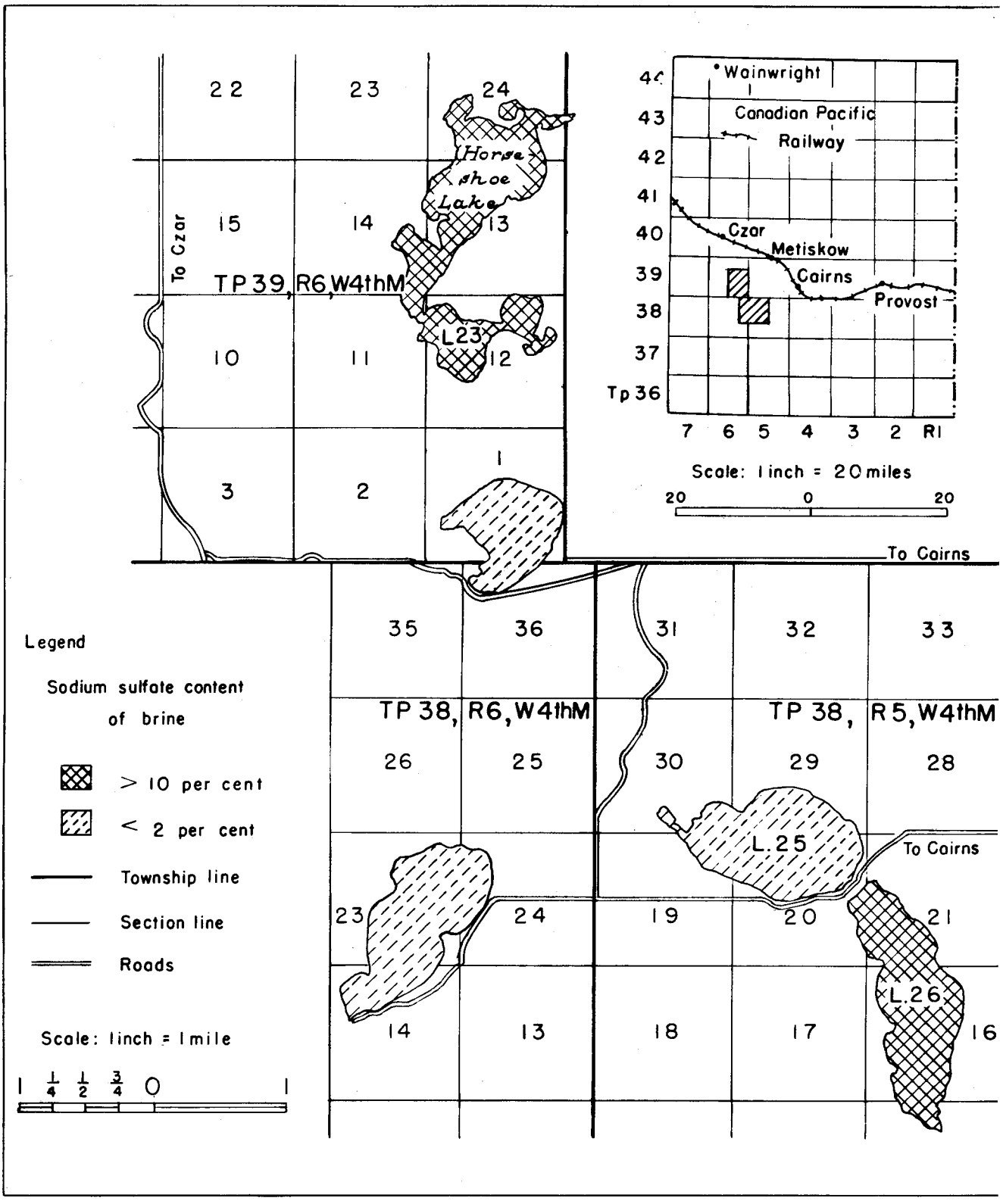

FIGURE 4 **SODIUM SULFATE CONTENT OF SOME LAKES IN THE AREA SOUTH OF CZAR.**

Table 6: Analysis of brine from Lake 23 (Horseshoe Lake)
(after Cole, 1926)

	Parts per million
NaCl	15,480
Na_2CO_3	122,000
$MgSO_4$	8,100
Na_2SO_4	112,000
S. G. at 15° C	1.212

The specific gravity during August, 1958 was found to be 1.186 at 15° C.

Cole was unable to find any evidence of intermittent crystal, but showed that a permanent crystal bed extended under the major part of the lake. This permanent crystal bed consists of alternate layers of pure crystal and of mud and crystal to a depth of 20 to 30 feet, although up to 57 feet of crystal and mud was found in the southern part of the lake. The lower 37 feet of this was hard compact crystal. Cole estimated that five million tons of sodium sulfate mixed with equal quantities of mud were present in this deposit.

Lake 26

Lake 26 is located in Secs. 9, 16, 21, Tp. 38, R. 5, W. 4th Mer. and covers an area of about 500 acres. It is approximately 10 miles southwest of Cairns, and 22 miles southeast of Czar by road (Fig. 4). The lake occupies a sandy depression in hilly country.

The brine was between 1 and 2 feet deep in mid-August, and crystal mixed with mud was found beneath the western part of the lake. At the beginning of September the depth of brine had decreased to a maximum of 1.5 feet, and the entire lake floor was covered by intermittent crystal 0.75 to 1 inch thick.

Analyses for brine and crystal are given in table 7. It may be calculated from these results that the sodium sulfate content of the brine increased

Table 7: Analyses of brine and crystal from Lake 26

	Brine, grams per litre			Intermittent Crystal, per cent
	August 7th	August 20th	September 5th	September 5th
Na	61.60	66.40	69.40	30.80
K	n.d.	n.d.	n.d.	n.d.
Ca	n.d.	n.d.	n.d.	0.01
Mg	0.10	0.10	0.26	n.d.
SO_4	73.2	88.8	70.5	66.2
CO_3	18.90	24.00	33.60	0.60
HCO_3	13.24	10.37	19.03	n.d.
Cl	5.36	4.26	5.32	0.35
Insoluble	-	-	-	3.5
S. G. at 15° C	1.149	1.164	1.166	Total 101.45
Temp. of lake, °C	26.0	20.0	24.0	24.0

from 9.5 to 10.3 per cent during August, followed by a decrease to 8.9 per cent after the precipitation of intermittent crystal in September. The sodium carbonate content of the brine increased during the same period from 2 to 5 per cent, and very little seemed to have crystallized out of the brine by September as the crystal contained negligible quantities of this salt (table 7).

Lake 25 is located in Secs. 19, 20, 29, 30, Tp. 38, R. 5, W. 4th Mer., and covers an area of 460 acres. This lake is less than 0.25 miles to the northwest of Lake 26 and is fresh, the water having a specific gravity of 1.009, no detectable sodium, and 9.3 grams per litre total solids.

Lakes 27 and 28

Lakes 27 and 28 are located about 7 miles north of Highway 12 and 9 miles north of Loyalist (Fig. 5). Lake 27 covers an area of about 160 acres in Secs. 16, 17, Tp. 36, R. 7, W. 4th Mer., and Lake 28 about 350 acres in Secs. 9, 16, Tp. 36, R. 7, W. 4th Mer. Both lie within depressions in hilly drift-covered country.

Lake 28 is probably the best economic prospect of the newly-described lakes in this report. The depth of brine during early August was 1.5 to 2 feet and the entire lake except for the marginal 20 feet appeared to have at least 2 feet of solid crystal on the bottom. At this time no intermittent crystal was observed; in September several inches of intermittent crystal covered the entire lake floor.

The increase of concentration of sodium sulfate in the brine, followed by a sharp decrease as a consequence of the precipitation of intermittent crystal

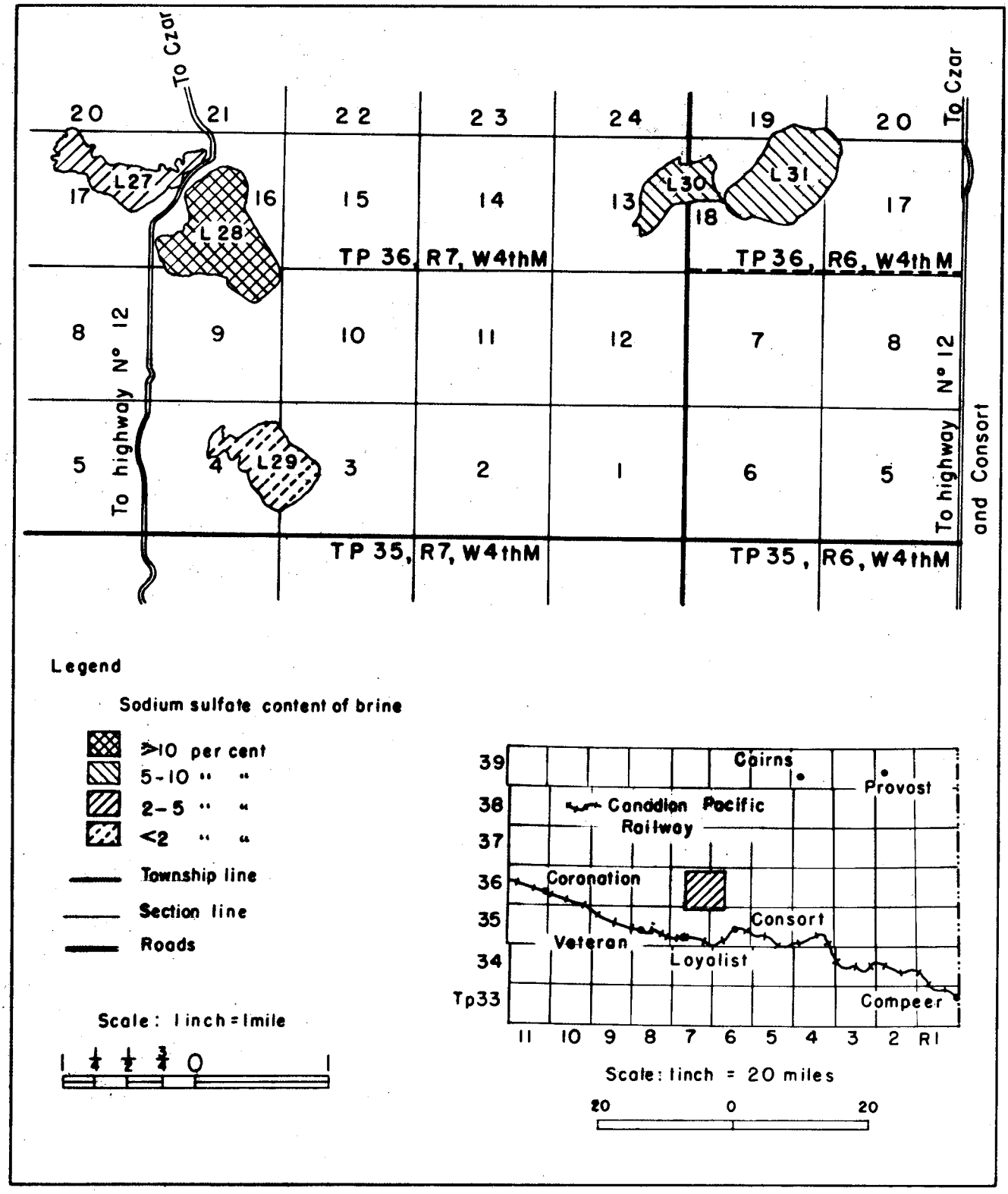

FIGURE 5 **SODIUM SULFATE CONTENT OF SOME LAKES IN THE AREA NORTH OF CONSORT.**

over a period of about three weeks is clearly indicated in the analyses (table 8). The course of concentration-variation of the salts in the brine is comparable to that outlined for Lake 26, although in this case the sodium carbonate content is only about 1 per cent.

Table 8: Analyses of brine and crystal from Lake 28

	Brine, grams per litre			Intermittent Crystal, per cent
	August 9th	August 19th	September 5th	September 5th
Na	59.47	74.10	52.24	30.9
K	n.d.	n.d.	n.d.	n.d.
Ca	n.d.	n.d.	n.d.	n.d
Mg	0.11	0.09	0.11	0.01
SO_4	100.6	112.8	72.7	66.9
CO_3	12.24	12.36	16.56	0.3
HCO_3	3.17	6.22	4.27	n.d.
Cl	3.27	3.12	4.19	0.35
Insoluble	-	-	-	3.00
S. G. at 15° C	1.153	1.176	1.130	Total 101.46
Temp. of lake, °C	25.5	18.0	24.0	24.0

This lake is fed by at least one fresh-water spring which rises in a small slough adjacent to the western shore of the lake. The water entering the lake from this source contained 0.9 grams per litre total solids.

Lake 27 lies about 200 yards to the northwest of Lake 26, just beyond the road which passes between the two lakes. This lake covers an area of about 135 acres in Secs. 16, 17, Tp. 36, R. 7, W. 4th Mer. The brine of this lake contained only about 2 per cent sodium sulfate and had a specific gravity of 1.028 (at 15°C). No significant change was noted in the concentration of the salts during the month of August, and the depth of brine was not estimated.

Lakes 30 and 31

Lakes 30 and 31 are joined by a narrow channel about 10 feet wide, and lie 3 miles east of Lake 28, and about 10 miles by road northwest of Consort. Their location is Sec. 13, Tp. 36, R. 7, and Sec. 18, Tp. 36, R. 6, W. 4th Mer. and their combined area is about 360 acres (Fig. 5).

These lakes fill the bottom of a deep depression in typical hilly drift covered country. The brine was found to contain about 6 per cent sodium sulfate and little carbonate (table 9). No attempt was made to investigate these lakes by boat, but no crystal was seen forming at the margins.

Lake 32 (Coates Lake)

Coates Lake occupies an area of 190 acres in parts of Secs. 16, 20, 21, Tp. 33, R. 1, W. 4th Mer., and is about 7 miles by road southeast of Altario.

The topography is somewhat flatter around Coates Lake than around those lakes previously described. A brine sample was collected in mid-August,

Table 9: Analysis of brine from Lakes 30 and 31

	grams per litre
	August 19th
Na	25.71
K	n.d.
Ca	n.d.
Mg	0.09
SO_4	44.0
CO_3	4.56
HCO_3	2.12
Cl	1.28
S. G. at 15° C	1.061
Temp. of lake, °C	19.0

and was found to contain about 13 per cent sodium sulfate and only a small amount of bicarbonate (table 10). In early September, the lake had dried completely. At this time the margins were composed of soft mud with a thin covering of anhydrous sodium sulfate. Although it was not possible with the equipment available to reach the middle area of the lake, it is believed that a crystal bed is probably not present.

Table 10: Analysis of brine from Lake 32 (Coates Lake)

	grams per litre
	August 19th
Na	57.06
K	n.d.
Ca	0.46
Mg	12.12
SO_4	176.3
CO_3	n.d.
HCO_3	3.90
Cl	9.72
S. G. at 15° C	1.191
Temp. of lake, °C	23.0

Other Lakes and Sloughs

The location and approximate area of some other alkali lakes and sloughs together with some fresh lakes for purposes of comparison are listed in table 11. Analyses for brines from these lakes are given in table 12.

Lake 35 is really three small lakes with connecting channels, and this is probably the only one of those listed in tables 11 and 12 worthy of further investigation.

Table 11: Location and area of some additional lakes in Alberta

Lake Number	Lake Name	Location, W. 4th Mer. Sec.	Tp.	R.	Approximate Area in Acres
1	Akasu	15, 16, 21, 22, 23, 26	52	13	800
2	-	20, 21, 28, 29	51	8	95
3	Birch	12, 13, 24	50	12	4,300
		7, 8, 16, 17, 18, 19, 20 21, 22, 27, 28, 33, 34	50	11	
4	-	NW 1/4, 14	50	11	30
5	-	14, 15	50	7	160
6	Thomas	(32, 33, 34, 35	47	12)	950
		(4, 8, 9, 17	48	12)	
7	-	2	48	3	75
11	-	13, 24	47	3	125
12	-	SW 1/4, 19	47	2	30
14	Bittern	5, 6, 7, 8, 18, 19, 20 21	47	21))	6,500
		1, 2, 11, 12, 13, 23, 24, 25, 26	47	22))	
15	Vernon	(5, 6, 7	46	10)	
		(11, 12, 13	46	11)	480
		(32, 33, 34	45	10)	
16	-	26, 27, 34	45	10	60
17	-	(34	44	10)	55
		(3	45	10)	
18	-	(36	43	6)	45
		(31	43	5)	
19	-	3, 10	43	1	180
20*	Reflex	(35, 36	42	1	1,000
		(1, 2	43	1	(in Alberta)
21	Dolcy	25, 26	42	4	440
22	-	(12, 13	41	8)	380
		(7	41	7)	
24	-	25, 35, 36	38	4	90
29	-	3, 4	36	7	150
33	Mudspring	4, 9, 10, 15, 16, 17 21, 22	33	20	1,400
34	-	35	31	1	30
35	-	(33	30	1	600
		(5	31	1	
36	-	(33, 34	27	1	30
		(3, 4	28	1)	
37	-	16	27	4	100
38	-	15	27	4	60

* This lake extends eastwards for 3 miles into Saskatchewan.

Table 12: Analyses of waters from lakes listed in table 11

Lake Number	Na	K	Ca	Mg	SO_4	CO_3	HCO_3	Cl	Na_2SO_4	S. G. at 15° C	Temp. of lake °C	Date Sampled
				grams per litre					per cent			
1	0.70	n.d.	0.22	0.03	0.0	0.06	0.73	0.00	0.00	1.008	25.0	June 28
2	0.00	2.61	0.07	0.08	0.0	0.00	0.85	0.00	0.0	1.008	25.0	" 25
3	4.62	0.11	0.02	0.03	7.3	1.20	1.58	0.35	1.4	1.016	25.0	" 24
4	27.34	n.d.	n.d.	n.d.	43.3	6.24	3.20	2.14	5.9	1.068	25.5	" 24
5	3.11	n.d.	0.02	0.2	5.1	0.42	0.12	1.07	5.3	1.014	25.0	" 27
6	5.35	n.d.	0.02	0.03	10.5	0.13	0.00	0.71	1.5	1.018	19.0	Aug. 5
7	4.67	n.d.	0.01	0.03	4.0	1.80	3.17	0.28	0.4	1.018	25.0	June 26
11	2.37	n.d.	0.01	0.14	5.2	0.24	0.85	0.14	0.7	1.008	25.0	" 26
12	1.85	n.d.	0.03	0.07	2.6	0.24	1.20	0.07	0.4	1.009	25.0	" 26
14	3.85	n.d.	0.01	0.28	5.9	0.84	0.98	0.11	0.8	1.015	22.5	Sept. 6
15	8.67	n.d.	0.01	0.04	13.0	1.83	2.44	0.46	1.8	1.025	19.0	Aug. 21
16	50.37	n.d.	n.d.	0.03	68.3	20.64	3.17	2.77	8.9	1.124	21.0	" 5
17	38.24	n.d.	n.d.	0.05	57.9	12.48	3.17	1.28	7.6	1.087	22.0	" 5
18	15.41	0.21	0.04	1.31	34.1	0.96	0.12	3.12	1.1	1.045	22.0	" 7
19	49.65	n.d.	n.d.	0.19	70.8	7.80	4.88	16.61	9.4	1.108	28.0	" 6
20	18.67	n.d.	n.d.	0.21	9.4	3.12	2.12	23.00	1.3	1.041	20.0	" 6
21	0.89	n.d.	0.20	0.04	0.0	0.12	0.97	0.11	0.0	1.003	20.5	" 6
22	8.74	n.d.	0.01	1.03	20.1	0.48	1.06	0.32	2.3	1.024	18.0	" 8
24	9.70	n.d.	0.07	0.30	19.2	0.24	1.66	0.28	2.6	1.015	30.0	" 9
29	2.09	n.d.	0.02	0.05	0.9	0.60	0.85	0.07	0.3	1.008	24.0	" 9
33	8.60	n.d.	0.02	0.01	10.4	1.80	1.83	4.12	1.3	1.025	26.0	" 16
34	57.80	7.10	0.29	13.78	140.4	0.08	1.95	15.54	13.0	1.222	12.5	" 19
35	29.57	n.d.	n.d.	2.23	66.8	1.44	0.12	3.1	8.6	1.070	16.5	" 19
36	4.22	0.33	0.09	0.01	11.5	0.72	0.61	0.32	1.2	1.014	22.0	" 11
37	63.13	0.07	0.6	8.77	187.4	0.48	0.73	2.06	15.7	1.200	24.0	" 11
38	68.39	4.95	0.36	12.12	200.0	0.20	0.20	4.97	17.01	1.226	24.0	" 11

Not mentioned in these tables is Dragon Lake, which covers about 600 acres in Secs. 20, 28, 29, 32, 33, Tp. 31, R. 1, W. 4th Mer. This lake was found to be dry in mid-August, and there was no evidence near the margins of the presence of a permanent crystal bed. Also not listed are two small lakes near Minburn, located in Sec. 12, Tp. 50, R. 11, W. 4th Mer. These lakes cover an area of about 25 acres, and the brine contains about 10 per cent sodium sulfate (Cole, 1926).

General Observations

Most of the alkali lakes discussed lie in a climatic zone which has less than 15 inches of rainfall per year, generally high evaporation, and which is subject to drought. Furthermore, it is observed that lakes with a high salt content are restricted to areas of hilly topography. Thus the general factors controlling the distribution of alkali lakes are aridity and topography. The factors controlling the distribution of such lakes in detail are obviously more complex.

Lakes within very short distances of each other may vary markedly in their salt content, for example Lake 28 had about 12.6 per cent sodium sulfate in solution, and Lake 27, lying 200 yards away had only 2 per cent. The most remarkable example of this feature is Lake 37, which contained about 15 per cent of sodium sulfate in solution, whilst several hundred feet away a small slough contained only about 1.5 per cent sodium sulfate in solution. Such examples as these have one common characteristic: the lake containing the highest concentration of salts seems to occupy the lowest topographical depression in the area.

The chemical composition of the glacial drift must be a major factor controlling the distribution of the alkali lakes, and chemical analyses of the overburden in the catchment area of these lakes would be instructive in understanding the mechanics of formation of the lakes.

The brines show a wide variation in the relative concentration of different salts, and this may perhaps be related to the source of the salts. The composition of the salts in the lakes is consistent in only one respect, namely the low concentration of calcium. Cole (1926) suggested that the sodium sulfate in alkali lakes may have been derived by a cation exchange type of reaction between sodium or potassium clays of drift material and calcium or magnesium sulfate in meteroic waters. Certainly the analyses of alkali lakes in Alberta lend indirect support to this hypothesis.

Description of some sodium sulfate deposits in Saskatchewan

A brief description of three of the six deposits of natural sodium sulfate in Saskatchewan being worked in 1954, is given below as a basis of comparison with the Alberta deposits. This account is derived entirely from a report by R. V. Tomkins (1954).

1. Sybouts East Lake

Sybouts East Lake is 3 miles long east to west, and over half a mile wide. In 1951, the brine was reported to be 10 inches deep and to contain 9.81 per cent of sodium sulfate. The permanent crystal bed covers 630 acres and has an average depth of 5.5 feet, and contains about 81 per cent Na_2SO_4,

13 per cent insoluble impurities, and 6 per cent soluble impurities. The total reserves of anhydrous sodium sulfate were calculated to be 3.5 million tons.

2. Chaplin Lake

The lake covers an area of nearly 20 square miles, but has a crystal bed only 6 inches thick. The brine, which is the source of the sodium sulfate, is up to five feet deep and contains 6.6 per cent sodium sulfate. The total reserves, brine and crystal bed, are about three million tons of anhydrous sodium sulfate.

3. Frederick Lake

Frederick Lake has an area of about 825 acres; in 1951 the brine was reported to be 4 inches deep, and had a specific gravity of 1.096. A permanent crystal bed underlies the entire lake and varies in thickness from 3 to 5.5 feet. Analyses show that it contained 85 per cent sodium sulfate, and less than 5 per cent insoluble impurities.

Conclusions

Tomkins (1954) has suggested that reserves of at least 500,000 tons of sodium sulfate should be present for a deposit to be commercially important. At present, the only known deposit in Alberta of possible economic value is Horseshoe Lake, which contains just over five million tons sodium sulfate mixed with about equal quantities of mud. In order to develop the deposit at Horseshoe Lake it is necessary to devise a method to separate the mud from the sodium sulfate in such a way that the resulting product is competitive in price with the cleaner deposits in Saskatchewan.

Better deposits than those described may occur in Alberta. Nevertheless, the results obtained from the investigation during the summer of 1958 do indicate areas where economic deposits may occur, although drilling data are necessary to determine whether it is possible to extract sodium sulfate from them on a commercial scale.

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