STATE OF OREGON

DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

702 Woodlark Building

Portland, Oregon

# G M I SHORT PAPER

## NO. 17

# SODIUM SALTS OF LAKE COUNTY, OREGON

by

Ira S. Allison
Professor of Geology
Oregon State College

and

Ralph S. Mason
Engineer
Department of Geology and Mineral Industries

1947



Price 15 Cents

## FOREWORD

Sodium salts are basic raw materials in American industry. Increase in industrial activity, especially in the chemical field, means increased demand for these salts. For example, large quantities of sodium carbonate are required in making aluminum, glass, pulp and paper, soap, caustic and bicarbonate, textiles, and water softeners, to give a partial list. The increased demand for sodium carbonate in these industries is reflected in the interest being shown in possible new sources of the natural salts.

Lack of railroad transportation facilities has been a primary obstacle in development of Oregon's deposits of sodium salts in Lake County, but with the present need for production in the Northwest, and the increased efficiency of trucking, this obstacle becomes less formidable.

As time and personnel allowed, the Department has carried on an investigation of sodium salts in Lake County. Dr. Ira S. Allison, professor of geology at Oregon State College, who cooperated in the work and is the senior author of the report, has been studying certain features of the geology of south central Oregon over a period of years. His experience has been valuable to the Department in this study.

The accompanying report is designed to supply factual information on the occurrences. The need for such a report is shown by the large number of inquiries concerning possible sources of sodium salts received by the Department, especially during the past two years.

F. W. Libbey
Director

January 28, 1947

CONTENTS



ILLUSTRATIONS



TABLES

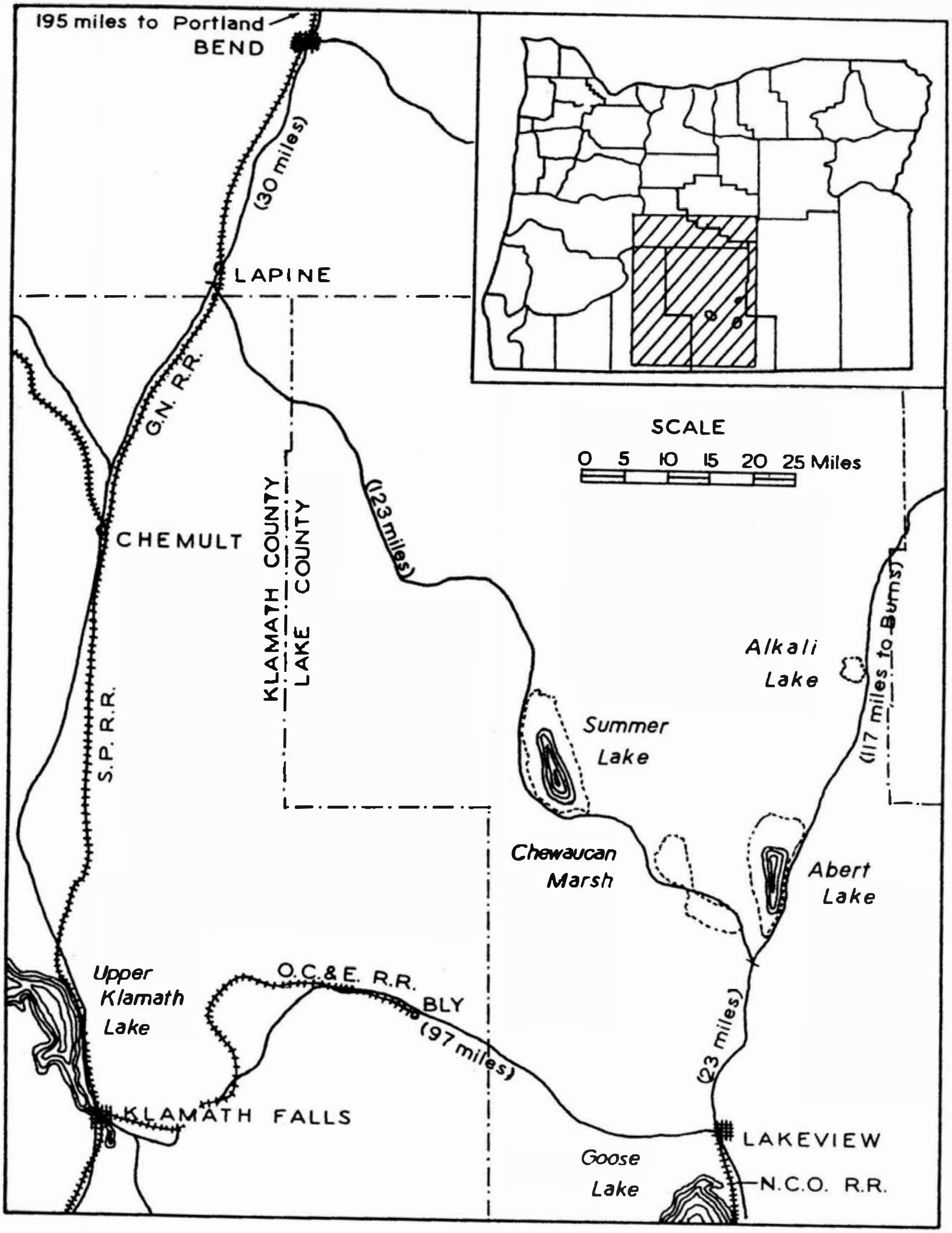


Plate I

Index map showing location of Summer, Abert, and Alkali lakes, Lake County, Oregon.

## INTRODUCTION

Summer, Abert, and Alkali lakes are alkaline lakes which occupy fault-block depressions in the high lava plains of south central Oregon (Plate 1). The geology of the region has been described* by Russell (1884), Waring (1908), Smith (1926), and others. These alkaline lakes are successors, but perhaps not direct descendants, of much larger, deeper lakes of late Pleistocene time (Allison, 1945; Meinzer, 1922; Russell, 1884; Waring, 1908). Perched beaches, wave-cut cliffs, terraces, and other shore features stand as much as 250 to 350 feet above the present shores.

The possible utilization of the alkalies of these lakes has been considered several times (Gale, 1916; Phalen, 1919). The Pearson Engineering Corporation of London explored Alkali Lake just before World War I but did not begin production. The American Soda Products Company, San Francisco, obtained a patent on 5320 acres of the Alkali Lake playa in 1918 and still holds title. The other lakes are on public land, the legal status of which is uncertain as both the State and the United States claim title. A small but unknown tonnage has been hauled out by truck from Alkali Lake from time to time and marketed for washing soda. A plan designed for solar evaporation of water pumped out of Summer Lake was established at the south end of Summer Lake in 1916, but the venture was not successful. So far as known no attempt has been made to produce salts from Abert Lake, although Van Winkle (1914) reported that preparations for recovering salt, soda, and borax were in progress in 1912.

Renewed interest in alkalies and production of chlorine in the Pacific Northwest recently prompted the Oregon Department of Geology and Mineral Industries to make further studies. A brief economic review was made by Stafford (1939). The present paper is based upon field work done mainly in August and September 1944. Several new analyses are reported herein.

## SUMMER LAKE

### General Relations

Summer Lake covers an area of about 70 square miles at high water stages but shrinks to about half that size during dry seasons. The lake has no outlet, so its size and depth change from year to year and from season to season according to changes in balance between inflow and evaporation. Its elevation in September 1944 was 4146 feet. Its average depth is less than 10 feet and most of the lake bed is nearly flat. At low water stages a salt-encrusted, sun-cracked playa extends over tens of square miles just outside the lake proper.

### Composition of Summer Lake Waters

Analyses of water from Summer Lake (Table 1) show that the waters are solutions mainly of sodium carbonate, sodium bicarbonate, and sodium chloride, with minor quantities of sulphate, potash, and silica. The absence of calcium and magnesium is normal (Clarke, 1924, p. 160, 180). The total salinity found in September 1944 (2.89 percent by weight) was nearly double that in February 1912, but was still low in comparison with 7 to 21 percent in Owens Lake (Clarke, 1924, p. 162) or about 33 percent in Searles Lake (Gale, 1919, p.171) in California.

The moderate salinity of certain lakes in the Great Basin led Gilbert (1882, 1890), Russell (1885), and Van Winkle (1914, p. 118) to suggest that these lakes formerly had dried up completely and deposited their previous loads of soluble salts. On the basis of the volume and composition of the influent waters and the assumed rate of evaporation in relation to the concentration and area of the present lake waters, Van Winkle (1914, p. 123) calculated that Summer and Abert lakes have been accumulating soluble salts again for a period of about 4,000 years.

*References are at the end of the paper.

Table 1.
Analyses of Summer Lake Waters
(grams per kilogram)

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $Na_2CO_3$ | 23.48[a] | 14.67 | 8.01 | 12.43 |
| $NaHCO_3$ | | 6.77[b] | 3.81[b] | 5.03[b] |
| NaCl | 9.27 | 8.33 | 4.58 | 8.84 |
| $Na_2SO_4$ | 2.15 | 1.82 | 1.03 | 1.69 |
| KCl | 1.38 | 1.07 | .51 | .68[c] |
| $NO_3$ | n.d. | n.d. | trace | n.d. |
| $SiO_2$ | .27 | .29 | .10 | .23 |
| Ca, Mg, Fe | | | trace | n.d. |
| Al | | | .02 | n.d. |
| Total dissolved solids | 36.55 | 32.95 | 18.06 | 28.90 |

a/ Total carbonates as $Na_2CO_3$
b/ By difference
c/ $K_2SO_4$ instead of KCl

Analyses 1, 2, and 3 recalculated from analyses published by Walton Van Winkle, U.S. Geol. Survey Water-Supply Paper 363, p. 119-120.

1. October 2, 1901, by Stillwell and Gladding.
2. 1902, by E. T. Dumble for Southern Pacific Company.
3. Collected in February 1912 by W. O. Harmen; analysis by W. Van Winkle.
4. Collected in September 1944; analysis by L. L. Hoagland, Oregon Dept. Geology and Min. Ind.

No buried mass of deposited salts, either as a thick solid body or as thin sheets interstratified with lake muds, has been found in the basin, although well-drillers in search of artesian water have penetrated the lake sediments in places to depths of several hundred feet (of course, outside the present margin of Summer Lake). The lack of a mass of salts commensurate with that to be expected from the evaporation of former pluvial lakes is probably the result of several factors: (1) small size of the drainage basin, (2) volcanic country rocks, (3) semi-arid climate, (4) youthfulness of the lake, (5) distribution of soluble salts throughout the lake muds, (6) deposits possibly concealed beneath the present lake, and (7) removal of salts by deflation.

The low salinity of Summer Lake waters hampers their use as a source of soda.

## Summer Lake Playa

### Sampling and results

Both the surface efflorescences and the underlying muds were sampled. Three areas, each of 25 square feet, were measured carefully and scraped clean of all efflorescent salts. The material thus taken up was then weighed and analyzed. The three samples with their natural moisture weighed 4.72, 4.84, and 7.84 pounds, respectively, of which the soluble salts when reduced to the anhydrous state formed 27, 29, and 41 percent by weight. Based on the average of these three samples, the crusts weigh 4.76 tons per acre, or about 3,000 tons per square mile, and average about 36 percent anhydrous salts. Most of the difference between the yields stated and 100 percent represents water of crystallization of natron, trona, mirabilite, or other hydrous minerals. A very small part is insoluble matter.

The chemical composition of the efflorescent salts on the playa of Summer Lake is shown in Table 2. The main constituent is sodium carbonate. A theoretical mixture of about 43 percent natron, 16 percent trona, 19 percent thermonatrite, and 12 percent of other minerals would meet the requirements of the analysis, but other combinations are possible.

The Summer Lake playa muds were sampled by means of 2- and 3-inch "Iwan" soil augers. Holes totaling 55 feet were bored at four widely spaced points. One hole on the west side of the lake was put down first to 12 feet with a 3-inch auger. Then a $1\frac{1}{4}$-inch bailer, consisting of a 4-foot section of galvanized pipe fitted with a ball check-valve, was used to deepen the hole by jouncing the bailer with a rope. Although the mud penetrated was quite soft, the hole did not cave or fill from the bottom. Sample intervals ranged from 6 inches near the surface to 1 or 2 feet at depth. Care was taken to avoid surface contamination. Each time the auger was filled, brought to the surface, and cleaned, a longitudinal slice of the cuttings was removed with the aid of a spatula and saved as a sample. Samples from the bailer necessarily were fluid muds. Samples were placed immediately in screw-top pint jars with labels taped on the covers.

Table 2.
Analysis of Salts from Summer Lake Playa
(in percentages by weight)

| | 1 | 2 |
|---|---|---|
| $Na_2CO_3$ | 70.80 | 35.54 |
| $NaHCO_3$ | 9.45 | 5.01 |
| NaCl | 12.12 | 6.43 |
| $Na_2SO_4$ | 7.83 | 4.15 |
| $K_2SO_4$ | 1.64 | .87 |
| Water of crystallization | ---- | 46.00 a/ |
| Total | 101.84 | 100.00 |

a/ By difference

1. Composite of 3 samples averaging 54 percent soluble salts (in anhydrous state), taken September 1944. Analysis by L. L. Hoagland, State Dept. Geology and Min. Ind.
2. Same, recalculated to percentages of original composite sample.

Upon analysis the soluble salt content of the playa muds was found to decrease in one representative section from 7 percent (reduced to anhydrous state) in the top 6 inches, to 4 percent in the second 6 inches, 3 percent in the second foot, and to 2 percent or less at a depth of 7 feet. All of the muds tested carried at least 1 percent soluble salts (on anhydrous basis). Such low concentrations seem to eliminate the playa muds themselves as direct, commercial sources of alkaline salts.

Possible recovery of efflorescent salts

The possibility of recovering soluble alkali salts from the surface efflorescences deserves mention. Such a proposal envisions the harvesting of the efflorescent salts as an annual crop with the aid of some type of scraper, revolving broom, or suction apparatus, or combination of these, and the purification of the salts at a plant located above high-water level.

The principal factors bearing on such an enterprise are: (1) the seasonal exposure of the playa surface, (2) temporary submergence and partial solution of the salts caused by the shifting of Summer Lake by the wind, (3) low prospective yield, perhaps 5 tons per acre, (4) the thin, friable or fluffy character of the efflorescence, (5) removal of salts by strong winds in summer, (6) damp, slippery mud (underlying the salts) which would hamper use of mechanical equipment, (7) loss of salts in mud-cracks, (8) presence of numerous ice-rafted basalt boulders strewn over the playa, (9) lack of local fuel (California fuel oil would be required), (10) long distance to market (about 85 miles by truck plus 275 miles by rail to Portland, Oregon).

Even if a system for collecting the salts could be worked out and a feasible method of treatment and purification devised, within the limits of permissible costs, the other physical and economic obstacles remain formidable. The principal products would be sodium carbonate and sodium chloride, the latter of little value at that location.

## ABERT LAKE

### General Relations

Abert Lake, situated at the west base of the Abert Rim fault scarp, covers about 60 square miles but unlike Summer Lake it has relatively little playa border, since much of the shore is fairly steep except at the north end where a playa flat of several square miles carries the usual efflorescence. Its elevation is about 4250 feet. The lake is very shallow and has no outlet. It is reported to have dried up completely during the summer of 1924. The concentration of salts dissolved in the lake varies greatly during the year, being nearly twice as great during the fall as in the spring.

### Composition of Abert Lake Waters

Seven analyses of water from Abert Lake are now available, of which five are given in Table 3. The quantities of sodium chloride range from 17 to 38 grams per liter, sodium carbonate from 8 to 22 g/l, and sodium bicarbonate from 4 to 13 g/l. Quantities of dissolved sulphates and other minor constituents are small. The total dissolved solids range from about 31 g/l in the sample taken in February (1912), to 67 and 78 g/l in the November (1945) samples. These differences probably are attributable partly to seasonal variations in the volume of the lake, partly to long-range variations, and partly to local variations produced by inflowing streams, springs, and seepages. The total salinity is about twice as much as that of Summer Lake. In Abert Lake sodium chloride constitutes about half of the total dissolved salts whereas in Summer Lake it forms only one-fourth to one-third. The greater concentration in Abert Lake is due in part to relative impoverishment of Summer Lake playa by deflation and consequent enrichment of Abert Lake by salts carried over the drainage divide by the wind. A low gap between Summer Lake and the Chewaucan River basin (tributary to Abert Lake), lying directly in the path of the prevailing northwesterly summer winds facilitates such a transfer of salts. The playa north of Abert Lake is relatively small and deflation losses undoubtedly are much less there, so that additions to the salt content of Abert Lake are cumulative.

Table 3.
Analyses of Abert Lake Waters
(in grams per liter)

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $Na_2CO_3$ | 10.61 | 8.51 | 18.32 | 19.08 | 22.53 |
| $NaHCO_3$ | 4.87 | 3.76 a/ | 6.52 a/ | 11.76 | 13.44 |
| NaCl | 21.38 | 17.34 | 28.61 | 32.54 | 38.26 |
| $Na_2SO_4$ | 1.05 | .86 | trace | 1.36 | 1.66 |
| $Na_3PO_4$ | n.d. | n.d. | n.d. | .29 | .41 |
| $Na_2B_4O_7$ | n.d. | n.d. | n.d. | .35 | .41 |
| KCl | 1.03 | .98 | 1.24 b/ | 1.48 | 1.81 |
| LiCl | n.d. | n.d. | n.d. | nil | nil |
| $Br_2$ | n.d. | n.d. | n.d. | .089 | .070 |
| $I_2$ | n.d. | n.d. | n.d. | .0002 | .0004 |
| $SiO_2$ | .23 | .10 | .31 | .23 | .23 |
| Total dissolved solids | 39.17 | 31.55 | 55.00 | 66.82 | 78.41 |

a/ By difference
b/ $K_2SO_4$ instead of KCl

1. Average of two samples taken midway on the west side of the lake, September 18, 1887; T. M. Chatard, U.S. Geol. Survey Bull. 60, p. 55.

2. Collected February 1912, from south end of lake; recalculated from analysis by W. Van Winkle, U.S. Geol. Survey Water-Supply Paper 363, p. 119-120. Two other analyses given by Van Winkle show intermediate concentrations.

3. East edge of lake, September 4, 1944. Grams per kilogram; recalculated from analysis by L. L. Hoagland, State Dept. Geology and Min. Ind.

4 and 5. Taken by U. T. Greene and R. S. Mason, November 17, 1945, both from the east edge of the lake; no. 4 near the south end and no. 5 north of the center. Analyses by W. P. Smith's Laboratory, Painesville, Ohio.

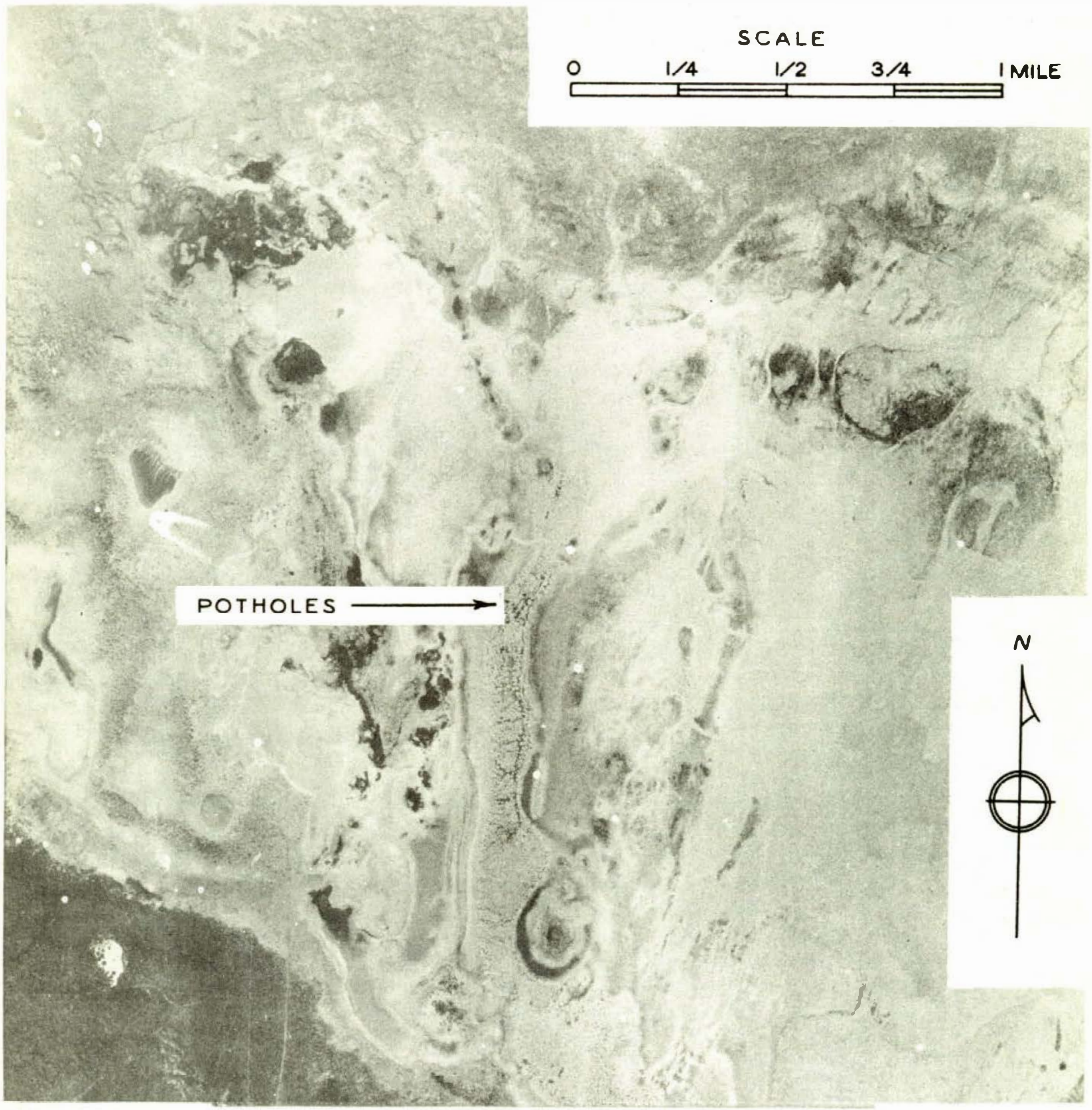


Plate 2
Aerial photograph of Alkali Lake playa, Lake County, Oregon,
showing distribution of "potholes" containing soda ash.

### Abert Lake Playa Muds and Efflorescences

One hole 30 feet deep was bored and sampled in the middle of the playa at the north end of Abert Lake. Essentially the same conditions exist there as at Summer Lake. The thin surface encrustations contained 39 percent soluble salts (on an anhydrous basis), but the salt content of the subsurface muds was found to decrease rapidly from 8 percent in the first foot to 4 percent at a depth of 12 feet, and to only 1 percent at 30 feet.

The chemical composition of the efflorescent salts is given in Table 4.

Table 4.
Analysis of Abert Lake Playa Salts
(in percentages by weight)

| | 1 | 2 |
|---|---|---|
| $Na_2CO_3$ | 78.95 | 31.55 |
| $NaHCO_3$ | .60 | .24 |
| NaCl | 15.55 | 6.21 |
| $Na_2SO_4$ | 1.11 | .44 |
| $K_2SO_4$ | 1.40 | .56 |
| $H_2O$ | n.d. | 61.00 a/ |
| Total | 97.61 | 100.00 |

a/ By difference.

1. Platy surface efflorescence, 1/16 inch thick, taken from the flat beyond the north end of Abert Lake, September 4, 1944; total soluble salts (dehydrated) 39 percent. Analysis by L. L. Hoagland, State Dept. Geology and Min. Ind.
2. Same, recalculated to percentage of original sample.

### Economic Considerations

The economics of producing salts from Abert Lake are practically identical with those at Summer Lake. Any attempt necessarily would involve evaporation of the lake waters. The low sulphate content of the water is favorable, but the low salinity and the high proportion of common salt of relatively little value are not. The high costs of recovering the salts and of transporting them to market are effective deterrents.

## ALKALI LAKE

### General Relations

Alkali Lake (Plate 2) is not a perennial lake like Summer and Abert Lakes, but a playa instead, covered with water only during wet seasons. Its elevation is about 4245 feet above sea level and its area is about 5 square miles. Its tributary drainage basin covers about 300 square miles, but there are no permanent streams in the area. Under the pluvial climate of Pleistocene time the basin held a large lake which at its highest stage was about 275 feet deep.

## Occurrence of Alkali Salts

The soda deposits at Alkali Lake occur both as widespread, thin efflorescent crusts like those at Summer Lake and as crystalline salts and brines in so-called "potholes". These "potholes" (Plate 3) range from small roundish depressions in the playa surface a few inches deep and a few feet wide to depressions several feet deep and 20 to 30 feet or more in diameter. Some of the smallest basins are barren of soda; others contain small cores of crystalline soda at the center, either at the surface or in the mud a few inches below the surface. The largest "potholes" contain masses of crystalline sodium salts that occupy most of each basin and weigh many tons. Coring tests reveal that these salts are thickest in the middle and thin gradually toward the edges. Such lenses extend approximately to the rims of the basins where their outer edges usually are concealed in a foot or more of soft, dark, sticky mud. The central parts of the soda lenses are generally exposed. In many of the "potholes" the water-level in September 1944 was at the top of the lenses of soda; in others, water a few inches deep overlay the soda, and in a few places open pools of water a few feet in diameter and a foot or two deep occupied the centers of the "potholes". Such open water contained crystal slush, evidently in process of crystallization. On May 25, 1946, no water remained in these "potholes" and the soda was dry. The soda lenses are partly covered with mud washed down by rains from the sides of the "potholes", and similar mud layers occur within the soda lenses themselves.

The origin of the "potholes" presents an interesting problem. Possibly they were initiated as artesian spring pits and associated mounds on the lake bed, and later modified by the pressure of crystal growth, by rainwash, and by deflation of dry salts from the rims.

The top parts of the soda lenses in the "potholes" are fine-grained and laminated, apparently as a result of intermittent deposition of the carbonate salts by evaporation of standing surface waters. The interior portions are relatively massive and coarse-grained, either from primary crystal growth or from recrystallization. Coarse crystals, several inches long, extending into the underlying and bordering soft muds, probably were formed in situ by crystal growth from saturated solutions.

Physical, optical, and chemical properties indicate that the bulk of the crystalline material is natron ($Na_2CO_3 \cdot 10\ H_2O$). Colorless crystals removed from the brines and exposed to the sun undergo dehydration and soon begin to crumble to a white powder*. A sample of well-developed crystals from one of the pools yielded 33 percent anhydrous salts; the theoretical yield of $Na_2CO_3$ from pure natron is 37 percent. A sample of the surface crusts outside the "pothole" yielded 26 percent, and the soft, brown material of sandy or granular texture immediately underneath the crust yielded 18 percent (both weighed as anhydrous salts).

## Composition of Alkali Lake Brine

The chemical character of the brine is shown in Table 5.

Table 5.
Analysis of Alkali Lake Brine a/
(in grams per kilogram)

| | |
|---|---|
| $Na_2CO_3$ | 178.02 |
| $NaHCO_3$ | nil |
| NaCl | 76.15 |
| $Na_2SO_4$ | 65.09 |
| $K_2SO_4$ | 28.79 |
| $SiO_2$ | 2.89 |
| Total dissolved solids | 347.70 b/ |

a/ Saturated brine from a "pothole", taken September 4, 1944; specific gravity 1.343. Analysis by L. L. Hoagland, State Dept. Geology and Min. Ind.

b/ Determined directly; not a summation.

---

*Natron loses 5 $H_2O$ at 34° C. (93° F.), a temperature reached almost daily in summer at this locality (in the air, but of course not in the evaporating pools).

The brines from the "potholes" are solutions mainly of sodium carbonate, sodium chloride, and sodium sulphate, and subordinately of a potassium salt. Solutions which seeped into a 17-foot hole in one hour and into an 8-foot hole overnight, both bored in November 1945, in the bottom of a "pothole" from which the solid salts had been removed in September 1945, were found to contain only 43.8 and 69.4 grams per liter, respectively, of total dissolved solids. The low salinity and the better showing of the overnight sample suggest progressive solution of salts from the playa muds by comparatively fresh underground waters. Further tests are needed to determine the rate of replenishment of salts in worked out "potholes" and the feasibility of obtaining commercial brines from wells or from a sump.

### Composition of the Deposited Salts

A series of analyses of the surface crusts on the playa flat and of the crystalline salts in the "potholes" at Alkali Lake is given in Table 6. The high percentage of sodium carbonate is noteworthy.

The average content of $Na_2CO_3$ in one "pothole" was found to be about 40 percent. This even exceeds the theoretical yield of natron. Percentages of $Na_2CO_3$ (on an anhydrous basis) in excess of 37 percent, however, are possible, both on account of partial dehydration of dry natron under a hot sun and by reason of the presence of other soda-bearing minerals such as trona ($Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$) or thermonatrite ($Na_2CO_3 \cdot H_2O$), which contain only about 16 and 14.5 percent water each. The low percentages of $NaHCO_3$ in the analyses do not permit much trona. The bulk of the material according to the analyses must be natron, more or less dehydrated by exposure, and other sodium carbonates.

Table 6.
Analyses of Crystalline Salts from Alkali Lake
(in percentages by weight)

| | 1 | 2 | 3a | 3b | 3c | 3d | 3e | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|
| $Na_2CO_3$ | 7.53 | 34.91 | 43.35 | 53.00 | 38.90 | 35.83 | 33.49 | 40.91 | 18.44 |
| $NaHCO_3$ | 4.64 | 3.92 | nil | nil | 2.01 | 1.00 | .67 | .74 | 1.44 |
| NaCl | 5.30 | 3.67 | 1.07 | 1.93 | 1.49 | 1.22 | 1.72 | 1.49 | 3.27 |
| $Na_2SO_4$ | 3.07 | 2.49 | 1.54 | 1.92 | 1.33 | .91 | .77 | 1.29 | 1.72 |
| $Na_3PO_4$ | .43 | n.d. | .11 | .09 | .12 | .11 | .10 | .11 | .18 |
| $Na_2B_4O_7$ | .62 | n.d. | .14 | .10 | .23 | .14 | .07 | .14 | .24 |
| KCl | 1.48 | 1.01 a/ | .36 | .33 | .74 | .45 | .37 | .45 | .89 |
| LiCl | nil | n.d. | nil | nil | nil | nil | nil | nil | nil |
| $Br_2$ | .0033 | n.d. | .0018 | .0010 | .0016 | .00078 | .00052 | .0011 | .00052 |
| $I_2$ | .0001 | n.d. | .0002 | .0004 | .0001 | .0001 | .0001 | .0002 | .0001 |
| $SiO_2$ | .21 | n.d. | .08 | .08 | .21 | .18 | .16 | .14 | .20 |
| Insoluble | n.d. | n.d. | .02 | n.d. | n.d. | n.d. | n.d. | ---- | n.d. |
| Difference b/ | ---- | 54.00 | 53.33 | 42.55 | 54.97 | 60.16 | 62.65 | 54.73 | ---- |
| Total | 23.28 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 26.38 |

a/ $K_2SO_4$ instead of KCl
b/ Essentially water of crystallization and a little insoluble matter

Analyses 1, 3, 4, and 5 by W. P. Smith's Laboratory, Painesville, Ohio; No. 2 recalculated from an analysis by L. L. Hoagland, State Dept. Geology and Min. Ind.

(Explanation of samples continued on page 11)

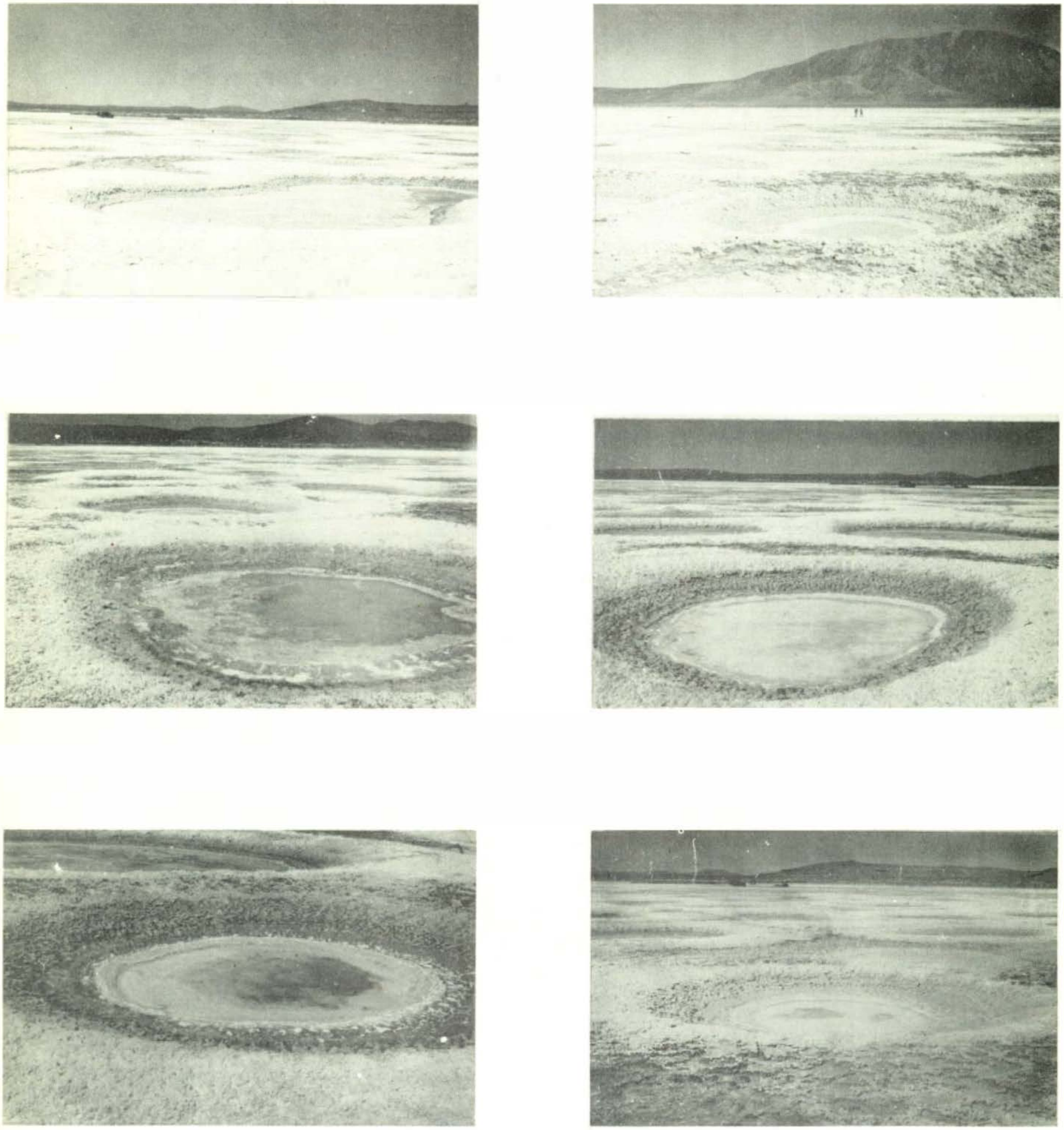

Plate 3
Views of typical "potholes" containing solid sodium carbonate,
Alkali Lake, Lake County, Oregon.

(Continued from page 9)

1. Surface crusts, November 1945.
2. Composite of three samples representing the top two feet of solid salts in a "pothole", September 4, 1944.
3. Lens of salts in a "pothole", November 1945; (a) top 3 inches; (b) 3 to 6 inches; (c) 6 to 18 inches; (d) 18 to 22 inches; (e) 22 to 28 inches.
4. Average of 3a to 3e inclusive.
5. Sample from depth of 42 inches in same "pothole" as No. 3.

## Quantity of "Pothole" Soda Available

In an area of one acre measured off in the midst of a large number of well-developed "potholes", detailed measurements and calculations revealed 49 "potholes" containing about 28,700 cubic feet or about 1200 tons of sodium salts (after making allowances for included mud and water). One area of 28 acres includes 1007 "potholes". This tract contains an estimated prospective yield of 10,000 to 15,000 tons of high-grade soda. The total area of "potholes" is not known exactly but is thought to range between 200 and 400 acres. The quantity of soda in sight, therefore, appears to be of the order of at least 75,000 and perhaps 200,000 tons.

Although hundreds of acres of the playa were examined, soda-bearing "potholes" were found only in one general area. Estimates based on the total area of the lake flat, therefore, are misleading. The widespread efflorescences, to be sure, do weigh several tons to the acre, but as with similar crusts on Summer Lake playa, special methods (of doubtful economy) of gathering and treating them would have to be devised.

Additional studies of the "potholes", the rate of refilling after removal of merchantable soda, the possible utilization of brines, and related matters are being made. The data already at hand show the presence of a modest quantity of readily available, high-grade soda at Alkali Lake.

## GLOSSARY OF CHEMICAL TERMS

Al - aluminum

$Br_2$ - bromine

Fe - iron

$I_2$ - iodine

KCl - potassium chloride

$K_2CO_3$ - potassium carbonate (potash)

$K_2SO_4$ - potassium sulphate

LiCl - lithium chloride

Mg - magnesium

$Na_2B_4O_7$ - sodium tetraborate

NaCl - sodium chloride (common salt)

$Na_2CO_3$ - sodium carbonate, anhydrous, (soda ash)

$Na_2CO_3 \cdot H_2O$ - sodium carbonate (Thermonatrite)

$Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$ - neutral and acid sodium carbonate (Trona)

$Na_2CO_3 \cdot 10H_2O$ - natural sodium carbonate (Natron), washing soda

$NaHCO_3$ - sodium bicarbonate (baking soda)

$Na_3PO_4$ - sodium phosphate

$Na_2SO_4$ - sodium sulphate

$SiO_2$ - silica, silicon dioxide

BIBLIOGRAPHY

Allison, Ira S.
1945 Pumice beds at Summer Lake, Oregon: Geol. Soc. America Bull. 56, p. 791-794.

Clarke, F. W.
1924 Data of geochemistry: U.S. Geol. Survey Bull. 770.

Gale, Hoyt S.
1916 Potash: U.S. Geol. Survey Mineral Resources, 1915, pt. 2, p. 107-108.

1919 Searles Lake: U.S. Geol. Survey Bull. 669, p. 164-174.

Gilbert, G. K.
1882 Contributions to the history of Lake Bonneville: U.S. Geol. Survey Ann. Rept. 2, p. 177-178.

1890 Lake Bonneville: U.S. Geol. Survey Mono. 1, p. 258.

Meinzer, O. E.
1922 Map of the Pleistocene lakes of the Basin-and-Range Province and its significance: Geol. Soc. America Bull. 33, p. 541-552.

Phalen, W. C.
1919 Salt resources of the United States: U.S. Geol. Survey Bull. 669, p. 129-131.

Russell, I. C.
1884 A geological reconnaissance in southern Oregon: U.S. Geol. Survey Ann. Rept. 4, p. 431-464.

1885 Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U.S. Geol. Survey Mono. 11, p. 224-230.

Smith, W. D.
1926 Physical and economic geography of Oregon; the southeastern lake district: Univ. Oregon Commonwealth Review, vol. 8, p. 199-253.

Stafford, O. F.
1939 Preliminary report upon Oregon saline lakes: Oregon Dept. Geology and Min. Industries Short Paper No. 1, p. 1-4.

Van Winkle, Walton
1914 Quality of the surface waters of Oregon: U.S. Geol. Survey Water-Supply Paper 363, p. 114-115, 117-123.

Waring, G. A.
1908 Geology and water resources of a portion of south-central Oregon: U.S. Geol. Survey Water-Supply Paper 220, p. 1-86.

## PUBLICATIONS

State Department of Geology and Mineral Industries, 702 Woodlark Building, Portland 5, Oregon

| BULLETINS | Price postpaid |
|---|---|
| 1. Mining laws of Oregon, 1942, rev. ed., contains Federal placer mining regulations . . . . | $ 0.20 |
| 2. Progress report on Coos Bay coal field, 1938: F.W.Libbey . . . . . . . . . . . . . . . . . . | 0.10 |
| 3. Geology of part of the Wallowa Mountains, 1938: C.P.Ross . . . . . . . . . . . . . . . . | 0.50 |
| 4. Quicksilver in Oregon, 1938: C.N.Schuette . . . . . . . . . . . . . . . . . . . . . . . . . . | 0.50 |
| 5. Geological report on part of the Clarno Basin, 1938: Donald K. MacKay . . . . . . . . . . . | (out of print) |
| 6. Prelim. report on some of the refractory clays of western Oreg.,1938: Wilson & Treasher . | (out of print) |
| 7. The gem minerals of Oregon, 1938: H.C.Dake . . . . . . . . . . . . . . . . . . . . . . . . | (out of print) |
| 8. Feasibility of steel plant in lower Columbia area, revised edition, 1940: R.M.Miller . . | 0.40 |
| 9. Chromite deposits in Oregon, 1938: John Eliot Allen . . . . . . . . . . . . . . . . . . . . | 0.50 |
| 10. Placer mining on Rogue River in relation to fish and fishing, 1938: H.B.Ward . . . . . . | (out of print) |
| 11. Geology and mineral resources of Lane County, Oregon, 1938: Warren D. Smith . . . . . . . | 0.50 |
| 12. Geology and physiography of northern Wallowa Mts., 1941: W.D.Smith, J.E.Allen, et al . . | 0.65 |
| 13. First biennial report of the Department, 1937-38 . . . . . . . . . . . . . . . . . . . . . | (out of print) |
| 14. Oregon metal mines handbook: by the staff | |
| A. Baker, Union, and Wallowa Counties, 1939 . . . . . . . . . . . . . . . . . . . . . . | (out of print) |
| B. Grant, Morrow, and Umatilla Counties, 1941 . . . . . . . . . . . . . . . . . . . . . | 0.50 |
| C. Vol. I, Coos, Curry, and Douglas Counties, 1941 . . . . . . . . . . . . . . . . . . . | (out of print) |
| Vol. II, Section 1, Josephine County, 1942 . . . . . . . . . . . . . . . . . . . . . | (out of print) |
| Section 2, Jackson County, 1943 . . . . . . . . . . . . . . . . . . . . . | 0.75 |
| 15. Geology of Salem Hills and North Santiam river basin, Oreg.,1939: T.P.Thayer (map only) . | 0.25 |
| 16. Field identification of minerals for Oregon prospectors and collectors, second edition, 1941: compiled by Ray C. Treasher . . . . . . . . . . . . . . . . | (out of print) |
| 17. Manganese in Oregon, 1942: by the staff . . . . . . . . . . . . . . . . . . . . . . . . . | 0.45 |
| 18. First aid to fossils, or what to do before the paleontologist comes, 1939: J.E.Allen . . | 0.20 |
| 19. Dredging of farmland in Oregon, 1939: F.W.Libbey . . . . . . . . . . . . . . . . . . . . | (out of print) |
| 20. Analyses and other properties of Oregon coals, 1940: H.F.Yancey & M.R.Geer . . . . . . . | (out of print) |
| 21. Second biennial report of the Department, 1939-40 . . . . . . . . . . . . . . . . . . . . | Free |
| 23. Investigation of reported occurrence of tin at Juniper Ridge,Oreg.,1942: Harrison & Allen | 0.40 |
| 24. Origin of the black sands of the coast of southwestern Oregon, 1943: W.H.Twenhofel . . . | 0.30 |
| 25. Third biennial report of the Department, 1941-42 . . . . . . . . . . . . . . . . . . . . | Free |
| 26. Soil: Its origin, destruction, and preservation, 1944: W.H.Twenhofel . . . . . . . . . . | 0.45 |
| 27. Geology & coal resources of Coos Bay quad., 1944: John Eliot Allen & Ewart M. Baldwin . . | 1.00 |
| 28. Fourth biennial report of the Department, 1943-44 . . . . . . . . . . . . . . . . . . . . | Free |
| 29. Ferruginous bauxite deposits in N.W.Oregon,1945: F.W.Libbey, W.D.Lowry, & R.S.Mason . . . | 1.00 |
| 30. Mineralogical and physical composition of the sands of the Oregon coast from Coos Bay to the mouth of the Columbia River, 1945: W.H.Twenhofel . . . . . . . . . . . | 0.35 |
| 31. Geology of the St. Helens quadrangle, 1946: W.D.Wilkinson, W.D.Lowry, & E.M.Baldwin . . . | 0.45 |
| 32. Fifth Biennial Report of the Department, 1945-46 . . . . . . . . . . . . . . . . . . . . | Free |

| G.M.I. SHORT PAPERS | |
|---|---|
| 1. Preliminary report upon Oregon saline lakes, 1939: O.F.Stafford . . . . . . . . . . . . . . | 0.10 |
| 2. Industrial aluminum - a brief survey, 1940: Leslie L. Motz . . . . . . . . . . . . . . . . | 0.10 |
| 3. Adv. report on some quicksilver prospects in Butte Falls quad.,Oreg.,1940: W.D.Wilkinson | (out of print) |
| 4. Flotation of Oregon limestone, 1940: J.B.Clemmer & B.H.Clemmons . . . . . . . . . . . . . | 0.10 |
| 5. Survey of nonmetallic mineral production of Oregon for 1940-41: C.P.Holdredge . . . . . . | 0.10 |
| 6. Pumice and pumicite, 1941: James A. Adams . . . . . . . . . . . . . . . . . . . . . . . . | (out of print) |
| 7. Geologic history of the Portland area, 1942: Ray C. Treasher . . . . . . . . . . . . . . . | 0.15 |
| 8. Strategic & critical minerals, a guide for Oregon prospectors, 1942: Lloyd W. Staples . . | (out of print) |
| 9. Some manganese deposits in the southern Oregon coastal region, 1942: Randall E. Brown . . | 0.10 |
| 10. Investigation of Tyrrell manganese and other nearby deposits, 1943: W.D.Lowry . . . . . . | 0.15 |
| 11. Mineral deposits in region of Imnaha and Snake rivers, Oregon, 1943: F.W.Libbey . . . . . | 0.15 |
| 12. Preliminary report on high-alumina iron ores in Washington County, Oregon, 1944: F. W. Libbey, W.D.Lowry, & R.S.Mason . . . . . . . . . . . . . . . . . . . | 0.15 |
| 13. Antimony in Oregon, 1944: Norman S. Wagner . . . . . . . . . . . . . . . . . . . . . . . | 0.15 |
| 14. Notes on building-block materials of eastern Oregon, 1946: Norman S. Wagner . . . . . . . | 0.10 |
| 15. Reconnaissance geology of limestone deposits in the Willamette Valley, Oregon, 1946: John Eliot Allen . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 0.15 |
| 16. Perlite Deposits near the Deschutes River, Southern Wasco County, Oregon,1946: J.E.Allen | 0.15 |
| 17. Sodium salts of Lake County, Oregon, 1947: Ira S. Allison & Ralph S. Mason . . . . . . . | 0.15 |

PUBLICATIONS
(Cont.)

| | | Price postpaid |
|---|---|---|
| **GEOLOGIC MAP SERIES** | | |
| 1. | Geologic map of the Wallowa Lake quadrangle, 1938: W. D. Smith & Others (also in Bull. 12) | $ 0.45 |
| 2. | Geologic map of the Medford quadrangle, 1939: F. G. Wells & Others | 0.40 |
| 3. | Geologic map and geology of the Round Mountain quadrangle, 1940: W. D. Wilkinson & Others | 0.25 |
| 4. | Geologic map of the Butte Falls quadrangle, 1941: W. D. Wilkinson & Others | 0.45 |
| 5. | Geologic map and geology of the Grants Pass quadrangle, 1940: F. G. Wells & Others | 0.30 |
| 6. | Preliminary geologic map of the Sumpter quadrangle, 1941: J. T. Pardee & Others | 0.40 |
| 7. | Geologic map of the Portland area, 1942: Ray C. Treasher | 0.25 |
| 8. | Geologic map of the Coos Bay quadrangle, 1944: J. E. Allen & E. M. Baldwin (sold with Bull. 27) | ---- |
| 9. | Geologic map of the St. Helens quadrangle, 1945: W. D. Wilkinson, W. D. Lowry, & E. M. Baldwin (sold with Bull. 31) | ---- |

**MISCELLANEOUS PUBLICATIONS**

| | |
|---|---|
| THE ORE.-BIN: issued monthly by the staff as medium for news about the Department, mines, and minerals. Subscription price per year | 0.25 |
| Oregon mineral localities map (22 x 34 inches) 1946 | 0.10 |
| Oregon quicksilver localities map (22 x 34 inches) 1946 | 0.25 |
| Landforms of Oregon: a physiographic sketch, (17 x 22 inches) 1941 | 0.10 |
| Index to topographic mapping in Oregon, 1946 | Free |
| Index to geologic mapping in Oregon, 1946 | Free |

---------*********---------