DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Professional Paper 95

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

1915

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1916

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THE COMPOSITION OF MUDS FROM COLUMBUS MARSH, NEVADA.

By W. B. Hicks.

INTRODUCTION.

The investigation of the dry lake of Columbus Marsh, in Nevada, which had for its economic motive the discovery of potash, was continued by the United States Geological Survey during the summer of 1913 under the supervision of Hoyt S. Gale. The work done included the drilling of a shallow well near the old well 400 and the collection of a set of surface samples of muds from the marsh. This exploration, together with the chemical investigation of the samples thus collected, has furnished further data concerning the character of the mud flat and thrown additional light on the conditions there.

The writer was associated with Mr. Gale during his study of this region and the field observations here recorded were made jointly and are results of mutual discussion. The accompanying map (fig. 1) is based on a plane-table survey made by Mr. Gale, and for this and other assistance the writer wishes to express due acknowledgment.

LOCATION.

Columbus Marsh is situated on or near the line between Esmeralda and Mineral counties, Nev.[1] Coaldale is a railroad station at the southeast corner of the marsh, and the Tonopah & Goldfield Railroad skirts the eastern margin of the mud flat itself. The marsh covers an area of 35 to 40 square miles and is roughly elliptical in outline, being about 9 miles from north to south and 6 miles or more in width. It is a broad mud plain with a rough, lumpy surface—a typical playa, the lowest part of the basin of a distinct drainage system, a physiographic feature characteristic of the Great Basin region. Little salt shows on the mud surface except about the margins of the plain, where several borax-producing plants were located in the earlier days of the borax industry. An accurate representation of this basin is given on figure 1.

PREVIOUS EXPLORATIONS FOR POTASH IN COLUMBUS MARSH.

EXPLORATIONS BY THE UNITED STATES GEOLOGICAL SURVEY.

LOCATION OF WELLS AND METHOD OF EXPLORATION.

In searching for potash during 1912 six shallow wells were put down by the United States Geological Survey in Columbus Marsh to depths ranging from 32 to 50 feet. Later two other wells were sunk to a depth of about 80 feet. These wells were located as follows:

Well No. 100, sec. 13, T. 2 N., R. 36 E.
200, sec. 12, T. 2 N., R. 36 E.
300, sec. 35, T. 3 N., R. 36 E.
400, sec. 8, T. 2 N., R. 36 E.
500, sec. 31, T. 3 N., R. 36 E.
600, sec. 15, T. 3 N., R. 36 E.
700, sec. 9, T. 2 N., R. 36 E.
800, sec. 5, T. 2 N., R. 36 E.

[1] Gale, H. S., Potash tests at Columbus Marsh, Nev.: U. S. Geol. Survey Bull. 540, p. 422, 1914.

The location of the wells is shown accurately on figure 1, which gives a clear conception of the area and extent of the mud flat as well as the distribution of the wells. The drilling

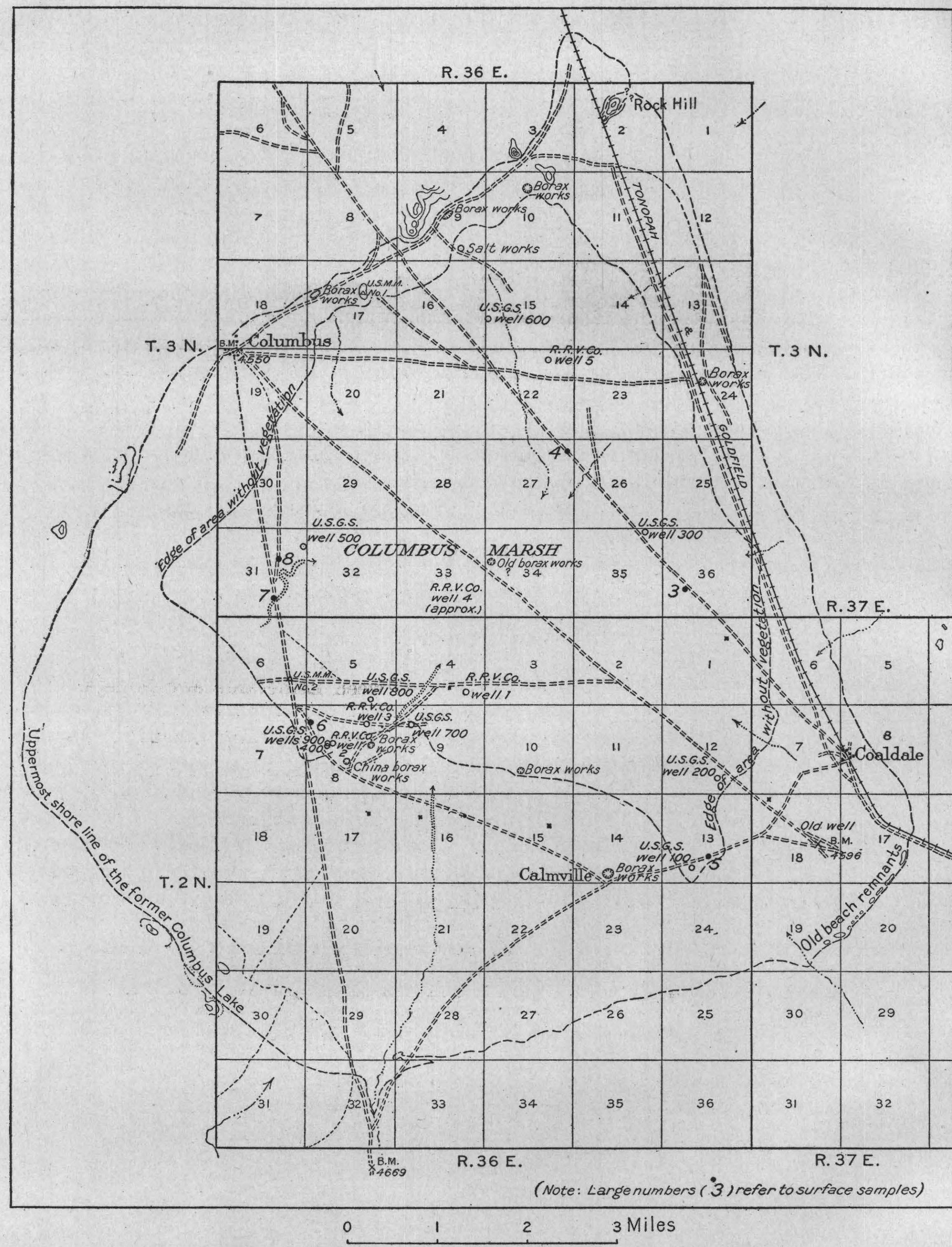

FIGURE. 1.—Map of Columbus Marsh, Nev.

and sampling were done by Charles E. Watson under the direction of Mr. Gale. The samples when received at the laboratory were air-dried. They were powdered without making a mineralogic study and preserved for analysis.

METHOD OF ANALYSIS.

The analysis of the samples from Columbus Marsh was concerned primarily with the estimation of the total soluble salts and the potassium. On extracting the muds with water, suspensions of a colloidal nature were obtained which would settle only after long standing, if at all. For practical analytical purposes in the estimation of the water-soluble salts it became necessary to clarify these suspensions by artificial means. For this purpose ammonium chloride was used, because of its volatility. The method was as follows:

The mud was digested on the steam bath for half an hour with 25 cubic centimeters of water and 0.25 gram of ammonium chloride for each gram of sample taken, this quantity of ammonium chloride being necessary in most cases for the clarification of the solution. The extract was either filtered and the residue washed with water, or made up to definite volume, filtered, and aliquots taken for analysis. In either case the filtrate which represented the extract from 2 to 4 grams of material was evaporated in a tarred porcelain dish (porcelain being used because of the lack of platinum), ignited to dull redness to drive off all ammonium salts, cooled, and weighed, the result being reported as total soluble salts. The ignited residue was dissolved in dilute hydrochloric acid and filtered, and the potassium was determined in the filtrate by what has been called the modified chlorplatinate method.[1]

Although it was presumed that the above-outlined procedure for the estimation of total salts would give somewhat high results, the method was thought to be sufficiently accurate for the work in hand. Being found rapid and practical, it was used in the earlier work on the muds that were of such a nature as to require artificial clarification of their extracts.

SUMMARY AND DISCUSSION.

The analytical data obtained in connection with the exploration of Columbus Marsh for potash during 1912 are summarized in the following table:[2]

Summary of previous analyses of muds from Columbus Marsh, Nev.

[W. B. Hicks, analyst.]

Well No.	Depth of well (feet).	Soluble salts (per cent of sample).			Soluble potash as K.					
					Per cent of sample.			Per cent of total salts.		
		Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
100	25	3.62	1.67	2.12						
200	49	22.30	4.67	9.73	0.68	0.06	0.54	8.46	0.34	5.52
300	50	26.91	14.10	18.27	1.01	.43	.65	4.69	2.40	3.58
400	38	17.30	5.17	8.66	1.31	.22	.84	20.90	1.67	9.75
400 [a]	38	6.30	5.17	5.96	1.31	.85	1.02	20.90	13.69	17.07
500	48	15.50	11.10	12.84	.84	.35	.55	6.69	2.38	4.30
600	46	19.12	10.51	13.46	.86	.26	.57	5.94	1.37	4.23
Average				12.59			.70			5.46

[a] Part below depth of 18 feet.

NOTE.—The complete data relative to wells 700 and 800 have not been published and so are not included here.

These data, exclusive of those for well 100, which was shallow and located at the extreme edge of the flat, show that well 300 has the highest and well 400 the lowest percentage of soluble salts. The reverse is true of their potash content. Wells 200, 500, and 600 show intermediate

[1] Hicks, W. B., A rapid modified chlorplatinate method for the estimation of potassium: Jour. Ind. and Eng. Chem., vol. 5, p. 650, 1913.
[2] See Gale, H. S., op. cit., pp. 423-424.

values in regard to both determinations. In all cases, however, high percentages of soluble salts correspond to low percentages of potassium in the salts. Accordingly, the average content of soluble potash is approximately constant for all the wells except well 400, in which it is unusually high. The percentage of soluble salts in the section from 18 to 38 feet of well 400 is low, but the percentage of potassium in these salts is exceptionally high. The maximum and minimum percentages of soluble salts from wells 300, 500, and 600 vary much less than the percentages from the other wells. This is true to a less degree in regard to the potash content. Although the muds from some of the wells average nearly 20 per cent in soluble salts, no salt beds or distinct saline horizons were found.

Only one sample of water was collected and analyzed from each of wells 300, 500, and 600. These samples were strong brines containing from 18 to 25 per cent of salts, of which 4 to 1.5 per cent was potassium. Six water samples were analyzed from well 400. These averaged 0.73 per cent of salts, of which 3.90 per cent was potassium. Four of these waters, two representing strong flows, came from the section between 18 and 38 feet, in which the salts extracted from the muds showed surprisingly high values in the percentage of potash. These waters were very dilute and nearly uniform in composition, containing on an average 0.47 per cent of salts, of which only 4.31 per cent was potassium. These low figures are at variance with the results obtained for the muds from the same horizon. The low concentration in salts might be explained by assuming that the waters came from strong flows and had not remained in contact with the muds long enough to extract large amounts of the salts. This would require the further assumption, in order to explain the low values for potash, that the potash in the muds was present in a relatively less soluble condition than the other salts. In any event discrepancies in the analytical results obtained for the muds and waters from the same horizon in well 400 are evident.

EXPLORATIONS BY THE RAILROAD VALLEY CO.

Subsequent to the investigations by the United States Geological Survey, described above, the Railroad Valley Co., of Tonopah, Nev., in its search for potash put down five holes in Columbus Marsh. These were shallow holes comparable to the wells of the Survey already described and were located as indicated on the accompanying map (fig. 1). So far as the writer is aware the results obtained by the Railroad Valley Co. in exploring Columbus Marsh have not been published.

UNITED STATES GEOLOGICAL SURVEY WELL 900.

LOCATION AND DETAILS OF DRILLING.

In order to discover the cause of the discrepancies mentioned above and to obtain more information concerning the character of the muds in Columbus Marsh, well 900 was put down in August, 1913, under the direction of Mr. Gale. This well was located in sec. 8, T. 2 N., R. 36 E., about 100 feet east of well 400, and was drilled to a depth of 67 feet. The drilling was done by Charles E. Watson, who used a small modified Empire core drill, the casing always following within a few feet or even going ahead of the bit. In a general way the muds encountered to the depth of 26 feet consisted of alternate layers of sand and clay; below this depth material much more consolidated was also encountered. Several water flows, some of which appeared to be rather strong, were observed as the drilling progressed. Only one, however—that struck at a depth of 3 feet—could be considered a brine, all the others being very dilute. A superficial examination of the muds as they came from the well was made by the writer, but no distinct saline horizons could be detected, the muds apparently being thoroughly washed with water and containing very little soluble matter. The sampling was also done by the writer, care being taken to obtain the most representative set of samples possible under the conditions attendant on the drilling. The muds were collected by averaging all the material representing a distinct layer as it came from the well. These were preserved in tin cans and shipped with the water samples to Washington for analysis.

RECORD OF THE WELL.

A detailed record of the well is given below. It agrees with that of well 400.

Record of United States Geological Survey well 900, Columbus Marsh, Nev.

Muds.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface, crystallized salt and sand	0.2	0.2
Sand with small amount of clay, greenish yellow	4.0	4.0
Clay, light gray and black, wet	.5	4.5
Sand, black with foul odor, very wet	5.0	9.5
Clay, black, sticky	.5	10.0
Sand and gravel, dark gray, moist	7.0	17.0
Sand with a small amount of clay, light gray, moist	2.5	19.5
Clay, with a small amount of sand, light gray	.5	20.0
Sand, fine, light gray, very moist	3.5	23.5
Hardpan, clay and consolidated material	2.5	26.0
Sand, nearly black, wet, without saline taste	3.0	29.0
Clay, greenish gray, smooth	.5	29.5
Sand, black, very moist	1.0	30.5
Hardpan, alternating layers of clay and more consolidated material	6.5	37.0
Clay, alternating layers of light gray and black	2.5	39.5
Hardpan, alternating layers of clay and more consolidated material	5.5	45.0
Sand, coarse, nearly black	3.0	48.0
Clay, black, sticky, soft	4.0	52.0
Hardpan	1.0	53.0
Sand, quicksand, nearly black, foul odor	1.5	54.5
Clay, light gray, soft, sticky	7.0	61.5
Sand, quicksand, nearly black	.5	62.0
Clay, light gray, very sticky	.5	62.5
Sand, mostly quicksand, with some fine gravel	4.5	67.0

Water encountered.

Sample No.		Temperature.	Depth.
		°C.	*Feet.*
1	Strong brine	21.7	2.5
2	Water, nearly fresh, strong flow, rising within 1.5 feet of surface	14.0	15.0
3	Water, nearly fresh, moderate flow	16.0	23.0
4	Water, nearly fresh, strong flow, rising within 2 feet of surface	16.5	27.0
5	Water, nearly fresh, weak flow	17.0	37.0
6	Water, nearly fresh, strong flow, rising within 1 foot of surface, foul odor	14.0	42.0
7	Water, nearly fresh, weak flow	(?)	47.0
8	Water, nearly fresh, strong flow, rising within 16 feet of surface, foul odor	15.0	54.0
9 [a]	Water, nearly fresh, weak flow	(?)	61.0
9	do	17.0	66.0

[a] Not sampled.

CHEMICAL DATA.

CLARIFICATION OF THE MUD EXTRACTS BY THE USE OF AMMONIUM CHLORIDE.

In the chemical investigations relating to Columbus Marsh and more particularly to well 900, the samples have been analyzed for soluble salts and potash, first by the method described above, in which ammonium chloride was used to clarify the solution, and then by a method in which the clarification was effected by filtration through Pasteur-Chamberland clay filters, the potash in all cases being determined by the modified chlorplatinate method already mentioned. In addition more complete analyses of some of the samples have been made, and the total potash in a number of them has been determined. The results of the analyses in which ammonium chloride was used as the clarifying agent are given on page 6. With the exception of the moisture determination the percentages in this paper refer to the material dried at 100° C.

Results of analyses of muds from well 900 with ammonium chloride as the clarifying agent.

[W. B. Hicks, analyst.]

Sample No.	Depth (feet).	Character of material.	Soluble salts (per cent of sample).	Potash as K.		Moisture (per cent).
				Per cent of sample.	Per cent of soluble salts.	
1	0.5	Surface	21.02	0.27	1.27	13.46
2	4.0	Sand	8.20	.28	3.45	18.60
3	4.5	Clay	12.07	.57	4.77	20.60
4	9.5	Sand	7.74	.34	4.34	18.75
5	10.0	Clay	8.63	.45	5.17	25.65
6	17.5	Sand	3.61	.55	15.10	4.91
7	19.5	do	5.50	.86	15.65	18.30
8	20.0	Clay	6.75	1.04	15.33	23.70
9	23.5	Sand	3.35	.91	17.00	16.44
10	26.0	Consolidated material	6.22	.92	14.77	19.27
11	29.5	Clay	6.15	.93	15.13	21.85
12	30.5	Sand	6.65	1.21	18.25	23.10
13	37.0	Consolidated material	6.71	1.29	19.22	25.90
14	39.5	Clay	7.86	1.46	18.60	29.30
15	45.0	Consolidated material	4.15	.45	10.68	16.65
16	52.0	Clay	5.65	.55	9.65	26.20
17	58.5	do	5.80	.41	7.05	41.70
18	62.0	Quicksand	2.28	.15	6.67	27.80
19	67.0	do	2.70	.36	13.12	24.90
Average			6.90	.68	11.33	

These results are in complete agreement with those obtained from well 400. Except in the surface material the percentage of soluble salts is low and nearly constant, while that of potassium is comparatively high, increasing at first with increasing depth to unusually high values in the section between 17 and 39 feet, and then falling off again. The samples for the whole well average 6.90 per cent in soluble salts and 11.33 per cent in potassium, against 8.66 and 9.75 per cent, respectively, for well 400; while in the section between 17 and 39 feet the muds from well 900 average 5.87 per cent in soluble salts and 16.12 per cent in potassium, against 5.96 and 17.02 per cent, respectively, for the muds from the corresponding section of well 400. In fact, the analytical data concerning the two wells are concordant in every particular. The unusually high percentage of potassium in well 400 is found at corresponding depths in well 900. Contrary to expectations, the percentages of both soluble salts and potash decline with increasing depth below 40 feet.

The muds from well 900 vary greatly, being composed of sand, clay, or material much more consolidated, or of mixtures of these, and a most surprising fact is that the analytical data give no indication whatever of such differences in the character of the material represented by the samples.

CLARIFICATION BY FILTRATION THROUGH PASTEUR-CHAMBERLAND FILTERS.

In searching for a method for the clarification of the extracts that would yield a clear solution containing without question only that material which water alone would dissolve from the muds, filtration through porcelain filters suggested itself. Experiments carried out by the writer [1] have shown that only slight changes result to moderately concentrated solutions on passing through Pasteur-Chamberland clay filters and that the alkalies from very dilute alkaline solutions are more or less absorbed by such treatment; therefore mud extracts that are alkaline and very dilute are likely to show appreciable changes in composition after being subjected to this method of clarification. As the mud extracts from the Columbus Marsh

[1] Jour. Ind. Eng. Chem., vol. 6, pp. 829-831, 1914.

samples were not excessively dilute, were composed largely of chlorides and sulphates, and were only slightly alkaline, it is believed that the values for the water-extractable material obtained by this method of clarification are nearly correct, some of them probably being a little low.

The following procedure was used: A 20-gram sample of the mud which had been dried and powdered was heated with occasional stirring for 1 hour on the steam bath with 400 cubic centimeters of water. It was then transferred to a measuring flask, cooled, and made up to 500 cubic centimeters, and 10 cubic centimeters of water was added to correct for the volume occupied by the mud. After mixing and allowing to settle the extract was filtered through a Pasteur-Chamberland clay filter using strong suction. After discarding the first 100 cubic centimeters of the filtrate, aliquots of 100 to 200 cubic centimeters were taken for analysis. The results are given below.

Analytical results obtained from mud samples of well 900 after clarification of the water extract by filtration through Pasteur-Chamberland clay filters.

[W. B. Hicks, analyst.]

Sample No.	Depth (feet).	Soluble salts (per cent of sample).	Soluble potash as K.		Ratio of values obtained by use of ammonium chloride to values obtained by use of Pasteur-Chamberland filters.		
			Per cent of sample.	Per cent of soluble salts.	Soluble salts.	Soluble potash.	
						In sample.	In soluble salts.
1	0.5	18.26	0.11	0.58	1.16	2.45	2.19
2	4.0	4.96	.09	1.83	1.65	3.11	1.88
3	4.5	7.03	.15	2.13	1.72	3.80	2.24
4	9.5	4.80	.11	2.29	1.61	3.09	1.46
5	10.0	3.77	.12	3.16	2.29	3.75	1.64
6	17.5	.56	.04	6.62	6.45	13.75	2.26
7	19.5	.49	.04	5.70	11.22	21.50	2.09
8	20.0	.61	.04	6.50	11.05	26.00	2.36
9	23.5	.74	.03	4.64	7.23	30.33	3.66
10	26.0	.54	.03	5.32	11.50	30.66	2.68
11	29.5	.75	.04	4.72	8.20	23.25	3.21
12	30.5	.79	.04	5.11	8.42	30.25	3.57
13	37.5	.76	.03	5.56	8.83	43.00	3.46
14	39.5	.94	.04	3.78	8.36	36.50	4.92
15	45.0	.52	.03	8.66	7.98	15.00	1.23
16	52.0	1.30	.07	5.45	4.35	7.86	1.77
17	58.5	1.36	.12	9.52	4.27	3.42	.74
18	62.0	.52	.03	6.59	4.38	5.00	1.01
19	67.0	.39	.03	10.15	6.93	12.00	1.29
Average		2.84	.06	5.17			

According to these data the amount of material extracted by water alone from the mud samples in well 900, exclusive of the surface material, is small, amounting on an average to only 2.84 per cent. The average content of potassium is 0.06 per cent of the sample, or 5.17 per cent of the soluble salts. The results from the section of the well between 17 and 39 feet, which yielded unusually high values for potassium by the other method of analysis, are even more striking. Here the average content of soluble matter is 0.69 per cent and that of potassium 0.04 per cent of the sample, or 5.32 per cent of the soluble salts. These figures are exceptionally low compared with those obtained by the use of ammonium chloride—a fact that becomes more evident by an examination of the columns of ratios in the table. Here it is seen that by the method in which ammonium chloride was used for clarification, from 1 to 10 times as much soluble matter and from 2 to 40 times as much potassium is dissolved from the muds as by the method in which the samples are extracted by pure water and clarified by filtration through clay filters. It is also evident that the ratio of the potassium extracted is in general from 2 to 4 times that of the soluble salts. In other words, the soluble salts extracted from the muds by the use of ammonium chloride contain a much higher percentage of potash than the pure water extract. The variation in the results obtained by the two methods is greatest in the case of the muds that contain the least amount of soluble salts. No appreciable changes corresponding to differences in the character of the material appear in the results of the analysis, or in the variations by the two methods.

A consideration of these data shows conclusively that the high figures obtained for potash in the samples from wells 400 and 900 have resulted from the method of clarifying the mud extracts with ammonium chloride. It further furnishes an explanation of the discrepancies observed above in the analyses of muds and waters from the same horizon.

TOTAL POTASH IN THE MUDS.

The total potash in a number of muds from well 900 was determined by the J. Lawrence Smith method.[1] The samples were selected from those showing high percentages of potassium in the ammonium chloride extract and represent the various kinds of material found in the well. The results are given in the subjoined table, which include also those for one sample from well 200, for comparison.

Total potash in muds from well 900 and percentage extracted with ammonium chloride and with water.

[W. B. Hicks, analyst.]

Sample No.	Depth (feet).	Character of material.	Total potash as K (per cent of sample).	Per cent of total potash extracted by—	
				Ammonium chloride solution.	Water.
200+9....	29	....	3.55	19.20	....
900+2....	4	Sand........................	2.84	9.88	2.82
900+3....	4.5	Clay........................	2.96	19.25	5.07
900+9....	23	Sand........................	3.26	27.90	.92
900+12...	30	.....do........................	3.30	36.70	1.21
900+13...	37	Consolidated material.......	3.46	37.30	.87
900+14...	39	Clay........................	3.72	39.20	1.08
900+16...	52	.....do........................	2.64	20.80	2.65
900+19...	67	Sand........................	2.84	12.68	1.07

According to these data the potash content of the muds is roughly constant without regard to the character of the material. Although only a small percentage of the total potash was extracted by water, from 10 to 40 per cent was carried into solution by ammonium chloride, the high values again being shown by the muds which came from the section of the well between 17 and 39 feet.

ANALYSES OF WATERS.

Incomplete analyses of the waters from well 900 were made. The results, which are set forth on page 9, are sufficient to give a fair idea of the character of these waters and to show the close similarity in composition of their dissolved salts.

[1] Treadwell, F. P., Analytical chemistry, 3d ed., vol. 2, p. 496, John Wiley & Sons, 1911.

Analyses of waters from well 900.

[W. B. Hicks, analyst.]

	1	2	3	4	5	6	7	8	9
Depth (feet)	2.5	15	23	27	37	42	47	54	66
Cl	55.18	54.90	53.36	53.00	51.00	52.48	48.62	49.40	49.28
SO_4	6.19	4.29	6.70	6.83	9.48	6.19	8.30	6.85	9.63
B_4O_7	.39	1.03	1.12	1.30	1.44	1.61	1.22	3.28	1.56
CO_3	....	.44	.44	.66	.48	.63	.36	2.38	1.02
K	1.91	3.45	3.53	3.65	3.04	3.59	3.00	3.36	3.73
Na, Ca (by difference)	35.89	36.33	34.85	34.56	34.56	35.45	38.50	34.73	34.78
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total salts	20.52	.62	.59	.50	.66	.38	.87	.31	.47

All the samples contained a small amount of calcium. No test was made for Mg or SiO_2.

With the exception of sample No. 1, which is a strong brine, the waters from well 900 are very dilute and of the same order of concentration. Their soluble salts are very similar in composition, consisting largely of sodium chloride with moderate amounts of sulphates, and containing borates, carbonates, and salts of potassium and calcium. Apparently the percentage of sulphates and borates tends to increase with depth. The potash is not unusually high and is approximately constant for all the waters.

ABSORPTION OF POTASH BY MUDS.

From the preceding data it is evident that the muds from well 900 contain a high percentage of potash. It is also known that only a small quantity of this potash is found in the water extract after filtration through porcelain filters, while a large amount is dissolved by solutions of ammonium chloride. Many investigators[1] have shown that rock-forming minerals are dissolved to a slight degree by water and to a larger extent by salt solutions. The magnitude of such solubility, however, is small.

From a consideration of these facts it is believed that a large percentage of the potash in the muds of Columbus Marsh is held in a loosely combined form, though the exact manner of retention is not known.[2] It is probable, however, that a large portion of this potash has been absorbed from solution and is held by colloids either mechanically or in a weak chemical combination. At the same time it is certain that a small amount of the soluble potash shown in the analyses has resulted from the solvent action of an ammonium chloride solution on the minerals present. This conclusion is emphasized by the fact that both the sands and the clays from well 900 contain approximately the same quantities of potash and give up similar amounts to solutions of ammonium chloride. However, the sand as well as the clay samples which gave the high potash values contain considerable colloidal matter. Furthermore, the muds from Columbus Marsh are still capable of absorbing considerable quantities of potash. Two grams of clay sample 200+9, from well 200, absorbed 0.0287 gram of potassium from a 0.5 per cent potassium chloride solution. This corresponds to an absorption of 1.43 per cent of the mud, an amount greater than that extracted by solutions of ammonium chloride from any of the samples from well 900 except No. 14.

Considering all the facts at hand, it is believed that large amounts of potash with small quantities of other salts have been absorbed from surrounding or percolating solutions and are held in a loosely combined form by the muds of Columbus Marsh, and perhaps by the muds of the desert basins in general. Such a conclusion is in accord with the fact, which has been long recognized, that clays selectively absorb potash, and perhaps it offers the best explana-

[1] For a bibliography on the solubility of rock-forming minerals see Clarke, F. W., The data of geochemistry, 2d ed.: U. S. Geol. Survey Bull. 491, p. 454, 1911.

[2] For bibliographies on the absorption of salts by clays see Van Bemmelen, J. M., Die Absorption, 1910; Clarke, F. W., op. cit., p. 477; Blanck, E., Landw. Zeitung (Fühling's), vol. 62, p. 560, 1913.

tion of the apparent disappearance of considerable quantities of the potassium salts from natural solutions or from the salts associated with the desert-basin saline deposits. Attention[1] has been repeatedly directed, through the analysis of many brines, saline incrustations, and muds, to the low content of potassium in comparison to that of sodium in these deposits. It is possible that in the desert basins the potash has been gradually absorbed from solutions by the muds, while the other salts, being less completely absorbed, have been gradually concentrated through evaporation, this process yielding the natural brines and salt incrustations with low potash content found in these regions at the present time.

CONCLUSIONS.

The data relating to wells 400 and 900 agree very closely. Water, as a rule, removes from the muds of well 900 only small amounts of soluble matter, but solutions of ammonium chloride extract larger quantities. The high percentages of potash found in the soluble salts from the muds of well 400, as well as the discrepancies between the results shown by the waters and muds from the same horizon, were a result of the method of analysis, in which the clarification was effected by ammonium chloride. High percentages of soluble salts in the muds usually correspond to low percentages of potassium in the salts. In such cases the variations in the water and ammonium chloride extracts are not so great.

The muds of Columbus Marsh are capable of absorbing more potash. It is believed that a large part of the potassium in the muds has been absorbed from surrounding or percolating solutions and is held in a loosely combined form, probably by colloids. Such a conclusion offers an explanation of the apparent disappearance of the potassium from the brines and saline deposits of the desert-basin regions.

SURFACE MUDS FROM COLUMBUS MARSH.

SAMPLES.

In order to determine the variations in composition of muds from different localities in Columbus Marsh, a number of samples of the surface material were collected in 1913. It was also thought that some relation between the composition of the muds and the "self-rising ground" of the marsh might be found. The samples represent the surface material to a depth of about 6 inches. They were collected by the writer and preserved in tin cans. The samples were taken at the plane-table stations established in mapping the flat and therefore represent for the most part the edge of the marsh. The localities from which these samples came are described below and are also indicated accurately on figure 1.

Localities from which surface samples were collected.

Sample No.	Location.	Character of surface material.
900+1	Sec. 8, T. 2 N., R. 36 E., at well 900	Sand and clay, moist. Surface smooth, moderately compact, and covered with thin layers of crystalline salts.
3	Sec. 36, T. 3 N., R. 36 E	Clay and sand, brownish, moist, sticky, containing salt crystals. Surface covered with film of crystalline salts.
	Sec. 27, T. 3. N., R. 36 E	Sand with some clay, brownish, loose, containing salt crystals. Surface dried to a rough, nearly white, crust.
5	Sec. 13, T. 2 N., R. 36 E	Sand, brown, moist. Surface smooth, loose, and contains no crystalline salts. Many fragmentary volcanic rocks scattered over surface. Area formerly worked for borax.
6	Sec. 8, T. 2 N., R. 36 E	Sand, brownish gray. Area covered with salt grass and formerly worked for borax. Sample taken from smooth surface between the ridges.
7	Sec. 31, T. 3 N., R. 36 E	Sand and clay, brownish. Surface smooth, compact, and covered with film of crystalline salts.
8	do	Sand and clay, brownish yellow. Surface rough and very loose, like freshly plowed ground, and covered with a thin film of crystalline salts.

[1] See Clarke, F. W., op. cit., pp. 142-247; Dole, R. B., Explorations of salines in Silver Peak Marsh, Nev.: U. S. Geol. Survey Bull. 530, pp. 330-345, 1913; Gale, H. S., Prospecting for potash in Death Valley, Cal.; and Salt, borax, and potash in Saline Valley, Inyo County, Cal.: U. S. Geol. Survey Bull. 540, pp. 407-421, 1914.

ANALYSES.

Only partial analyses of the surface samples from Columbus Marsh were made, but the data are complete enough to show the composition of water-soluble matter in these muds. The results of the analyses, made on the material dried at 100° C., are tabulated below.

Analyses of surface muds from Columbus Marsh.

[W. B. Hicks, analyst.]

	900+1	3	4	5	6	7	8
Cl	40.30	53.30	48.15	49.20	34.15	53.20	45.40
SO_4	21.30	2.31	4.15	5.78	4.44	3.45	2.92
B_4O_7	1.14	2.21	1.45	6.21	25.88	3.30	3.01
CO_3	None.	None.	4.67	.75	.92	None.	4.93
SiO_3	.23	3.20	2.60	.43	1.53	1.30	4.80
K	.58	.50	.47	.51	1.91	2.08	.67
Ca	5.89	None.	None.	.37	2.72	.29	None.
Na (by difference)	30.56	38.48	38.51	36.75	28.45	36.38	38.27
Mg	None.	Trace.	Trace.	None.	None.	None.	None.
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Soluble salts	18.26	11.27	20.00	11.75	6.53	7.24	10.96

DISCUSSION AND CONCLUSION.

From these results it will be seen that the soluble salts in the surface muds of Columbus Marsh, while containing a large amount of sodium chloride, vary widely in composition. All contain small quantities of potash and silica and varying amounts of sulphates and borates. Sample 900 + 1 shows exceptionally high sulphates, sample 6 high borates, and samples 4 and 8 considerable carbonates. According to the composition of the soluble salts, the mud samples may be classified as follows:

Samples 3 and 7, consisting largely of chlorides.
Sample 900+1 consisting largely of chlorides and sulphates.
Samples 4 and 8, consisting largely of chlorides and carbonates.
Samples 5 and 6, consisting largely of chlorides and borates.

Samples 3, 7, and 900 + 1 came from smooth, rather compact areas; samples 5 and 6 from localities formerly worked for borax, in which the surface material is more or less loose and covered in salt grass; and samples 4 and 8 from rough, very loose surfaces known as "self-rising ground." These facts indicate that the presence of carbonates in the surface material is a factor in causing the "self-rising ground," and that borates and perhaps alkalies in general tend to produce similar effects. The data, however, are not conclusive, because too few samples have been examined.