POTASH RESOURCES OF NEBRASKA.

By W. B. Hicks.

INTRODUCTION.

The alkali lakes of Nebraska attracted attention many years ago, and about 1900 A. M. McCarty shipped a carload of alkali crust to Omaha from the shores of the lake which now bears his name. After this meager attempt at exploitation interest in these lakes lagged until students of the University of Nebraska became interested in their alkali content, probably as a result of classroom discussion with Profs. Barbour and Condra and of packing-house experience in Omaha. Among these students were J. H. Show and Carl Modesitt, who began exploring the region about 1910 and for several years collected and analyzed the waters of many lakes. Their investigations led them to believe that Jesse Lake offered the best possibilities of commercial exploitation because it contained larger quantities of richer brine and was more favorably located than the other lakes.

Explorations for potash in the region proceeded slowly at first but became more rapid as the value of the deposits began to be recognized. Gradually many data were accumulated, particularly by the potash-producing companies and by Dr. G. E. Condra, of the Nebraska Conservation and Soil Survey. Reports were prepared by Dole, Hance, Ziegler, Barbour, Condra, and others, as indicated in the bibliography on page 139. These authors presented data on the potash content of certain lakes, with other valuable information, but, except for a rather indefinite estimate by Condra, no attempt was made to estimate the quantity of commercial potash brines in Nebraska.

With the primary purpose in view of getting a more precise estimate of the quantity of brine available for potash production in the Nebraska region, the writer spent three months in the fall of 1918 in the region, visited all the potash plants and nearly all the productive lakes, did a considerable amount of exploration, collected many samples of brine, water, sand, and mud for analysis, copied a large amount of unpublished data from the records of producing companies, and obtained much information from Dr. Condra and others in regard to the region. The data thus procured have formed the basis for this report.

Acknowledgments are due to Dr. G. E. Condra, director of the Nebraska Conservation and Soil Survey, who contributed much information concerning the potash region; Mr. W. E. Sharp, president of the American Potash Corporation, who gave free access to his records, which contain a vast amount of data relating to the productive potash lakes; Mr. W. E. Richardson, vice president of the Hord Potash Co., who furnished data regarding the potash lakes on the Hord ranch; Prof. E. H. Barbour, of the University of Nebraska; Messrs. T. E. Stevens, J. H. Show, Carl Modesitt, and Charles Runey, of the Potash Reduction Co.; Mr. W. G. Haldane, of the Western Potash Works; Mr. John O'Brien, of the National Potash Co.; Mr. D. C. Atkins, of the Nebraska Potash Works Co.; Messrs. Frank Abegg and C. L. Emerson, of the Alliance Potash Co.; Mr. R. D. Kirkpatrick, of the Standard Potash Co.; Mr. A. L. Kreiss, of the William Berg Co.; Mr. D. E. W. Jones, and many others.

POTASH LAKES.

Shallow lakes are abundant in depressions scattered all over the sand-hill region of Nebraska. They are reservoirs for rain and spring water, and they range in size from mere ponds to lakes covering about 600 acres and in depth from practically nothing to about 5 feet. Some are fresh; others are nearly saturated with salts; and still others show all degrees of saturation between these two extremes. Some persist throughout the year with little diminution in volume; many of them go completely dry during the summer.

Fresh-water lakes are common in Brown, Cherry, Grant, Arthur, Keith, Box Butte, and Morrill counties, the southern part of Garden County, and the northern part of Sheridan County. They are also scattered through the potash-producing section. Most of them show a heavy growth of grass around the edge and in the shallow water, also muskrat houses in the fall. However, some of the fresh-water lakes are practically free from grass. The bottoms of many of these lakes are pervious or semipervious, affording underground drainage, which explains the freshness of the water. However, a lake that is practically fresh on the surface may rest on a practically impervious layer below which is a subsurface body of strong brine.

Potash lakes as here represented contain alkaline water carrying 1 per cent or more of salts and are often characterized by swarms of flies and a putrefying odor. They occur principally in Sheridan and Garden counties. Many of them dry up in summer. Each one rests on a bottom of impervious mud, below which is usually a subsurface body of salts, which rests on a second impervious bottom.

In some lakes there is a third body of salts and impervious layer. Below the potash deposits beds containing fresh water usually occur. In most lakes only a small portion of the subsurface material contains commercial brines, and in some lakes none of it does.

There are more than 100 known productive lakes in Nebraska, scattered over an area of some 800 square miles and covering an aggregate area of more than 6,097 acres. Many of them are indicated on the accompanying map (fig. 26), and most of them are listed in the following table:

Location and area of productive potash lakes in Nebraska.

Sheridan County.

Name.	Location.	Area (acres).
Acme	Sec. 20, T. 25 N., R. 44 W	7
Ash Nos. 1–4	T. 24 N., R. 44 W	16
Ashburgher	Secs. 13–24, T. 24 N., R. 45 W	37
Bauer	T. 25 N., R. 45 W	60
Bennett	Sec. 28, T. 26 N., R. 45 W	117
D. Briggs No. 1	T. 25 N., R. 45 W	18
D. Briggs No. 2	Secs. 28, 29, 32, 33, T. 25 N., R. 45 W	114
D. Briggs No. 3	Sec. 10, T. 25 N., R. 45 W	17
D. Briggs school sections Nos. 1–5	Sec. 35, T. 26 N., R. 45 W	35
T. Briggs	Sec. 1, T. 25 N., R. 45 W	25
T. Briggs school section No. 1	Sec. 36, T. 26 N., R. 45 W	37
T. Briggs school section No. 2	do	55
Cat	Sec. 7, T. 24 N., R. 45 W	5
Cook	Sec. 8, T. 24 N., R. 45 W	50
Donovan No. 1	Sec. 28, T. 25 N., R. 46 W	18
Fenner Nos. 1–2	Sec. 30, T. 25 N., R. 46 W	44
Floyd	Secs. 32–33, T. 24 N., R. 44 W	200
Hancock	Sec. 17, T. 24 N., R. 45 W	15
Hedge	Sec. 25, T. 26 N., R. 45 W	30
Herrian Pond	Sec. 29, T. 25 N., R. 45 W	7
Ed. Herrian	Sec. 32, T. 25 N., R. 45 W	8
Jesse	Secs. 25–26, T. 25 N., R. 46 W	320
Annie Jesse	T. 25 N., R. 45 W	28
Frank Jesse Nos. 1–2	Secs. 19 and 29, T. 25 N., R. 45 W	30
Joy Nos. 4, 7, 13	T. 26 N., R. 44 W	84
Krause No. 1	Sec. 29, T. 26 N., R. 45 W	90
Krause No. 3	Secs. 21 or 22, T. 25 N., R. 45 W	20
Krause No. 4	do	18
Krause No. 6	Sec. 21, T. 25 N., R. 45 W	16
Lawless Nos. 1–7	Sec. 34, T. 26 N., R. 44 W	28
Lilly	Sec. 33, T. 25 N., R. 45 W	35
Long	Secs. 7, 8, and 9, T. 26 N., R. 45 W	300
Peter Long	Secs. 20, 21, and 29, T. 26 N., R. 44 W	293
McFall	Secs. 22, 26, and 27, T. 24 N., R. 45 W	40
Marks	Sec. 18, T. 26 N., R. 45 W	15
Mulhall	Sec. 32, T. 25 N., R. 44 W	35
Mumper	Sec. 34, T. 24 N., R. 44 W	25
Murray	Secs. 25 and 26, T. 24 N., R. 45 W	8
Oldag	Sec. 22, T. 26 N., R. 45 W	5
Patmore Nos. 1–4	Secs. 3 and 10, T. 25 N., R. 45 W	15
N. C. Peterson Nos. 1–2	Secs. 15, 16, and 22, T. 25 N., R. 46 W	20
Plant	Sec. 22, T. 24 N., R. 44 W	18
Potmesil	Sec. 27, T. 26 N., R. 44 W	33
Rogers-Smith	Sec. 29, T. 24 N., R. 45 W	5
School section	Secs. 15, 16, 21, and 22, T. 26 N., R. 45 W	21
Sessler	Secs. 8 and 9, T. 26 N., R. 44 W	140
Shriner	Secs. 14, 23, and 24, T. 26 N., R. 45 W	105
Snow	Sec. 21, T. 25 N., R. 44 W	80
Stoughton	Sec. 18, T. 26 N., R. 44 W	30
Wilkerson No. 1	Secs. 22 and 27, T. 26 N., R. 45 W	27
Wilkerson No. 2	Secs. 27 and 34, T. 26 N., R. 45 W	55
Wilkerson No. 3	Sec. 27, T. 26 N., R. 45 W	12
Wilkerson No. 4	Secs. 13 and 14, T. 25 N., R. 45 W	81
Windmill	T. 24 N., R. 44 W	5
(Unnamed)	Sec. 36, T. 26 N., R. 45 W	35
Do	Secs. 26, 27, and 34, T. 26 N., R. 45 W	60
		3,107

Total number of lakes, 56.

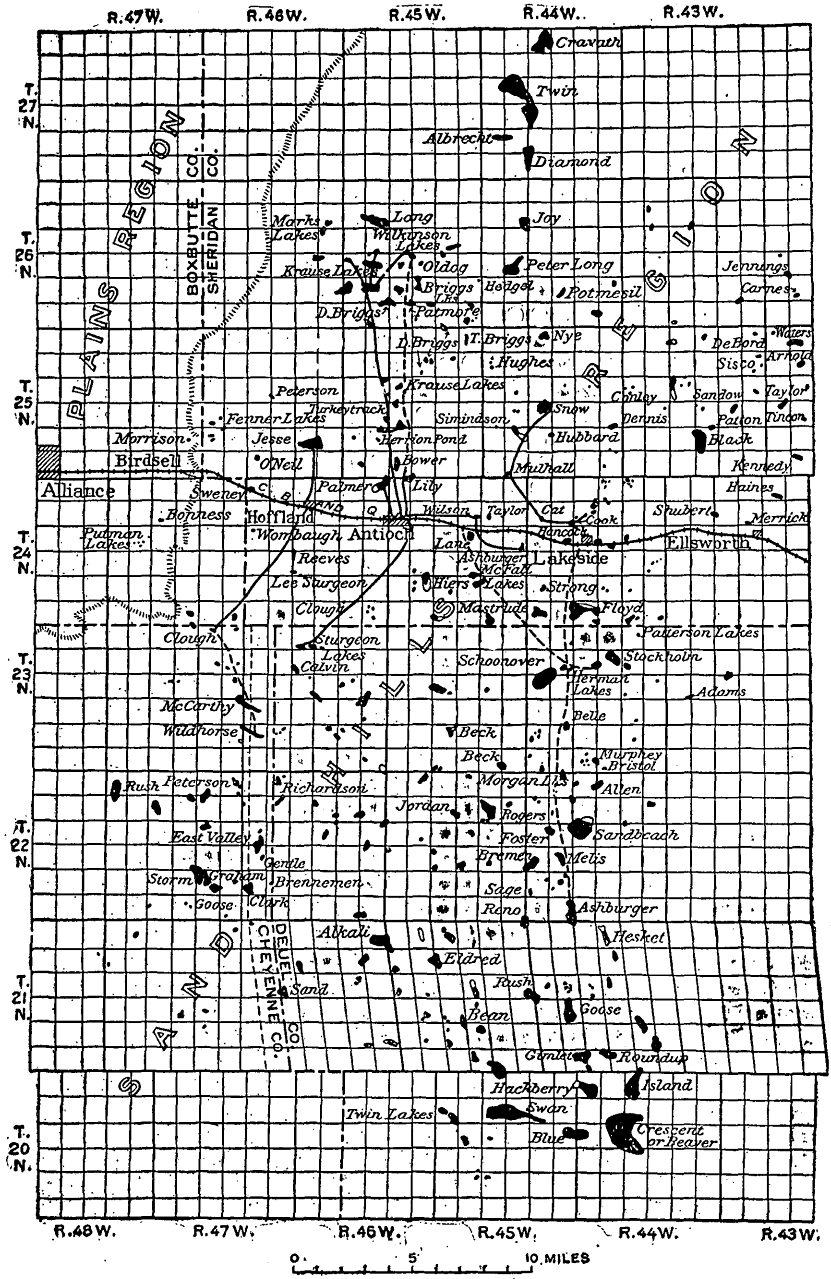

FIGURE 26.—Map showing potash-lake district in western Nebraska. (After the Nebraska Conservation and Soil Survey.)

Location and area of productive potash lakes in Nebraska—Continued.

Garden County.

Name.	Location.	Area (acres).
Alkali	Sec. 1, T. 21 N., R. 46 W	200
Ashburgher	Secs. 32 and 33, T. 22 N., R. 44 W	200
Barbwire	Sec. 5, T. 23 N., R. 44 W	16
Bristol	Sec. 31, T. 22 N., R. 44 W	60
Eldred Nos. 1-2	Secs. 8, 9, 16, T. 21 N., R. 45 W	56
Herman No. 1	Sec. 8, T. 23 N., R. 44 W	100
Herman No. 2	do	25
Do	do	15
Clyde Johnson	Sec. 8, T. 22 N., R. 46 W	70
Miles	Sec. 27, T. 23 N., R. 46 W	26
Richardson	Sec. 5, T. 22 N., R. 46 W	100
Robbins	Sec. 21, T. 23 N., R. 45 W	6
Sturgeon	Secs. 4 and 9, T. 23 N., R. 46 W	90
Little Sturgeon	Sec. 3, T. 23 N., R. 46 W	33
Trester	Secs. 23, 25, and 26, T. 23 N., R. 44 W	150
		1,147

Total number of lakes, 16.

Morrill County.

Name.	Location.	Area (acres).
Archer	Sec. 25, T. 22 N., R. 47 W	25
Clark	Sec. 30, T. 22 N., R. 46 W	115
Clough	Sec. 2, T. 23 N., R. 47 W	15
East Valley	Secs. 18 and 19, T. 22 N., R. 46 W	180
Gentle	Sec. 19, T. 22 N., R. 46 W	37
Ida Rhine	T. 23 N., R. 47 W	100
McCarty	Sec. 19, T. 23 N., R. 46 W	[a] 20
Rock Nos. 1-3	T. 23 N., R. 47 W	10
		502

Total number of lakes, 8.

[a] Small neck in southeast corner of McCarty Lake. The main body of water covers an area of about 300 acres and is practically fresh.

Box Butte and Cherry counties.

Name.	Location.	Area (acres).
Boness	Sec. 9, T. 24 N., R. 47 W	20
Phelan	Sec. 36, T. 24, N., R. 47 W	10
Hathorne	Secs. 21 and 28, T. 34 N., R. 39 W	120
		150

Total number of lakes, 3.

Lakes whose location is in doubt.

Name.	Location.	Area (acres).
Avery	(?)	22
Bluestem	T. 23 N., R. 46 W	80
Butch	(?)	15
Cody No. 1	T. 26 N., R. 45 W	65
Cody No. 2	do	33
Cowlin	(?)	18
Gammon	T. 26 N., R. 45 W	20
Kent	do	40
Kicken No. 1	T. 22 or 23 N., R. 45 W	280
Kicken No. 2	do	35
Kicken No. 3	do	3
Krause school section	T. 26 N., R. 45 W	75
Mitchell	do	80
Rice Nos. 1-6	T. 23 N., R. 47 W	200
Little Sessler	(?)	17
Thompson No. 1	T. 24 N., R. 45 W	40
Thompson No. 2	do	48
Wilson	(?)	120
		1,191

Total number of lakes, 18.

In addition to the lakes listed in the table there are a number of reported productive lakes about which very few data are at hand. These are listed on page 132.

POTASH RESERVES.

Early in 1918 Condra[1] made an estimate of the supply of high-testing productive brines and stated that it would be greatly reduced in four years if the rate of production at that time continued. This estimate corresponded to more than 100,000 tons of potash (K_2O) and was moderate considering the data available. Since Condra's estimate was made the potash-producing companies have continued their explorations to such an extent that they now have more or less reliable data on most of the lakes that show any indication of potash. However, this does not signify that the region has been explored thoroughly, as it is known that a considerable number of productive lakes have been very incompletely explored, that nearly fresh lakes which show no indication of potash on the surface may contain productive brines in the subsurface sands, and that some wells sunk in valleys at a considerable distance from lake beds have encountered low-grade potash brines.

Through the courtesy of the potash-producing companies and Dr. Condra, information concerning most of the potash-yielding lakes has been made available for use in the preparation of this report. The data on individual lakes are of a confidential nature and can not be disclosed. They are approximately complete for some lakes and very incomplete for others. Largely with such information as a basis, an attempt has been made to calculate the quantity of potash in the known producing lakes. In the calculation an acre-foot of brine containing 10 per cent of solids was considered to weigh 1,450 tons and an acre-foot of 5 per cent brine 1,400 tons. For convenience in estimating subsurface volumes the voids were placed at 33⅓ per cent, which is somewhere near the truth. The result should be considered simply as a rough estimate. It is in all probability a minimum, (1) because there are probably a good many unexplored productive lakes, (2) because the reported productive subsurface area of most of the lakes is small compared with the surface area, and undoubtedly other parts of the subsurface material contain at least low-grade brines, and (3) because small quantities of potash leached from the surrounding hills are continually being carried to the lakes.

All the productive lakes about which sufficient data were at hand to form a basis for an estimate were included in the calculations, and

[1] Condra, G. E., Preliminary report on the potash industry of Nebraska: Nebraska Conservation and Soil Survey Bull. 8, p. 36, 1918.

these lakes are listed on pages 127–129. A summary of their estimated potash content is shown in the following table:

Estimated potash content of productive lakes in Nebraska.

County.	Area (acres).		Brine (short tons).	Solids (short tons).			Potash (K_2O) (short tons).
	Surface.	Sub-surface.		Surface.	Sub-surface.	Total.	
Sheridan	3,107	697	15,872,000	146,590	329,215	475,805	115,360
Garden	1,147	196	4,655,000	103,150	83,440	186,590	40,910
Morrill	502	130	2,607,700	40,880	42,020	82,900	17,670
Box, Butte, and Cherry	150	38	266,000	750	13,720	14,470	2,440
In doubt	1,191	263	9,353,000	76,260	105,190	181,450	38,730
	6,097	1,324	32,753,700	367,655	573,585	941,215	215,110

The data on productive lakes in Sheridan County are further classified according to townships in the following table:

Estimated potash content of productive lakes in Sheridan County, Nebr.

Township.	Area (acres).		Brine (short tons).	Solids (short tons).			Potash (K_2O) (short tons).
	Surface.	Sub-surface.		Surface.	Sub-surface.	Total.	
T. 25 N., R. 46 W	402	214	1,429,000	26,440	128,170	154,610	42,920
T. 24 N., R. 45 W	160	63	554,000	2,200	37,360	39,560	8,780
T. 25 N., R. 45 W	492	131	1,527,000	21,345	41,690	63,035	12,500
T. 26 N., R. 45 W	1,059	106	9,180,000	41,920	57,280	99,200	20,550
T. 24 N., R. 44 W	264	104	1,307,000	20,715	35,285	56,000	15,580
T. 25 N., R. 44 W	122	37	326,000	5,550	19,750	25,300	5,060
T. 26 N., R. 44 W	608	42	1,549,000	28,420	9,680	38,100	9,970
	3,107	697	15,872,000	146,590	329,215	475,805	115,360

About one-third of the potash in the productive lakes is represented by brines containing 10 per cent or more of solids, nearly half by brines containing from 5 to 10 per cent of solids, and less than one-fourth by brines containing from 1 to 5 per cent of solids. These data are shown in the following table:

Estimated potash content of productive lakes in Nebraska classified according to strength of brines.

[Short tons.]

County.	10+ per cent brine.		5 to 10 per cent brine.		1 to 5 per cent brine.		Total.	
	Solids.	K_2O.	Solids.	K_2O.	Solids.	K_2O.	Solids.	K_2O.
Sheridan	189,710	49,665	169,495	36,540	116,600	29,155	475,805	115,360
Garden	3,140	940	131,860	29,950	51,590	10,020	186,590	40,910
Morrill	28,440	6,230	21,530	4,840	32,930	6,600	82,900	17,670
Box Butte and Cherry			13,720	2,310	750	130	14,470	2,440
In doubt	54,600	11,600	107,070	22,930	19,780	4,200	181,450	38,730
	275,890	68,435	443,675	96,570	221,650	50,105	941,215	215,110

In addition to the productive lakes whose estimated potash content is indicated in the foregoing pages, there are a good many reported productive lakes, particularly in Sheridan and Garden counties, about which very few data are at hand. Among these lakes are Backus, Beck, Boyer, Butcher, Camp, Cary, Curb, Gaunt, Gillis, Hog Valley, Krause No. 2, Howard Miller, Josh Miller, Murphy, Old Lady, Patton, Peterson, Sand, Sand Hill, Schoonover, Sam Smith, Taylor, Tin Barn, and Wild Horse. They cover an area of about 2,000 acres and probably contain about 250,000 tons of solids, including 50,000 tons of potash (K_2O). If these figures are approximately correct, they more than balance the 48,000 tons of potash (K_2O) which had been produced from the Nebraska mines by the end of 1918.

Immense quantities of water which contain less than 1 per cent of solids but which carry relatively high percentages of potash in the solids occur throughout the potash-producing region and also far to the east in Cherry, Grant, and other counties. Some idea of the volume of such dilute surface waters in the region may be gained by considering reports on certain groups of lakes in Sheridan, Garden, and Cherry counties. Data on 27 lakes in Sheridan County, including Collins, Donnahue, Goose, Johnson, Krause, Ranch House, Reed, Ross, Twin, and some 19 lakes on the Spring ranch scattered over the productive region, indicate that these lakes cover an aggregate area of about 3,000 acres and contain 12,000,000 tons of surface water, 40,000 tons of solids, and about 10,000 tons of potash (K_2O). Data on 54 weakly alkaline lakes in Garden County indicate a surface area of 2,200 acres, 11,000,000 tons of water, 25,000 tons of solids, and 5,000 tons of potash. Data on 16 selected lakes in the vicinity of Merriman, in Cherry County, including all that have shown the best indications of potash, namely, Club House, Eli, Hale, Hathorne, Jessen, Mud, Nelson, Preacher, Round, S. B., Snyder, Snyder's Goose, Steel, Steer, Twin, and Walker lakes, indicate an aggregate area of about 2,000 acres, 10,000,000 tons of surface water, 50,000 tons of solids, and 10,000 tons of potash. There are many other lakes containing a very low percentage of solids scattered throughout the productive region or bordering on it, so that the actual quantity of potash in such surface waters is probably several times as great as that indicated by the data cited. Moreover, it is probable that the quantity of such dilute waters in the subsurface sands exceeds that at the surface.

COMPOSITION OF BRINES.

Commercial potash brines vary much in salinity and in the composition of the dissolved salts. The salts are composed of carbonates, bicarbonates, sulphates, and chlorides of sodium and potassium in varying proportions. Carbonates usually predominate, bicarbonates are high, and sulphates are variable but often high. The following analyses of selected brines from lakes in widely separated parts of the productive region are probably representative:

Composition of productive potash brines in Nebraska.

[E. T. Erickson, analyst.]

	1	2	3	4	5	6	7	8	9	10	11
K	12.89	14.51	23.84	11.03	23.40	18.21	20.82	21.93	7.60	22.94	17.72
Na	28.33	28.56	19.05	29.60	20.74	25.49	23.05	21.77	30.11	20.49	24.72
Cl	2.36	5.58	4.15	3.99	3.71	6.16	1.47	2.36	14.62	4.61	4.90
SO_4	4.72	1.10	20.02	1.90	14.84	3.29	11.90	12.44	20.28	5.90	9.64
CO_3	30.33	36.27	21.65	33.80	26.52	34.43	31.42	28.39	14.13	28.65	28.56
HCO_3	21.37	13.90	11.20	19.52	10.69	12.36	11.34	13.07	13.26	17.41	14.41
SiO_2	....	.08	.09	.16	.10	.06	....	.04	....	....	.05
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Salinity	2.67	6.34	5.36	3.79	4.49	10.52	5.17	7.12	3.09	2.73	......
K_2O equivalent	15.54	17.50	28.75	13.30	28.20	21.95	25.10	26.42	9.15	27.65	21.32
Specific gravity at 25° C.	1.022	1.056	1.044	1.033	1.038	1.096	1.044	1.062	1.025	1.022	......
Ratio Na/K	2.20	1.97	0.80	2.69	0.89	1.40	1.11	0.99	3.95	0.89	140

1. Alkali Lake.
2. Ashburgher Lake (Garden County).
3. Floyd Lake.
4. Hathorne Lake.
5. Jesse Lake.
6. Mitchel Lake.
7. Phelan Lake.
8. Plant Lake.
9. Stoughton Lake.
10. Sturgeon Lake.
11. Average.

Jesse Lake has yielded far more potash than any other lake of the sand-hill region and consequently is relatively of greater interest. Three analyses of brine from this lake are tabulated below.

Composition of potash brines from Jesse Lake.

	1	2	3	4
K	22.35	25.10	23.40	23.62
Na	21.10	18.41	20.74	20.08
Cl	3.20	3.99	3.71	3.63
SO_4	14.60	16.18	14.84	15.21
CO_2	28.86	26.52	26.52	27.30
HCO_3	9.89	9.80	10.69	10.13
SiO_2	....	....	.10	.03
	100.00	100.00	100.00	100.00
Salinity	12.39	19.32	4.49	12.07
K_2O equivalent	27.16	30.25	28.20	28.53
Ratio Na/K	.94	.73	.89	.85

1. Jesse Lake water. Colorado School of Mines Quart., vol. 10, No. 3, p. 21, 1915; J. H. Show, analyst.
2. Brines from subsurface sand 300 feet from shore, collected in 1912; J. F. Breazeale, analyst.
3. Brine from subsurface sand from east side of lake, collected in 1918; E. T. Erickson, analyst.
4. Average.

NOTE.—Analyses 1 and 2 have been recalculated to ionic form and to 100 per cent by W. B. Hicks.

The foregoing analyses are believed to represent fairly well the composition of the productive brines of the potash region. They indicate that the average composition of the brines of the region is very similar to that of the brine of Jesse Lake, although the latter is richer in potash. It should be noted in this connection that the brine of Richardson Lake is said to be composed almost exclusively of carbonates, and the brine of one of the Wilkerson Lakes is so rich in sulphate that large quantities of sodium sulphate crystallize out of it in cold weather. There may be other abnormalities, but most of the brines conform to the type indicated in the tables.

ORIGIN OF NEBRASKA POTASH.

The geologic history of Nebraska as generally interpreted[2] precludes any deep-seated origin of the potash brines in the sand hills. The Dakota sandstone, which contains fresh water, lies 2,500 feet or more below the surface and is covered by several hundred feet of Benton and Niobrara strata, overlain by the Pierre shale, an impervious formation, in places more than 2,000 feet thick. Above the Pierre shale are a number of formations which were deposited in shallow lakes and which carry fresh water where they are water bearing. The deposits forming the sand hills are probably about 100 feet thick in the valleys of the potash region. Nearly all the waters from depths greater than 30 feet in this region that have been analyzed are practically fresh, and the composition of the dissolved salts, so far as known, is distinctly different from that of the productive brines. Underground waters tributary to the sand-hill region from the west and northwest are also fresh and differ in composition from the waters of the potash section. These facts seem to show conclusively that potash brines in the sand-hill region are confined to a relatively thin layer near the surface.

Petrographic examination by E. S. Larsen of 13 samples of sand collected by the writer from the potash region, including potash-bearing sands of Jesse Lake and other localities, shows that they are composed largely of quartz, feldspar, and volcanic ash and are practically free from clay, calcareous matter, and other cementing materials. Quartz makes up more than half of the material; plagioclase ranging from albite to labradorite and mostly andesine is next in abundance; potash feldspar usually makes up several per cent of the samples. Volcanic-glass fragments of the kind that make up rhyolitic ash beds are present in all the samples and range in amount from about 1 to 5 per cent. Fragments of chert or related material are rather abundant. Hornblende, augite, tremolite, biotite, epidote, garnet, zircon, titanite, magnetite, apatite, calcite, and hypersthene are present in very small amounts, and minute needles of an unidentified mineral are rather abundant in some of the quartz

[2] See bibliography (p. 139), particularly the report by Darton.

and feldspar grains. For the most part the mineral grains and volcanic glass are but slightly decomposed or altered. These sands differ from ordinary sands in the abundance of feldspar, especially plagioclase, in the freshness of all the minerals, and in the presence of volcanic glass. They are sands such as might be formed under conditions of aridity from andesitic and latitic tuffs with some admixture of ordinary quartz-rich sands, such as are commonly derived from the weathering of granites and similar rocks.

Samples of fine sandy material known as Box Butte clay, from the table-land northwest of the potash region, contain probably from 10 to 20 per cent of volcanic glass, 5 per cent of potash feldspar, and a considerable amount of fine material composed of calcite, clay, etc. The glass is more or less altered.

Potash is contained in the sands principally as a constituent of potash feldspar and of volcanic glass, and the percentage is not exceptional. Such potash is present in insoluble combinations and is rendered soluble in nature only after prolonged weathering. The freshness of the mineral grains of the sands and the comparatively slight indications of alteration as shown by petrographic analysis lead to the belief that no large quantity of the potash in these sands has been rendered soluble by weathering processes and that the sands can not be considered the direct source of the potash in the productive lakes of Nebraska. The potash content of a number of samples of sands from the potash region and vicinity is shown in the following table:

Percentage of potash (K_2O) in Nebraska sands.

[E. T. Erickson, analyst.]

No.	Description.	Percentage of potash (K_2O).
S- 7	Wind-blown sand along Niobrara River	2.15
S-10	Sand from 4-foot hole at Hay Springs	2.52
S- 6	Sand from 7-foot hole on southwest bank of Broncho Lake	2.54
S- 4	Sand from blow hole 4 miles north of Antioch	1.95
S- 3	Sand from 4-foot hole on north bank of Boness Lake	2.82
S-18	Sand from depth of 3½ feet at south end of Jesse Lake	2.56
S-24	Sand from depth of 15 feet at south end of Jesse Lake	2.58
S- 1	Sand from depth of 12 feet in Jesse Lake	2.29
S- 5	Sand from potash horizon in McIntyre Lake	1.86
S-52	Sand from depth of 10 feet in Stoughton Lake	2.43
S-38	Sand from depth of 10 feet in Eli Lake	1.81
S-12	Sand clay 4 miles west of Gordon	2.43

Dilute waters from the table-land immediately northwest of the potash region are low in potash and rich in sodium and calcium and have little relation to the potash brines of the sand hills. The following four analyses probably represent typical waters of this region:

Composition of dilute waters northwest of and adjacent to the Nebraska potash region.

[Samples collected Nov. 17, 1918. E. T. Erickson, analyst.]

	1	2	3	4	5
K	0.76	1.14	1.25	0.93	1.02
Na	8.81	13 11	10.72	12.70	11.34
Ca	12.84	9.31	9.73	7.66	9.89
Mg	1.51	1.14	2.50	4.49	2.41
Cl	7.6	1.14	2.74	6.73	2.84
SO_4	2.77	14.10	1.99	11.60	7.61
CO_3	....	....	....	....	....
HCO_3	58.95	49.05	56.37	42.99	51.84
SiO_2	13.60	11.01	14.70	12.90	13.05
	100.00	100.00	100.00	100.00	100.00
Salinity	397	526	401	535	465
Ratio Na/K	11.6	11.5	8.6	13.6	11.1

1. Niobrara River water at bridge on road from Alliance to Hay Springs.
2. Water from well 54 feet deep on Watson's farm, 26 miles north of Alliance.
3. Water from well 90 feet deep at Hay Springs.
4. Water from wells 200 feet deep at Gordon (city water supply)
5. Average.

The ratio of sodium to potassium in these dilute waters is about 11.1 to 1, whereas the ratio of sodium to potassium in the brine of Jesse Lake is 0.85 to 1 and the average ratio in the brines of the potash region is 1.4 to 1. (See table below.) These figures show conclusively that the dilute waters represented in the preceding tables of analyses are not the main source of potash in Nebraska.

Dilute waters from beds underlying Jesse Lake and vicinity are somewhat similar in composition to the dilute waters northwest of the region, but one conspicuous difference is that they are much richer in potash. Their potash content and their general composition can be explained by considering them as mixtures of dilute waters such as are represented in the preceding table and of dilute waters having a saline content similar in composition to that of the waters of Jesse Lake. The second group of dilute waters would represent leaching of the sand hills. The composition of such a mixture would depend on the relative proportion of the two types of waters and also on the exact composition of the two waters making up the mixture. Analytical data on three samples of water from beds underlying Jesse Lake and vicinity are given in the following table:

Composition of waters from beds underlying Jesse Lake and vicinity.

[E. T. Erickson, analyst.]

	1	2	3	4
K	5.38	8.45	7.54	7.12
Na	4.40	5.81	15.30	8.50
Ca	8.87	5.87	4.79	6.51
Mg	4.66	4.11	.91	3.23
Cl	....	....	3.88	1.29
SO_4	6.39	7.25	.46	4.70
CO_3	4.66	....	....	1.55
HCO_3	51.11	51.24	53.42	51.93
SiO_2	14.53	17.27	13.70	15.17
	100.00	100.00	100.00	100.00
Salinity	387	341	438	....
Ratio Na/K	0.82	0.69	2.03	1.20

1. Water from well half a mile north of Jesse Lake.
2. Water from 98-foot well on edge of hill 150 yards southwest of Jesse Lake.
3. Water from artesian well in Jesse Lake.
4. Average.

As is indicated in the following table, dilute waters east and northeast of the potash region are richer in potash than the dilute waters from the northwest represented on page 136.

Composition of dilute waters east and northeast of the Nebraska potash region.

[E. T. Erickson, analyst.]

	1	2	3	4
K	2.71	3.41	2.51	2.88
Na	6.10	9.78	7.19	7.69
Ca	11.77	9.79	8.08	9.87
Mg	1.01	1.28	5.02	2.44
Cl				
SO_4		.85		.28
CO_3	4.23		2.07	2.10
HCO_3	50.40	50.21	65.40	55.34
SiO_2	23.78	24.68	9.73	19.40
	100.00	100.00	100.00	100.00
Salinity, parts per million	236	235	638	
Ratio Na/K	2.25	2.87	2.86	2.67

1. Water from Niobrara River near Valentine.
2. Water from 96-foot cased well at Merriman (city water supply).
3. Water from 150-foot railroad well at Hyannis.
4. Average.

The ratio of sodium to potassium in the dilute waters east and northeast of the potash region as represented in the foregoing table is 2.67 to 1. Relatively this means a much larger percentage of potassium than is contained in the dilute waters northwest of the potash region. The increased percentage of potash is no doubt due, at least in part, to admixture of leachings rich in potash from the sand hills, which means simply that potash is gradually leaving the sand-hill region through surface and underground drainage.

There appears to be a subsurface drainage in the potash region from the northwest toward the southeast, and it is presumed that considerable quantities of potash are leaving the potash region through this means. Unfortunately no analytical data are available to show the potash content of dilute waters southeast of the potash region.

The alkali content of the lakes of the potash region is such as might result from various mixtures of the leaching of plant ashes and of sediments. As has been pointed out by Hance, Ziegler, and others, the quantity of alkali would not require any excessive growth of vegetation in the region or to the northwest to account for the potash. It is therefore concluded that the alkali content of these lakes was derived primarily from the leaching of vegetable ashes resulting from many destructive fires, and to a lesser extent from the leaching of underlying rocks. On the assumption that this view of the origin of potash in Nebraska is correct, the following suggestions are offered with the hope that they may throw some light on existing conditions in the potash region and on the potash reserves.

Such leachings of ashes and underlying rocks from the table-land to the west and northwest and also from the sand hills themselves were partly absorbed by the sand and partly concentrated in valleys. In the valleys the leachings finally reached the lowest areas, where they were absorbed by the sand and concentrated by evaporation, forming intermittent lakes. At the same time there was present a body of ground water such as now underlies the region to the northwest and probably the sand hills, which was being forced to the surface by capillarity or otherwise and which was being concentrated by evaporation. The intermingling of the leachings and of the ground water at the proper concentration caused the precipitation of carbonates and silicates of calcium and magnesium and the deposition of sediments, which finally formed an impervious layer between the ground-water horizon and that of the leachings. In Jesse Lake such an impervious layer was laid down at a depth of about 15 feet from the surface. The leachings coming into the lake were continually concentrated by evaporation, until in Jesse Lake the brines contained more than 10 per cent of solids. At the same time the leachings carried into the basins small quantities of clay and other fine-grained materials, which were deposited in large part on the floors of the lakes and which finally formed a more or less impervious layer of mud between the present surface lakes and the subsurface potash beds.

Some of the leachings did not reach the low valleys but were absorbed by the sands on the hills and slopes. In dry weather the leachings thus absorbed were forced toward the surface by capillarity and were gradually concentrated by evaporation. Finally the sand hills as well as the valleys contained potash-bearing waters, but as most of the leachings reached the valleys and only a comparatively small portion was absorbed on the hills and slopes the great bulk of the potash of the region was concentrated in the lakes of the valleys. After the last destructive fire and the final leaching of the ashes rain water falling on the sand hills was absorbed by the sands and mixed with the potash-bearing waters already there, and this mixture gradually made its way to the potash lakes. Such a process of leaching out the potash in the sand hills is believed to be in progress to-day. The leachings are probably very dilute, such as are represented by the fresh waters in the beds underlying Jesse Lake, as shown on page 136, but the composition of the dissolved salts is more probably similar to that of the productive potash lakes.

This view implies that only small quantities of potash are being leached from the sand hills and reaching the potash lakes and that no large potash reserves are likely to be found in regions not occupied by lakes. It is assumed, however, that some potash lakes may have been covered over by sand when the hills were shifting as sand dunes and that much of the potash thus covered may not have yet been leached out. Such conditions are believed to be exceptional.

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