SALINES.

THE SALT RESOURCES OF THE IDAHO-WYOMING BORDER, WITH NOTES ON THE GEOLOGY.

By CARPEL LEVENTHAL BREGER.

INTRODUCTORY AND HISTORICAL NOTES.

Valuable areas of salt-bearing land lie along the Wyoming-Idaho border in Bannock County, Idaho, and the middle-western part of Uinta County, Wyo. The deposits occur west of the Salt River valley, or Star Valley, as it is locally known. In the old days, before the advent of railroads in the West, relatively large amounts of salt were boiled from the brine springs in this region and were hauled by ox team to supply Idaho and Montana mining camps. The emigrants to the Northwest along the Lander route also drew upon this region for their salt. Indeed, some forty years ago, in the reports of the Hayden Survey, this area was briefly described as containing the finest salt works west of the Mississippi. In those days, from a couple of the brine springs on Stump Creek (Smoking Creek of the Hayden Survey), as much as 200,000 pounds of salt was boiled per month, selling in the late sixties at $1.25 a hundred pounds at the springs.

Since then, however, the area has decreased in importance. The railroads have passed it by; other salt works—those of the Great Salt Lake region—have taken its markets on account of easier railroad connection, and to-day all the Star Valley salt deposits together furnish annually only a couple of hundred tons or less, which is consumed by local ranchmen for table and stock use.

Interest in these salt deposits has recently been revived, owing to the discovery of rock salt beneath the brine springs in lower Crow Creek. James Splawn and H. Hokanson, in deepening these springs in 1902, encountered a formation of rock salt 6 feet below the surface and this has been penetrated for a thickness of 20 feet without reaching the bottom. The exceptional purity of the salt, its cheapness of production, and the probability of railroad connections in the near future lend interest to the deposits of the entire district. (See fig. 48.)

LOCATION.

The only rock salt encountered in the region to date occurs on the southeast side of the Crow Creek valley, along the route from Montpelier, Idaho, to Star Valley. The locality is opposite the Lowe ranch, 38 miles northeast of Montpelier, and 12 miles southwest of

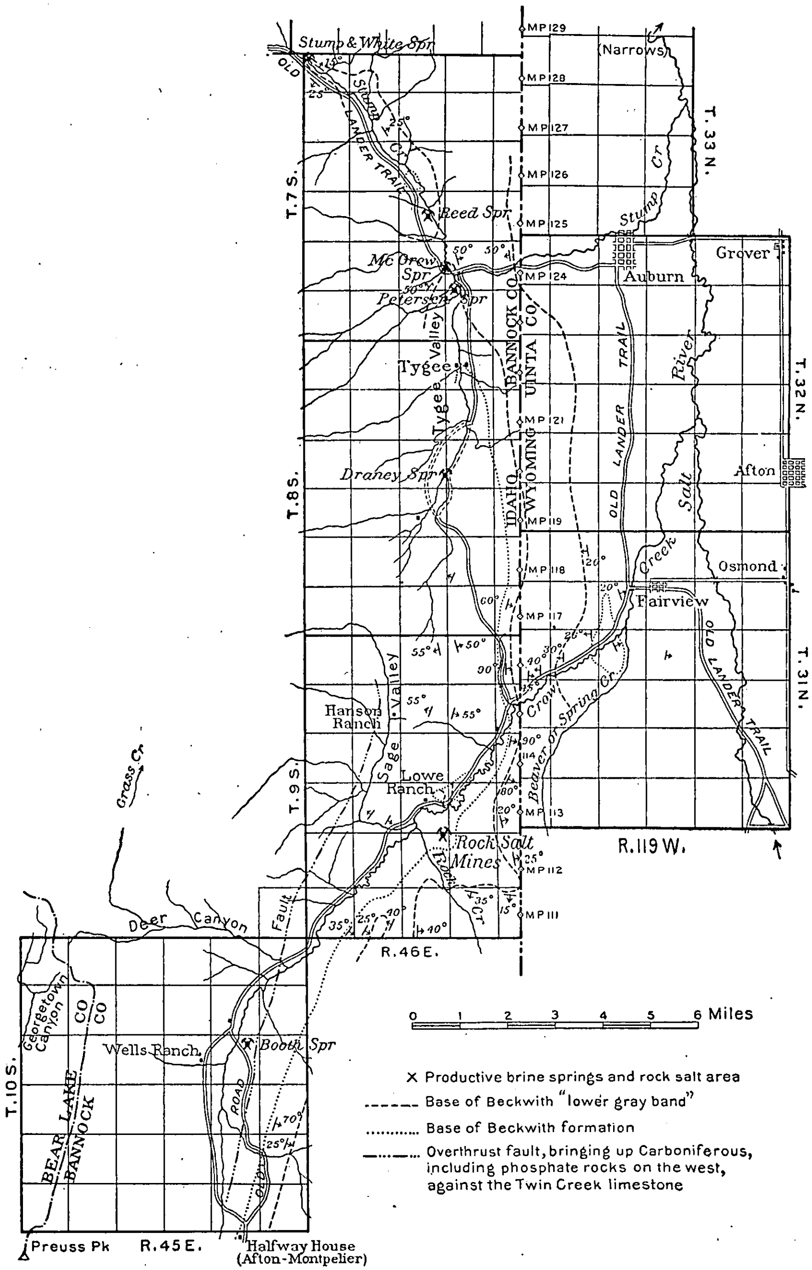

FIGURE 48.—Sketch geologic map of part of Idaho-Wyoming border country.

Afton, Wyo. The property is owned by John W. Booth, of Afton, who also owns a brine spring in upper Crow Creek, 6 miles nearer Montpelier. The latter has not been worked in recent years.

The principal operating brine springs are located on Stump Creek and in Tygee Valley, which are west of Star Valley, on the Idaho side of the state line. Most of the springs are near the junction of Stump and Tygee creeks. The Petersen spring, now owned and operated by Soren Petersen, of Auburn, is located on Tygee Creek, about half a mile southwest of the junction. The McGrew spring, owned and operated by John C. McGrew, of Stump Creek, is located on Stump Creek about half a mile northwest of the junction; and a mile farther north, up Stump Creek, are the Reed springs, owned and operated by Sydney Reed, of Auburn. Still farther up Stump Creek, about 5 miles above the Reed springs, occur the old Stump and White springs. These have not been operated in recent years. To the south, up Tygee Creek, the next worked spring is the Draney, 4 miles south of the Petersen spring.

Another salt-producing area is situated on the Wyoming side of the boundary line, south of Star Valley, on the route from Smoot and the upper end of Star Valley to Thomas Fork. This locality is on Salt Creek and is reported to be 7 or 8 miles northeast of Green's ranch, or the head of Thomas Fork. The plats of the General Land Office show it in the SW. ¼ sec. 26, T. 29 N., R. 119 W., east of the middle of the quarter. This brine spring was not visited.

THE SALT.

MODE OF OCCURRENCE.

The productive brine springs have no immediate relation to the solid rock formations occurring near by. The springs occur in the valley bottoms in barren patches of stony clay or gravel, which are rendered soggy by the contained brine. These salty places may be recognized at a distance by their gray color; in some of them a little salt incrusts the barren surface. Near by are terraces of reddish clays which will be described in connection with the geology.

A brine spring is made by digging a hole about 3 feet deep, 2 to 4 feet wide, and 3 or 4 feet long. This soon fills with water so saturated with salt that it frequently has a sirupy consistency or appearance when dipped up.

CHEMICAL COMPOSITION AND QUALITY.

Analyses of the rock salt of the district, made by Chase Palmer at the United States Geological Survey chemical laboratories, show:

Composition of rock salt of Idaho-Wyoming district.

Soluble ("salt")	91.79
Insoluble[a]	6.42
Moisture	.85
	99.06

According to Doctor Palmer's figures, the "salt" of the above analysis shows the following composition:

Analysis of "salt" from Idaho-Wyoming district.

Sodium chloride ($NaCl$)	98.900
Calcium sulphate ($CaSO_4$)	.817
Potassium chloride (KCl)	.261
Magnesium chloride ($MgCl_2$)	.022
	100.000

The rock salt is stained a reddish-brown color owing to the presence of clay containing ferric oxide. When the rock salt is dissolved in water and evaporated, the iron oxide disappears, leaving a brilliant pure-white product. This pure-white salt may be observed incrusting the ground near the water-filled shafts in the rock salt and along the ditches which are used to drain the shafts of water. Samples of this natural sun-dried white salt from the shafts and ditches, which probably represent more nearly average conditions for the entire body of rock salt, conform with the sample of raw rock salt analyzed in showing over 98 per cent of pure salt or sodium chloride, with practically negligible amounts of potassium and magnesium. The white salt has a slightly higher content of lime sulphate—1.48 per cent as compared with 0.817 per cent in the sample of raw rock salt analyzed.

A partial analysis of commercial table salt boiled from one of the Stump Creek brine springs was also made by Doctor Palmer. This analysis probably represents the usual quality of the salt boiled from the various brine springs of the Tygee-Stump Creek region. The analysis shows only a trace of magnesium and 0.73 per cent of lime (CaO), equivalent to 1.77 per cent of calcium sulphate ($CaSO_4$). The salt is thus similar chemically to the Crow Creek rock salt in the low

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[a] Composed as follows:

Red clay	SiO_2	4.36
	Fe_2O_3	.27
	Al_2O_3	.88
	MnO	Trace.
Lime and magnesium sulphates and carbonates	MgO	.13
	CaO	.67
	SO_3	.11
	CO_2	Not determined.

or almost negligible magnesium content and the high percentage of pure salt or sodium chloride.

A comparison of the Idaho-Wyoming salts with other salts of the United States is indicated in the following table: [a]

Composition of various rock salts and brines.

SOLUBLE PORTIONS OF ROCK SALT.

	Sodium chloride ($NaCl$).	Calcium sulphate ($CaSO_4$).	Magnesium chloride ($MgCl_2$).	Calcium chloride ($CaCl_2$).
Crow Creek, Bannock County, Idaho	98.9	0.82	0.022	
Retsof, N. Y	98.7	.484	.055	
Pearl Creek, N. Y	96.9	.437	.103	
Petite Anse, La	99.1	.330		
Belle Isle, La	96.4	3.051	.74	
Saltville, Va	99.1	.448		
Do	93.05	2.400		

BRINES.

	Sodium chloride ($NaCl$).	Calcium sulphate ($CaSO_4$).	Magnesium chloride ($MgCl_2$).	Calcium chloride ($CaCl_2$).
Crow Creek, Bannock County, Idaho	98+	1.48	0.022	
Stump Creek, Bannock County, Idaho	98+	1.77	Trace.	
Pearl Creek, N. Y	97.48	1.68	.55	0.26
Syracuse, N. Y	95.33	2.30	.85	1.52
Bay City, Mich	91.95	2.39	2.48	3.19
Kanawha, W. Va	79.45		4.07	16.48
Pittsburg, Pa	81.27		4.80	13.93
Colorado City, Tex	95.86	1.63	1.46	.173
Salt Lake, Utah (refined brine, or commercial salt)	98.3	.68		.345

The above table shows that the Idaho salts are above the average in quality and compare favorably with some of the best salt produced. It may be stated that the chemical quality of salt is determined by (1) the amount of pure salt, or sodium chloride, in it and (2) the amount of impurities it contains. The impurities comprise (1) material which is usually neither harmful nor beneficial and consists chiefly of lime carbonate, gypsum, calcium chloride, clayey matter, etc., and (2) material which may be harmful, as magnesium chloride and calcium sulphate, which cause the finer grades of salt to "cake" or take up moisture, or soluble iron and iodine, which are usually considered physiologically injurious.

As to the physical quality of the salt, a brilliant pure-white product can be obtained from these deposits, as is shown by the incrustations about the shaft and ditches in the Crow Creek rock-salt deposit, and as may frequently be observed in the Stump-Tygee boiled or commercial salts, when these have been handled at all carefully. Commonly, however, the salt is boiled in smoke and cinder filled log cabins, where little or no precautions as to cleanliness are taken. The result has been that much of the salt lacks the brilliancy of whiteness requisite for the finer or table grades. However, as the

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[a] After Harris, G. D., Rock salt, its origin, geological occurrences, and economic importance in the State of Louisiana, together with brief notes and references to all known salt deposits and industries of the world: Geol. Survey Louisiana, Bull. No. 7, 1908.

Idaho salt has been boiled largely for sheep and stock use, cleanliness has not been so imperative in its production. Brilliant pure-white salt has been and can be obtained from the brines when treated with merely ordinary care.

TREATMENT.

Present methods.—The equipment and methods of treatment in this region have been and are now very crude. The brine is dipped up in pails by hand and poured into sheet-iron shovel-shaped troughs or pans, which are about 10 feet long, 3 or 4 feet wide, and 10 inches deep. Each pan rests on a three-sided fire box, about 3 feet high, built of rough field stone held together with clay. The front of the box is left open for firing. The salt or brine is stirred with a shovel as the water boils off, and a common to medium fine grade product is the result. There is no equipment for milling or grinding. The pans and fire boxes, two or three in number, are inclosed in a log cabin. It is locally reported that boiling takes place more rapidly under cover than out of doors. As to fuel, there are no extensive forests in this locality, nor indeed any forests at all worthy of the name; but timber patches and windfallen logs in the mountains west of Tygee and Stump creeks furnish ample fuel for present needs. The hauling of fuel appears to be the most laborious and costly item. With railroad connections, cheap coal could be obtained from the Evanston, Kemmerer, and southwestern Wyoming fields or from possible coal fields in the Snake River canyon country, about 35 miles north of the salt district.

Possibilities of solar evaporation.—The abundance of sunshine and the dryness of the atmosphere in this region are very favorable conditions for the cheaper and cleaner process of solar evaporation in place of the more rapid boiling process which has heretofore been used. Should this process be attempted, however, the methods in use about Salt Lake and San Francisco, where brine is allowed to overflow extensive diked flats and evaporate, would be impracticable here, owing to the nature of the topography. The brine would have to be carried to evaporating pans, but in several places this could be done by gravity, the brine being piped directly from the spring, without pumping. The use of raised storage tanks, however, would be desirable. With a faucet supplying each pan and an automatic drip or flow of the brine from the faucet at nearly the rate of evaporation in the pan, the items of fuel and labor would be reduced to a minimum of expenditure, and the resulting salt would have a maximum of cleanliness.

Treatment of rock salt.—The rock salt on Crow Creek has been blasted out with dynamite in two surface pits or shafts about 20 feet square. One of these shafts is reported to have penetrated 20 feet of rock salt without reaching the bottom and to show at that depth cleaner salt than at the surface. Both shafts were filled with water at the time of the writer's visit. The water is drawn off prior to working by means of barrels and a crane, horses furnishing the power. The rock salt is sold in large, rough chunks or is hammered into finer fragments and sacked.

MARKET AND PRICES.

The salt of this district supplies the sheep herders and stockmen of eastern Idaho and middle western Wyoming. The raw, broken rock salt is now supplanting the boiled white salt for stock use on account of its cheapness. The finer grades of white salt are consumed for table use locally in Star Valley and vicinity, and a little finds its way now and then to Montpelier. In 1908 the rock salt of Crow Creek sold for 50 cents per 100 pounds sacked, or 40 cents in bulk. In 1909 the price of the rock salt was reduced to 40 cents sacked and 30 cents in bulk. The white or boiled salt of Tygee and Stump creeks sells for 75 cents per 100-pound sack for the finer or table and dairy grades and 50 cents for the coarser or stock grades.

ACCESSIBILITY.

Haulage to the nearest railroad station, Montpelier, Idaho, on the Oregon Short Line, costs at present 50 to 80 cents per 100 pounds, so that under existing conditions outside markets are out of the question. With a railroad in the Star Valley, however, the salt of this district would command the markets of western Montana, northern and western Wyoming, and northern and eastern Idaho. The Burlington, Union Pacific, Oregon Short Line, and independent railroad interests have surveyed routes that pass through Star Valley. Just now there are persistent rumors of construction by the Burlington in the very near future. There can be no question that in time the country will have railroad communication, for not only is the valley one of the richest and most progressive farming and grazing districts of the Wyoming-Idaho border country, but there is an abundance of minable phosphate rock, beautiful building stone, Portland cement, and lime in the mountains both east and west of Star Valley and Crow Creek, in addition to the salt deposits. All these resources might be profitably developed with railroad connections.

Star Valley furnishes the easiest route to upper Snake River, Pacific Creek, Two Ocean Pass, and the Yellowstone. Such a railroad would probably reach the valley via Crow Creek from the Oregon Short Line at Montpelier, Idaho, and would pass the Crow Creek salt deposits. A spur from Star Valley to the phosphate deposits in the mountains on the west would pass through Stump Canyon and tap the salt deposits in Stump and Tygee creeks. There has also been some talk of running a spur southward into Star Valley from a projected trunk line extending up Snake River from a point near Idaho Falls, instead of from Montpelier.

GEOLOGY.

General relations.—A geologic examination of the rock salt and brine springs indicates that rock salt of some kind will probably be found immediately underlying all the brine-spring areas. Contrary to expectation, however, the rock salt and salt springs have no intimate relation to the formations comprising the older bed rocks, except that the salt may have been originally derived from the Beckwith formation and that the occurrence of anticlines and domes near the present salt areas may have induced more or less local saline additions by underground waters. At present the workable salines are associated with a mass of reddish clays which form late Cenozoic valley deposits and which will be referred to at length in succeeding paragraphs.

Bed-rock formations.—The bed-rock formations occurring in the vicinity of the salt areas in Stump Creek include the Nugget sandstone[a] (nonmarine Lower or Middle Jurassic), Twin Creek limestone (light-colored marine shales and shaly limestones of Upper Jurassic age), and Beckwith formation (red sandstones and conglomerates of Jurassic-Cretaceous age). These same formations, particularly the Beckwith, appear also to constitute the bed rock in the Salt Creek area in Wyoming. At only one locality do rocks older than Jurassic occur in the vicinity of the salt deposits. This is at the upper salt springs on the east side of Crow Creek, 6 miles southwest of the rock-salt locality. Here Carboniferous cherty limestones form a rock ridge projecting up through the Pleistocene terrace of red clays.

Of the bed-rock formations, only the Beckwith (Jurassic-Cretaceous), as the probable original source of the salt, needs particular description here. This formation consists of red sandstones and conglomerates with two conspicuous gray bands. The lower gray band is a dark greenish-gray calcareous sandstone, 250 to 600 feet thick, and occurs 1,200 feet above the base of the formation. The lower 1,200 feet consist of red sandstones and shales, apparently without conglomerates. The conglomerates seem to be confined in the salt district to the interval above the lower gray band, constituting most of the rocks for a thickness of 850 feet. They are succeeded by the second or upper gray band, a massive limestone, more or less marly and light blue-gray in color. This rock attains a thickness of

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[a] The Nugget, Twin Creek, and Beckwith formations were so named by A. C. Veatch (Report on the geography and geology of a portion of southeastern Wyoming, with special reference to coal and oil; Prof. Paper U. S. Geol. Survey No. 56, 1907). The Nugget, comprising the "Triassic Red Beds" of the Hayden Survey, has heretofore been considered of Triassic age, but the occurrence of Triassic faunas in the old "Permo-Carboniferous," underlying the Nugget, may relegate this formation to a higher horizon.

100 feet in Stump Canyon and northward, where it forms a resistant ledge that may easily be traced by its light color. The divisions of the Beckwith formation maintain these characters throughout the area covered by the present reconnaissance observations from Red Mountain, near the Afton-Montpelier "Halfway House," northward to the headwaters of Stump Creek, a distance of about 35 miles.

Post-Beckwith emergence.—There is some evidence that shortly after the close of the Beckwith deposition, in early Cretaceous time, the immediate vicinity of the salt region became permanently dry land, unaffected by the temporary resubmergence which brought in the later Cretaceous and early Eocene coal-bearing rocks near by in Wyoming.

Prior to the deposition of the Wasatch formation (Eocene) in the Western States the entire north-central Rocky Mountain country was permanently uplifted and subjected to profound folding and overthrust faulting by a major or Cretaceous-Eocene uplift. The intense erosion during and following this uplift resulted in the filling up of extensive early Tertiary fresh-water lakes in Wyoming, Colorado, and Utah—the Wasatch, Green River, Bridger, Wind River, and similar lakes. The salt region, however, does not appear to have been flooded by the waters of any of these lakes. The evidence suggests that it has been subject more or less continuously to erosion since the major Cretacous-Eocene uplift, and probably since the earlier Cretaceous, post-Beckwith uplift.

Oligocene (?) lake conglomerates and antiquity of Crow and Tygee valleys.—The region contains, however, remnants of perhaps minor lake beds which are of importance in showing the antiquity of Crow and Tygee valleys. These lake-bed remnants consist of light-colored conglomerates that are present on Crow Creek, in Tygee Valley, and perhaps also along Stump Creek. All these conglomerates occur near and in the valley bottoms and rise as a flanking crust along the hill slopes, mounting unevenly to various elevations, but, unlike the Wasatch, they are not spread over any of the higher hilltops. The pebbles, well rounded and worn, are a heterogeneous mixture, originating locally within the present drainage courses and limits. This last fact, coupled with the fact that there has been no important bed-rock erosion in the valley bottoms beneath the conglomerates, tends to prove that their age is more recent than that of the Wasatch. Bowlders of this conglomerate, already consolidated, occur as pebbles in the Pliocene or Pleistocene red stony clays. The age of the conglomerate is therefore apparently Oligocene or Miocene, probably the former. The great antiquity of the valleys of Crow and Tygee creeks, which must have been excavated before these Oligocene (?) conglomerates were washed into them, is thus established.

Post-Oligocene (?) probable aridity; salt formation.—On the withdrawal of the waters in which were deposited the Oligocene (?) conglomerates, the valleys of Crow, Tygee, and Stump creeks must have become again subject to erosion or possible filling. There are, however, in these valleys, no records of any more sediments in the interval between the Oligocene (?) conglomerates and the late Pliocene or Pleistocene red clays which overlie the salt. This suggests probable aridity in the salt region. During this period the salt deposits were formed. The neighboring regions afford better evidence of aridity.

Lake Bonneville beds in Bear Lake valley as climatic indicators.—During this interval there existed in the Salt Lake valley an extensive lake, of which the present Great Salt Lake is a drying-up remnant. This former lake, known to geologists as Lake Bonneville, overflowed in various early stages of its fluctuating level so far north as to flood Bear Lake valley, and drained northward into Portneuf River or into Blackfoot River. Its varying levels are commonly accepted as being due to varying degrees of climatic humidity. It is reasonable to suppose that notably arid intervals were included in such climatic variations, and that in the main the extensive retreats of Lake Bonneville represent arid intervals, and the advances indicate returning humidity. During some earlier, post-Oligocene stages of Lake Bonneville, probably Pliocene, there were formed the white marls and marly sandstones and conglomerates which are well developed southeast of Montpelier and about Georgetown, Idaho.

The deposition of these Pliocene (?) whitish marls was evidently succeeded by a period of climatic aridity, indicated by the lowering of the waters of Lake Bonneville and their temporary withdrawal from the Bear Lake valley, so that the marls were subjected to denudation.

Pliocene or Pleistocene return of humid conditions.—This arid period was followed, in late Pliocene or Pleistocene time, by a return of humid climatic conditions in which the waters of Lake Bonneville again rose, in fact higher than before, flooding the Bear Lake valley and overflowing to the head of Thomas Fork valley. This period of returning humidity marks the deposition in Lake Bonneville of the younger unconsolidated sands and silts which are finely developed in several slightly dissected terraces south, east, and northeast of Dingle. These deposits cover the earlier consolidated white marls.

Pliocene or Pleistocene red clays of Tygee and Crow creeks.—The period of returning Pliocene or Pleistocene humidity appears to have affected the salt region, where it seems to have developed glaciation in the Salt River Mountains, perhaps coincident with the late glaciation of the Wasatch, Uinta, Wind River, and Bighorn ranges. To this period also may be ascribed the red stony clays which cover all the salt deposits in Stump, Tygee, and Crow creeks. These clays are unassorted or unbedded and sandy and commonly contain an abundance of large angular bowlders. In places the clay may be nearly free of bowlders for a thickness of 50 feet or more over several acres. When such bowlderless portions are cut, as frequently happens, into rain-washed bare slopes, they acquire a characteristic "old rose" tint. This peculiar color is, however, observable only when viewed at a distance—a couple of hundred yards or more. By this characteristic color the clays and possible underlying salty areas may be recognized at a distance of half a mile or more. On close inspection the color of the clay is seen to be a nondescript brownish red or pinkish buff. The clay contains a small amount of disseminated salt, which may have been deposited originally with the clay or derived later by percolating ground waters from the underlying salt bodies.

The bowlders in the clay are mostly angular, and many of them are over a foot thick. Along Rock Creek, near the rock-salt deposits, the bowlders include 4-foot cubes of heavy ferruginous conglomerate of the Beckwith formation, which have been transported half a mile or more. The bowlders are scattered irregularly throughout the mass of clays and are nowhere in beds or otherwise assorted. In parts of the clay the bowlders are very abundant, especially in the lower part. Commonly a gravel of smoothly worn pebbles underlies the stony red clay.

The Pliocene or Pleistocene red stony clays occur in the valley bottoms along the foot of the mountains. They form delta-like terraces, the upper surface of which, though much dissected, appears to have sloped gradually away from the hills. These terraces rise for 200 feet above the present valley bottoms. They are not, however, continuous, but are isolated patches at or near the mouths of the larger incoming lateral streams. One of the best developed of these terraces is situated about the brine spring on upper Crow Creek. This terrace is half a mile wide and flanks the hills for a length of 2 miles. One of the best preserved terraces is that occurring about the rock-salt locality on Crow Creek, at the mouth of Rock Creek. Perhaps the largest terrace extends along the west side of Stump Creek and Tygee Valley, from a point near Tygee post-office northward to and beyond the Reed springs on Stump Creek. This terrace is 4 miles long and half a mile wide and embraces most of the productive saline areas noted in the present report.

In age the red stony clays over the salt are regarded as late Pliocene or more probably Pleistocene. Their unconsolidated character and the fact that they are still preserved in areas particularly subject to erosion suggest late geologic age; but their high elevation, their dissection, and the evident fact that they were formed under conditions not existing at present indicate a period preceding the Recent.

As to the origin of the red clays, it is apparent that their restriction to locations at or near the mouths of streams necessitates the inference that they are delta deposits of some sort. They are too flat-topped to be considered alluvial cones or morainal deposits, although they may originally have been such. They have been, at least part of the time, under water, which accounts for their terrace-like aspect. That ice was active in supplying some of the detritus is indicated by the massive, unbedded character of the clays and the irregular disposition, angularity, and large size of the bowlders. Indeed, it seems quite probable that the lake itself in which these delta-like terraces of red clay were planed off owed its origin to ice—to the presence of glaciers in lower Star Valley which dammed up the northward-flowing drainage of Salt River. That such glaciers existed is proved by the occurrence of extensive moraines in the lower Star Valley, as recorded by A. C. Peale, of the Hayden Survey.[a]

Relation of red clays to salt.—In the rock-salt locality on lower Crow Creek the stony clays rest immediately on the rock salt. For 2 feet above the salt bowlders are particularly abundant. In the brine-spring area on upper Crow Creek, as well as in all the worked brine areas along Tygee and Stump creeks (possibly except at the Draney spring), the stony clays are separated from the underlying salt bodies by round pebble gravels. From 2 to 6 feet of these gravels have been encountered in the springs or within a radius of a few yards. The gravels may represent disintegrated Oligocene (?) conglomerate or may indicate later creek gravels older than the red clays.

AGE AND ORIGIN OF THE SALT.

The salt was originally disseminated in small amount in the red sandstones, conglomerates, and shales of the Beckwith formation at the time these rocks were laid down in the shallowing and disappearing Jurassic-Cretaceous seas. The anticlines into which the porous Beckwith rocks are folded have localized the underground water circulation. On the crest of one of these anticlines are located all the productive salt areas on Stump Creek and lower Tygee Creek; the Draney spring is near the crest of the same anticline. The Crow Creek rock-salt area is on the crest of a prominent dome, at the mouth of a small tributary, Rock Creek.

The present productive salines were deposited during pre-Pleistocene time in the form of alkali flats at or near the mouths of incoming lateral streams or valleys. The salt-bearing waters reaching the main valleys sank into the gravels or spread over the surface. On evaporation or partial evaporation of the waters the salt was left behind, either on the surface or in the gravels.

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[a] Eleventh Ann. Rept. U. S. Geol. and Geog. Survey Terr., for 1877, 1879, p. 641.

The hypothesis of pre-Pleistocene alkali flats and saline evaporation in the valleys to account for the present deposits is favored by the ideal conditions presented by the anticlinal folding of the salt-bearing, porous Beckwith rocks, coupled with the climatic aridity which has been shown to have preceded the Pleistocene. The long duration of the arid conditions, which may have extended nearly as far back as the period of the Oligocene (?) conglomerates, and the antiquity of the existing drainage features also support this hypothesis.

With the resumption of humid climatic conditions in the Pleistocene period the alkali flats were buried under an outwash of the stony red clays. These clays have blanketed the salt with a nearly waterproof cover which has protected the soluble mineral from being eroded or from being dissolved and carried away. Where recent erosion has washed the covering of Pleistocene red clays from the river bottoms the buried alkali flats yield their salt in the present productive brine-spring areas.

ESTIMATED EXTENT OF SALT DEPOSITS.

Probability of rock salt underlying the springs.—Solid salt deposits of some kind apparently underlie all the productive brine-spring areas. This is borne out by (1) the saturated character of the brines, (2) the similarity of geologic conditions in the single rock-salt area positively known to contain rock salt and in all the brine-spring areas, and (3) the fact that this rock-salt area itself was originally a brine-spring area similar to those of the present brine springs. Rock salt has been reported under the Petersen spring, in Tygee Valley, and under the Booth spring, on upper Crow Creek, but on authority of uncertain value. Whether the underlying solid salt will prove to be a mass of rock salt with small amounts of disseminated red clay, as at Crow Creek, or whether the salt occurs in gravels incrusting the pebbles is conjectural. Shallow digging or drilling would undoubtedly display the character and amount of salt available under the brine-spring areas.

Rough estimates of salt bodies underlying the brine springs.—Definite estimates of the amount of salt underlying the brine areas are, with the present data, impossible. Although the existence of rock salt underneath is more or less demonstrable, the thickness and continuity of the salt bodies, or old alkali flats, is problematic, particularly in the absence of any borings. From surface indications, however, it appears probable that the salt body to the west of the Stump and Tygee forks is more or less continuous from the Petersen spring northward to the McGrew residence, or nearly a mile. The Reed springs draw upon a probably large acreage of salt underlying the red-clay terrace near by, on the west side of Stump Creek. The acreage of the salt body supplying the Draney spring, in Tygee Valley, is wholly conjectural in the absence of borings. At the old Stump and White springs, on upper Stump Creek, the narrow valley and the presence of bed rock on both sides suggest a very small salt body, not much exceeding a couple of acres. The salt body supplying the Booth spring, in upper Crow Creek, if it underlies any large part of the red-clay terrace, would be very extensive. In the absence of diggings or other data, however, its extent is problematic.

Rough estimate of rock-salt body on Crow Creek.—The rock salt on Crow Creek has been penetrated for a thickness of 20 feet. Not only is the bottom not in sight, but the salt becomes purer at that depth, containing less clay than at the top. This suggests a great thickness at the particular points penetrated. The rock salt appears to underlie much of the terrace of red clays near the mouth of Rock Creek, but that the salt extends to any great extent under Crow Creek valley in front of the terrace seems improbable, though by no means impossible. The extreme north end of the terrace may not contain any salt; fresh-water springs emerge here. The south end of the terrace has been cut through by Rock Creek and may perhaps also prove now destitute of salt. Conservative estimates of the portion of the terrace regarded as in all probability now underlain by salt indicate an area of approximately 113 acres. On the assumption that an average thickness of 15 feet can be mined out or dissolved out, this area would yield a little over 74,000,000 cubic feet of rock salt. By weight this would produce a trifle over 5,000,000 short tons of soluble salt (the rock salt being assumed to average 8 per cent clay and solid matter and 92 per cent soluble salt).

Possibility of salt in Star Valley.—The existence of anticlines in the sandstones of the Beckwith formation in the hills on the west side of Star Valley and the presence in places of the Pleistocene stony red clays suggest the possibility that old buried salt flats may exist under portions of the valley. None of these have yet come to light, so far as known, but unless local conditions prevented the formation here of pre-Pleistocene salt flats it is probable that future diggings may discover buried salt bodies in some portions of Star Vallev proper.

SUMMARY AND CONCLUSIONS.

The workable areas along the Idaho-Wyoming border consist of isolated patches or salt bodies. These were formed during a long period of pre-Pleistocene climatic aridity by salt-bearing waters from the lateral streams (either surficial or underground drainage), which reached the valley bottoms, evaporated, and left their salt behind, either on the surface or in the gravels. The existence of anticlines and domes near by in the porous sandstones and conglomerates of the Beckwith formation had aided in the accumulation of salines to intensify the salinity of some of the drainage. The salt flats produced have been preserved by a covering of Pleistocene stony red clays.

Although the salt bodies or old alkali flats are thus meager in extent, especially in comparison with the other prominent salt-producing areas of the United States, the conservative estimate of 5,000,000 tons for the Crow Creek rock-salt body and the possibility of a larger salt body near the Tygee and Stump Creek forks indicate that the amount of salt apparently in sight in some of the present areas would be sufficient (if proper railroad connections existed) to yield returns on large-scale workings for a long time. It also appears quite probable that all the areas, including the smaller brine springs, contain sufficient salt to return the sums that may be advisedly invested in their development.

As to quality, salt can be easily obtained here which is above the average in chemical purity, as is indicated by the representative analyses given. This salt could be produced most cheaply and with the maximum of cleanliness by a process of solar evaporation.

At present the market for the salt of the area described is limited to the immediate vicinity, owing to the absence of railroad connections. With a railroad in Star Valley, however, the salt of this area would command the markets of eastern Idaho, western Wyoming, and much of Montana.

DEPOSITS OF SODIUM SALTS IN WYOMING.

By Alfred R. Schultz.

INTRODUCTION.

Wyoming is noted for its salt, sulphur, iron, alkaline earth, mud, and hot springs, which are scattered all over the State. In addition to the deposits formed from these mineral springs there occur in Wyoming extensive deposits of soluble salts of sodium and magnesium—sodium sulphate, sodium carbonate, and magnesium sulphate—for the most part in small drainage areas or basins which have no outlet. Many of these depressions are locally called "lakes," as they form the lowest parts of the basins and during the spring and early summer months are covered with shallow waters. During wet seasons some of these "lakes" contain water throughout the year. A few of the soda lakes, as the Wilkesbarre and Wilmington lakes, never become dry and form no solid deposits, the soda being entirely in solution. The soda basins or "alkali lakes" are more or less irregular and the deposit of salt in the different parts of the basin of varying thickness. The salt beds are usually very thin along the edge of the basin and thicken toward the center. In some localities these alkali deposits have been utilized, but for the most part no effort has been made to develop them for commercial purposes. A few of the mineral springs in Wyoming have been developed for their medicinal value and have attained considerable commercial success.

In the Yellowstone Valley salt springs are numerous, but thus far no effort has been made to utilize the brine in the manufacture of salt. Extensive beds of salt of great purity occur in Crook County west of the Black Hills and in western Uinta County along the Salt River Mountains. Salt springs and deposits are known to be present in Bannock County, Idaho, and western Uinta County, Wyo., along the state line. In both of these localities salt has been produced for many years. The salt-producing area in Uinta County, Wyo., lies south of Star Valley, on the route from Smoot, in upper Star Valley, to Thomas Fork. The salt developments are located on Salt Creek, in the SW. ¼ sec. 26, T. 29 N., R. 119 W., about 8 miles northeast of Green's ranch or the head of Thomas Fork. The brine springs in this part of Wyoming are similar to the workable springs along the Idaho-

Wyoming border described by C. L. Breger in the preceding paper in this bulletin. It is highly probable that in this vicinity rock salt will be found beneath the surface similar to the rock-salt deposits discovered in 1902 on lower Crow Creek, a tributary to Salt River in eastern Idaho.

No attempt will be made in this paper to describe all the various salt deposits, mineral springs, and alkali flats in Wyoming or to give their distribution. A few of the largest and most important soda deposits and lakes will be briefly described, and a short discussion of the sodium-carbonate developments at Green River will be presented.

ALKALI DEPOSITS.

LAKES AND PONDS.

In various places in Wyoming there are thick deposits of high-grade soda in the beds of dry lakes or ponds, ranging from those a few feet in diameter to some that cover several hundred acres and lying at various elevations above the sea. Most of these alkali deposits seem to have a common origin, and they occur in all parts of the State. Alkali deposits are found here and there and alkali crusts form in abundance about all depressions, ponds, or "dry lakes" in geologic formations above those of Paleozoic age. They are most abundant in the Triassic beds, but occur in all the geologic formations from the Paleozoic down to the soils of the present time. The Mesozoic and Cenozoic formations contain many times as much alkali as the Paleozoic and lower rocks.

In some localities the amount of alkali stored in clays and shales is enormous. In the midst of the Red Desert there are clay beds of a dull-red color which have a rather pulverulent surface during dry weather. Only a few inches below the surface in many of these beds the alkali amounts to 30 or 40 per cent of the mass. When there is a slight rainfall the clay forms a protective covering and none of the alkali escapes. During periods of heavy rain, which rarely occur, the water often finds its way through this clay mantle and, following the alkali surface, carries away all the salts that will pass into solution. At such times the water draining from these places and entering the soil is nearly saturated with salts. In many of these small basins the alkali is left unprotected on the surface, where it is deposited on the evaporation of the water that brings it into the depression either by drawing it up from below through capillary attraction or by carrying it in from the surrounding country on the surface or through underground seepage.

In the fall, when the surface becomes a powdery mass, the winds carry away the soda in huge clouds of dust. The air is so filled with the desiccated salts that anyone at a distance of 4 or 5 miles from these beds and unacquainted with the conditions would pronounce the dense white clouds the result of some great conflagration. Often in the fall, when the wind is blowing from 40 to 60 miles an hour, anyone standing on the slope of the mountains can see a cloud of alkali dust rising to a height of 50 to 100 feet from every dry alkali pond and extending for some distance beyond its borders. In this way the annual supply of alkali washed into these depressions is to a certain extent reduced, but this reduction is not equal to the storage and in consequence the deposits are increasing in volume. There are numerous alkali flats in the region of the Red Desert similar to the flats east of the Boars Tusk, in T. 23 N., R. 104 W., and north and east of Black Rock, in T. 22 N., R. 101 W. Some of these are large, others small, but the history is much the same for all. Most of these flats are too small to be taken into consideration in this preliminary paper.

ORIGIN.

The large size of some of these salt deposits and their number and areal distribution have given rise to considerable speculation as to the source of the soda and magnesium compounds in the "soda lakes." It is believed by some that the salt is brought in by the water draining into the lakes from the surrounding country and is held in solution until the water evaporates, the crystallized material being deposited in beds ranging in thickness from a few inches near the borders of the lake to several feet near the center. Others believe that the soda is brought from other sources through the agency of springs. Both of these theories are tenable and to account for all the conditions and the observed facts regarding the deposits in the various lakes both theories are required.

It was formerly believed that much if not all of the alkali in the arid West was formed through the decomposition of granitic rock by the oxidation of the feldspars, but it is now known that none or at best very little of the alkali so abundant in Wyoming has originated through the direct decomposition of the granites in the vicinity of the granitic masses.

During the late eighties it was argued that the alkali found in extensive deposits or dry lakes in Wyoming was derived largely from springs in the immediate vicinity of some of these lakes. This theory is set forth by Ricketts [a] in the following manner:

> It was at first generally supposed that the soda arose simply by the evaporation of surface waters that had drained through the soil into the lakes and in this way dissolved the sodium salts. For many reasons this supposition was doubted, and it is now proved to be incorrect. While it is true that the soda deposits occur in basins with no visible outlet, there are also a great number of such basins with lakes or ponds in them which contain only alkali waters, or, when dry, but a thin crust of the alkalis or alkaline earths. The true soda deposits, on the other hand, though the basins in which they occur are not of abnormal area, always contain exceedingly large quantities of the salts peculiar

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[a] Ricketts, L. D., Ann. Rept. Territorial Geologist Wyoming, 1887, p. 46.

to them, and these are pure and are not, as a rule, a mixture of sodium, magnesium, and calcium salts, which would be present if they were the result of the evaporation of surface waters. Mr. Arthur L. Stone, of Laramie City, has found that the Union Pacific Lakes near Laramie are fed by springs whose waters are highly charged with sodium sulphate. Finally, at Rock Creek there are in one and the same basin some lakes containing pure sulphate of magnesium, others which contain with the latter also large quantities of sulphate of sodium, and still others which contain no deposits whatever. For these reasons it seems very certain that all of the large deposits of soda in Wyoming arise from the evaporation of the waters of springs which feed the lakes and which are highly charged with soda.

In a later report[a] Ricketts makes the following statement:

> There can be no question but that these deposits all arise through evaporation of the water of mineral springs which feed into lakes and have no way of escaping.

That Ricketts as well as others was led astray in making his deductions on the origin of the Wyoming soda deposits was in part due to the assumption that the salts were pure and not, as a rule, a mixture of sodium, magnesium, and calcium salts. That the salts in these "lake deposits" are seldom pure is clearly set forth by Knight:[b]

> The salts stored in the basins, either in solution or as a solid, compare in chemical constitution with the salts found in the soils and as efflorescent crusts. To be sure, the sulphate of lime is quite insoluble and in consequence is very rapidly precipitated when concentrated in depressions. The difference in the salts found in the same basin but in different depressions is very interesting but is accounted for in several ways. In the first place, there is no deposit of pure Epsom salt or magnesium sulphate, for it always contains some Glauber salt or sodium sulphate, unless one selects pure crystals for analysis. The relations between these deposits with varying composition should be considered in discussing their origin. The deposit rich in Epsom salt occupies the lowest point in the basin. Magnesium sulphate is more soluble than sodium sulphate at ordinary temperature, and in the case of a heavy rain when the soda has been deposited in the small depressions above the large ones, the freshet would carry away the magnesium sulphate to the lowest depressions, where it is found. The magnesium sulphate, being much more soluble, would also tend to store the Epsom salts in the lowest depression on account of the percolation of the water, rich in these salts, to the lower level.

Knight is the chief advocate in recent years of the theory that the Wyoming soda lakes are formed by the soda brought in by the water from the country draining into the lakes. More than any other one man he has carefully studied the Wyoming alkali deposits and proved that they were formed by accumulating salts that remained after the evaporation of the water in the small basins and "dry lakes." This theory can best be set forth by quoting at length from Knight's report as follows:[c]

> While it is possible that considerable alkali is being brought to the surface with spring water, the amount is insignificant as compared with the supply that is constantly being derived from the soils and other formations.

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[a] Ricketts, L. D., Ann Rept Territorial Geologist Wyoming, 1888-1889, p. 67.

[b] Knight, W C , and Slosson, E. E , Alkali lakes and deposits: Bull. Wyoming Exper. Sta. No. 49, 1901, pp. 84-85.

[c] Idem, pp 85-88.

In looking into the "spring" theory careful observations were made at nearly all of deposits of note in the State. In no instance were springs found on a level with or above the deposit or water line. In five instances deposits were found without any appearance of moisture, and in digging into the mass no water was found. In other places the deposits were underlaid with a saturated solution of sodium sulphate and other salts, while in other localities the soda is always in solution. In the latter instance I believe that there are springs that feed the lakes; but whether or not the waters are rich in sodium or other salts has not been determined. There are many instances where the water came up and filled an opening made when blocks of the salt were being removed, and following this the opening was immediately filled with crystallized salts. This was in all probability due to the water below the deposit and the superincumbent weight was sufficient to force it to the surface. In one instance of this kind when the cube of soda was taken out for the world's fair the bed of salt was pierced several times with an inch bar, and through this opening the water came in at the rate of 450 gallons per hour. This solution had a gravity of 31° Baumé, and an analysis made for sulphur trioxide proved it to contain 19 per cent SO_3, corresponding to 76 per cent of Glauber salts or 57 per cent of Epsom salts. Both these salts were present. While the springs play some part in the accumulation of the soda deposits, they must be considered of minor importance as compared with other factors.

From personal observations it is my opinion that the alkalies have been derived from the soils and the strata which surround the deposit or drain into them. In localities where there are vast beds of shale and clay with undrained depressions we always find alkali being stored. There is no exception to this statement so far as I am aware. In hundreds of places there are slight depressions at the present time, where there is an accumulation of salts going on; but no one has pretended to measure the amount that accumulates annually.

* * * * * * *

In summing up the evidence relating to the origin of the so-called alkali salts of Wyoming I have arrived at the following conclusion: Primarily the alkali has been produced by the decomposition of the various rocks containing these elements. These salts appear to have been formed extensively during the Mesozoic and Cenozoic eras, but in place of being stored in deposits were carried down with the sediments. Later through the mountain-making agencies these formations were brought to the surface and through the influences of decomposition and erosion have been converted into soil. The salts have remained in the soils so formed, since there has not been sufficient water to leach them out. The decomposition of the rocks is still in progress, and from this source and the storage already accumulated in the soils the deposits of alkali have been formed and are being increased.

There are hundreds of places in Wyoming where sodium salts are being accumulated; but as a rule they do not form beds of much consequence. Upon the Laramie plains alone there are no less than one hundred slight depressions containing more or less alkali. In the majority of cases the alkali is found in the fall of the year in a thin crust upon the bottom of small ponds which have recently dried up. The deposits which are to be discussed under the above heading are those where there has been a considerable storage of alkali and where it forms masses of sodium sulphate and associated salts to a thickness of 1 or more feet.

Since the alkali deposits look very much alike and have been deposited under similar conditions a general discussion of the beds will not be out of place at this point. In many instances the name alkali lake has been applied to the soda deposits, since in the early spring and often into late summer the deposits are covered with water. The water accumulates through the melting snows and rain and is often a foot or two in depth; but beneath this one can find a solid bed of crystallized alkali. Later in the season these so-called lakes are deposits of snow-white alkali, which when seen from a distance resembles a snow-covered basin.

The deposits vary in size from a few to 100 acres, and in thickness from a few inches to 10 or possibly 15 feet. The salts are always found resting upon a muddy bed, which is usually very soft, and without difficulty one can force a pole to 5 or 6 feet below the hardened deposit. The mud varies in color from almost black to bluish, and contains many crystals of sodium sulphate. When it is removed from the bed it has a strong odor of sulphureted hydrogen, and often one is conscious of an odor resembling that rising from dissolving sodium hyposulphite. This mud always contains quite a percentage of salts found in the deposits.

For many years it was supposed that all of the alkali deposits were of crystalline purity, and for commercial purposes they could be quarried, dried, and made ready for the market. Upon making a careful section of several deposits it was found that none of the beds were pure; but were alternating layers of salts, sand, and mud. The thickness of the sodium sulphate bands depends upon the rapidity with which the salts were washed into the depression. It appears that at the close of each season, or during the fall, all of the water was evaporated and upon the alkali deposit the winter's wind carried the usual amount of sand. On the following spring the melting snow and rains carried into the depression not only the salts, but also muddy water which settled to the bottom and made a stratum of mud or muddy deposit. In some instances the accumulations of alkali of one or more previous seasons might have been dissolved, and all of the sand and mud concentrated at the bottom of the deposit or stratum. It is a rule that the deposits are mixtures of the various salts arranged in bands of varying thicknesses and alternating with other bands containing large percentages of sand or mud.

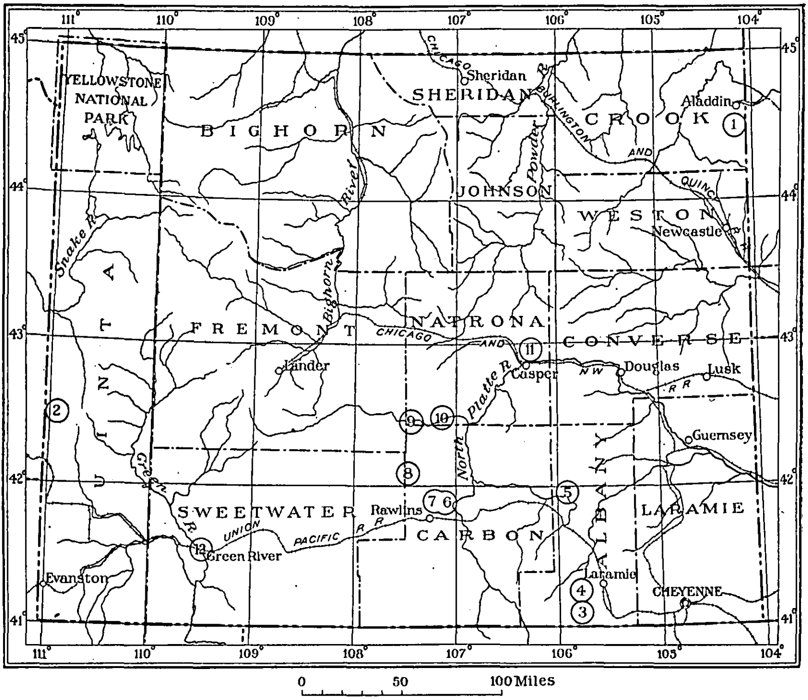

FIGURE 49.—Map showing location of the more important soda deposits in Wyoming. 1, Crook County salt deposits; 2, Uinta County salt deposits; 3, Downey soda deposits; 4, Union Pacific soda deposits; 5, Rock Creek soda deposits; 6, Rankin soda deposits; 7, Dillon soda deposits; 8, Bothwell soda deposits or Bull Spring soda lake; 9, Morgan soda deposits; 10, Independence group soda deposits; 11, Gill soda deposits; 12, Green River soda deposits.

DISTRIBUTION.

Soda lakes of considerable size and importance are located in Albany, Carbon, Natrona, Sweetwater, Fremont, and Johnson counties. (See fig. 49.) Many of the lakes are small and of little or no economic importance. Others are large in areal extent but contain very thin beds and so far as investigation has progressed seem to be of no commercial value.

Of the counties above mentioned Albany, Carbon, and Natrona contain the most numerous soda lakes. The lakes outside of these counties, as well as many of those within these counties, have no commercial value at the present time. Some of the more important lakes are briefly described in the accompanying table, which gives the geologic horizon, location, and approximate area of the basin, the thickness of the salt beds where known, and such additional information as bears directly on the deposits themselves.

Statements regarding some of the larger alkali deposits in Wyoming.

Location.	Name of alkali deposit or lake.	Number of deposits or lakes.	Area covered.	Thickness or depth.	Age of underlying rocks.	Remarks.
Albany County.			*Acres.*	*Feet.*		
22 miles southwest of Laramie; secs. 15, 21, 22, T. 13 N., R. 75 W.	Downey	3	100	0–10	Triassic	North Lake, the lowest of the three, has a good quality of soda. Middle Lake, the second lowest, has a good quality of soda. South Lake is soft and miry and contains no hard beds of soda.
13 miles southwest of Laramie.	Union Pacific	4	60	0–40	Cretaceous (Benton)	Big Lake, Track Lake, Red Lake. Besides four large lakes that vary from 4 to 40 acres, there are near by scores of depressions containing small quantities of alkaline water or salts.
12 miles northwest of old Rock Creek station, Union Pacific Railroad.	Rock Creek group	Numerous.	Several hundred.		Triassic	Numerous small depressions contain alkali; the largest covers about 90 acres. The lower parts of these depressions contain more magnesium sulphate; the higher parts contain sodium sulphate. There are about 26 small lakes or ponds, many of which are of no importance on account of small size or thin deposits.
	Brooklyn	1	90	0–1		
	Philadelphia	1	40	4–7		
	Chicago	Group.	1–10	0–6		
Carbon County.						
3 miles northeast of Browns Canyon.	Rankin	Numerous.	Several.		Cretaceous	These deposits are usually under water.
7 miles northeast of Rawlins.	Dillon				do.	
30 miles northwest of Rawlins, secs. 23 and 26, T. 25 N., R. 89 W.	Bothwell deposits or Bull Spring Lake.	1	30	0–20	Tertiary	Part of Red Desert. There are several smaller alkali deposits to the west and south that drain into this one. Red Desert has numerous small alkali lakes.
Natrona County.						
7 miles below Split Rock post-office, south of Sweetwater River; T. 28 N., R. 88 W.	Morgan	1	100	0–15+	do.	This lake lies in a long, narrow depression south of Sweetwater River in the southwest corner of Natrona County. The thickest part of the alkali deposit occupies about 6 acres.
Sweetwater Valley, near Independence Rock.	Independence group	Many.			do.	The alkali deposits occur in two pronounced old river channels north of the present Sweetwater River. The channels are about 3 miles apart and are separated by a marked divide. The lakes in Series I, or the Dupont Lakes, occupy the southern channel, and those in Series II, or the Berthaton Lakes, the northern channel. The Dupont claims comprise also many lesser lakes of little importance.
	Series I (Dupont claims):					
Sec. 12, T. 29 N., R. 87 W.	New York and Philadelphia		110	0–20		Two claims on one lake.
Secs. 23, 10, and 11, T. 29 N., R. 86 W.	Wilmington		160	0–40+		Lake containing water throughout the year.
	Wilkesbarre		50			Do.
	Omaha		4	0–8		Large percentage of sodium carbonate and bicarbonate. Used by the Mormons for raising bread.
	Series II (Berthaton claims).	2	640 80			All lie in an old channel of Sweetwater River about 3 to 4 miles in length.
8 miles northeast of Casper; sec. 26, T. 35 N., R. 78 W.	Gill	4		20+	Cretaceous	Soda pits have been sunk to a depth of 12 to 20 feet, but the entire thickness of the soda has not been determined.

CHEMICAL COMPOSITION.

The alkali deposits in the "soda lakes" may be divided into two classes—(1) those that contain considerable quantities of carbonates and consist chiefly of sodium carbonate, sodium sulphate, and sodium chloride, and (2) those that contain very little carbonate and consist chiefly of sodium sulphate, sodium chloride, and magnesium sulphate. Traces of other salts, as potassium, lithium, iron, aluminum, manganese, borates, nitrates, sulphites, and phosphates, are associated with these principal salts in many of the deposits. Regarding the salts of the "soda lakes," E. E. Slosson makes the following statement:[a]

> The salts found in the soda lakes are the same as those which occur in the soil of the surrounding region and form alkali crusts as they are drawn up from below with the water and left on the surface as this evaporates. Of these salts the most abundant in Wyoming is sodium sulphate. This exists in two forms—with water of crystallization and without. The former has the chemical symbol $Na_2SO_4.10H_2O$, and is called mirabilite in mineralogy and Glauber's salt in medicine. The pure crystals contain 55.91 per cent of water and 44.09 per cent of the dry sulphate. It forms large, transparent crystals, which, when exposed to the air, lose all their water of crystallization and fall into a fine white powder (Na_2SO_4), known as thenardite.
>
> Magnesium sulphate ($MgSO_4.7H_2O$), epsomite, or Epsom salts, is found as long, needle-shaped crystals or short, thick crystals about a quarter of an inch thick, and contains 51.2 per cent water of crystallization, which it loses in part when exposed to dry air.
>
> Sodium carbonate ($Na_2CO_3.10H_2O$), sal soda, or natron, contains 62.9 per cent water of crystallization when fully hydrated, but will lose from a half to nine-tenths of it to dry air.
>
> Sodium chloride ($NaCl$), common salt, or halite, contains no water of crystallization.

The chemical composition of some of the Wyoming alkali deposits is shown in the following table, compiled from the report of Knight and Slosson, already cited:

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[a] Knight, W. C., and Slosson, E. E., Alkali lakes and deposits: Bull. Wyoming Exper. Sta. No. 49, 1901, p. 106.

Chemical composition of some of the larger Wyoming alkali deposits.

Name of alkali deposit or lake.	Sample as received.											Calculated as dry salts.							
	Laboratory No.[a]	Water.	Insoluble.	Sodium sulphate.	Sodium chloride.	Sodium carbonate.	Calcium sulphate.	Magnesium sulphate.	Magnesium chloride.	Sodium borate.	Sodium bicarbonate.	Sodium sulphate.	Sodium chloride.	Sodium carbonate.	Calcium sulphate.	Magnesium sulphate.	Sodium bicarbonate.	Analyst.[b]	Remarks.
Albany County.																			
Downey	162	44.41	0.11	28.24	0.28			26.96				50.90	0.50			48.60		S.	Crystallized salt in middle of northern Downey Lake.
Do	178	55.43	2.24	39.17	.12		0.80	2.24				92.54	.28		1.89	5.29		S.	Clear crystal mixed with mud and water 6 feet below surface.
Do	163	74.60		6.93	1.16			17.31				25.61	5.28			70.11		S.	Solution above sample No. 162.
Do	176	72.79	.13	12.77	.86	0.05		13.40				47.18	3.17	0.18		49.47		S.	Solution in blast hole from which No. 178 was taken.
Do	173	75.89	.02	11.50	.45	.06		12.08				47.74	1.86	.24		50.16		S.	Solution from southern Downey Lake.
Do	175	49.29	.51	19.67	.50			30.03				39.18	1.00			59.82		S.	Crystallized salt from ditch in southern Downey Lake.
Do	182	55.94	.10	41.02	.12			1.82				95.46	.28			4.26		S.	Pure crystal at north end of northern Downey Lake.
Union Pacific (Big Lake, Track Lake, Red Lake).	172	55.55	.09	42.75	.70			.91				96.37	1.58			2.05		S.	Marketable dried soda.
Do	A	46.87	13.86	34.85	1.16		1.45	.97				94.23	3.14			2.63		P.	Average sample from lakes.
Do				44.90			1.75	.60	6.43	1.46								P.	Specific gravity 1.0487.
Do				75.63			1.46	.70	3.00	1.21								P.	Specific gravity 1.0725.
Do				93.07			2.01	1.43	4.16	.75								P.	Specific gravity 1.0887.
Rock Creek group (Brooklyn, Philadelphia, Chicago, and others).	88	44.50	.65	12.13	.38			42.34				22.13	.69			77.18		S.	From surface of largest lake.
Do	89	48.03	.08	24.49	.24			27.16				47.19	.46			52.35		S.	From depression in a small lake.
Do	90	51.08	1.13	10.22	.46			37.11				21.41	.95			77.64		S.	From large deposit about 1 mile north of No. 88.
Do	91	49.66	.58	40.52	.42			8.82				81.43	.84			17.73		S.	From deposit immediately north of No. 90.
Do	92	27.71	64.96	1.20	.66			5.47				16.33	9.06			74.61		S.	From mud beneath No. 89.
Carbon County.																			
Bull Spring or Bothwell	158	46.99	4.15	44.92	1.32			2.62				91.94	2.69			5.37		S.	Sampled at surface.
Do	159	42.99	1.79	55.05	.17			Tr.				99.68	.32					S.	Sampled at 1 foot depth.
Do	160	17.08	10.71	69.16	.84			2.21				95.78	1.16			3.06		S.	Sampled at 2 feet depth.
Do	157	34.11																S.	Selected crystals.
Dillon	168	35.18	8.57	38.22	3.75		13.27	1.01				88.92	2.35			8.73		S.	Surface deposit.

[a] Numbers used by E. E. Slosson in Bull. Wyoming Exper. Sta. No. 49.

[b] S., E. E. Slosson; P., H. Pemberton and G. P. Tucker; A., D. H. Attfield; R., L. D. Ricketts.

Chemical composition of some of the larger Wyoming alkali deposits—Continued.

Name of alkali deposit or lake.	Sample as received.											Calculated as dry salts.						Analyst.[b]	Remarks.
	Laboratory No.[a]	Water.	Insoluble.	Sodium sulphate.	Sodium chloride.	Sodium carbonate.	Calcium sulphate.	Magnesium sulphate.	Magnesium chloride.	Sodium borate.	Sodium bicarbonate.	Sodium sulphate.	Sodium chloride.	Sodium carbonate.	Calcium sulphate.	Magnesium sulphate.	Sodium bicarbonate.		
Natrona County.																			
Morgan:																			
Top crust	....	6.93	0.43	84.86	1.55	6.23	.....	.....	.....	.....	.....	91.60	1.68	6.72	.....	.....	.....	A.	Sampled by D. H. Attfield in February, 1891. (See Jour. Soc. Chem. Ind., January, 1895.)
New deposit	....	53.89	.41	43.93	.77	1.00	.....	.....	.....	.....	.....	96.14	1.68	2.18	.....	.....	.....	A.	
Old deposit	....	40.70	25.40	32.28	.45	1.17	.....	.....	.....	.....	.....	95.24	1.33	3.43	.....	.....	.....	A.	
Independence group:																			
New York	149	53.02	.33	36.80	3.81	6.04	.....	.....	.....	.....	.....	78.86	8.20	12.94	.....	.....	.....	S.	Surface sample.
Do	150	36.66	39.05	17.87	2.94	4.48	.....	.....	.....	.....	.....	70.66	11.62	17.72	.....	.....	.....	S.	Sample from 4 inches depth.
Do	151	47.58	9.67	40.86	.77	1.12	.....	.....	.....	.....	.....	95.58	1.80	2.62	.....	.....	.....	S.	Sample from 4 to 12 inches depth.
Wilmington	152	51.99	9.14	21.42	2.90	14.55	.....	.....	.....	.....	.....	55.14	7.47	37.42	.....	.....	.....	S.	Deposits along shore of lake.
Do	153	55.10	.74	42.34	.28	1.54	.....	.....	.....	.....	.....	95.80	.60	3.60	.....	.....	.....	S.	Deposits from bottom of lake.
Do	154	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	24.40	17.71	57.89	.....	.....	.....	S.	Lake water; specific gravity 1.104.
Wilkesbarre	....	.....	9.23	.....	.....	.....	.....	.....	.....	.....	.....	39.04	1.83	59.00	.....	.....	.....	R.	Dried sample.
Omaha	79	36.67	.97	25.88	4.83	26.83	.....	.....	.....	.....	4.82	41.51	7.74	43.02	.....	.....	7.73	S.	Surface sample.
Do	78	45.21	.71	6.85	.05	47.18	.....	.....	.....	.....	.....	12.67	.09	87.24	.....	.....	.....	S.	Salt from surface to 10 inches depth.
Do	77	49.97	19.04	2.94	1.50	26.55	.....	.....	.....	.....	.....	9.49	4.84	85.67	.....	.....	.....	S.	Salt from 10 to 14 inches depth.
Do	76	53.17	18.29	4.66	1.16	17.31	.....	.....	.....	.....	5.41	16.36	4.05	60.62	.....	.....	18.97	S.	Salt from 14 to 17 inches depth.
Do	148	39.46	30.30	11.25	.95	18.04	.....	.....	.....	.....	.....	37.20	3.14	59.66	.....	.....	.....	S.	Salt from 2 feet depth.
Berthaton	80	51.21	7.01	15.61	2.63	21.00	.....	.....	.....	.....	2.54	37.36	6.30	50.26	.....	.....	6.08	S.	Surface sample.
Do	81	53.87	3.06	14.75	2.66	59.55	.....	.....	.....	.....	.....	34.27	6.16	59.57	.....	.....	.....	S.	From large lake and from best product of deposit.
Do	84	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	20.44	13.84	65.72	.....	.....	.....	S.	Solution from upper lake.
Gill	....	1.61	.....	94.50	.54	.....	.....	2.52	.....	.....	.....	.....	.....	.....	.....	.....	.....	R.	Undetermined and loss 0.83.

[a] Numbers used by E. E. Slosson in Bull. Wyoming Exper. Sta. No. 49.

[b] S., E. E. Slosson; P., H. Pemberton and G. P. Tucker; A., D. H. Attfield; R., L. D. Ricketts.

UTILIZATION.

Thus far the utilization of the natural sulphate of sodium for the manufacture of sodium compounds has not been entirely successful in Wyoming, owing to the difficulty encountered in liberation of the water of crystallization. In 1885 the Laramie Chemical Works erected an alkali factory to manufacture carbonate and caustic soda out of the natural material. The plant was equipped with large reverberatory furnaces with small iron pots sunk in the floor. During the experimental stages it was found that this method was too expensive. Experiments conducted at the State University discovered a cheaper method of driving off the water from the natural product; but the results of these experiments have not been applied in a commercial way. The plant was compelled to close down in the late nineties, as it could not successfully compete with alkali manufacturers of the East, owing to the high price of labor. The crude soda from the Union Pacific Lakes near Laramie was converted at the Laramie Chemical Works into marketable products, as caustic soda, salt cake, soda ash, and concentrated lye. During six months in 1885 a total of 35 tons of caustic was produced, and in 1887 this plant manufactured approximately 4,000 pounds of salt cake, 4,800 pounds of concentrated lye, 8,000 pounds of caustic soda, and 16,000 pounds of soda ash. In 1892, 1,670 tons of salt cake were shipped from Laramie. Later the salt was dried and utilized for glass making, some of it being shipped to glass plants in the East. Considerable quantities of soda, obtained from the Union Pacific Lakes, were used by the Laramie Glass Company, which was organized in 1887 and began the manufacture of window glass the same year. At first pot furnaces were used, but these proved unsatisfactory and were soon replaced by furnaces similar to those used at the Rock Island (Ill.) and other eastern glass factories.

In obtaining the soda for the chemical works and the glass plant the purest soda crystals from the surface were scraped up when the lake was dry and kept in large heaps in the open air while being worked up. The outer layer of such a heap loses, of course, its water of crystallization and becomes white powder, but at a depth of an inch or two the crystals are entirely unchanged. Good crystals have even been found in the interior of a small heap of soda that had been exposed to the weather for over six years. The chief impurities are magnesium and calcium salts and chlorides. The average output is, however, as pure as the commercial "salt cake" made by the Le Blanc process, which usually contains 93 to 95 per cent of sodium sulphate. The sulphate from the lakes contains more magnesium salts than the Le Blanc sulphate, but on the other hand it is freer from iron and therefore better suited for glass making. In the works at Laramie the soda was dried by methods in imitation of the old Le Blanc process, which involved useless labor and expense. According to analyses made in 1891 in the Wyoming experiment station laboratory the final product was less pure than when it was put into the calcining furnace. It is not at all necessary to use the high heat of the Le Blanc process, because the water of crystallization is entirely driven off at a temperature a little above 212° F., or the sodium sulphate can be precipitated in anhydrous form from a hot solution without difficulty. The application of a few elementary chemical principles to the problem would have saved many thousand dollars that have been wasted in the attempt to utilize the soda deposits of the Laramie Plains. In recent years nothing has been done with the crude material in a commercial way. The Syndicate Improvement Company erected a soda plant in 1892 on its soda deposits in Sweetwater Valley, near Independence Rock, in southwestern Natrona County. Operation was begun on the Berthaton claims and after the erection of the soda plant the company commenced to manufacture bicarbonate of soda, but was unsuccessful in the manufacture of any of the soda compounds, and in a short time the plant was shut down. The cause of failure was not learned. There seems to be no apparent reason why the valuable deposits of soda found in these lakes can not be made to take the place of a large amount of the imported product.

The Wyoming deposits of sulphates and of the mixture of the sulphate and carbonate of sodium are of considerable interest and importance on account of the large amounts in which they occur, their purity, and the fact that there is a large market for such material where facilities for placing it on the market are available. Much of the Wyoming sodium sulphate needs only to be dried to furnish a superior grade of the salt cake of commerce, elsewhere obtained as a by-product in the manufacture of common salt. The mixture of the carbonate and sulphate when dried furnishes a cheap raw material from which soda ash, caustic soda, salt cake, concentrated lye, and various other sodium salts may be manufactured. In many localities this mixture is supplanting sodium carbonate in the manufacture of glass. It would seem that the sulphate deposits ought to be one of Wyoming's valuable resources, although at present none of these deposits are utilized at any place in the State.

Besides the surface alkali deposits or so-called soda lakes there are numerous soda springs scattered throughout Wyoming and at many of them the waters are so highly charged with alkali that they build up considerable deposits around the spring and along the valley or flats over which the water flows. These springs and soda deposits are too numerous to describe further. Like the spring waters, much of the well water throughout the State contains a large amount of alkali salts. A notable example is the water of the wells at the city of

Green River. As the salts obtained from these wells are at present placed on the market, a short description of the wells and the process of manufacturing the commercial product will be given.

GREEN RIVER SODA DEPOSITS.

In some respects the Green River soda deposits are somewhat similar to the "soda lakes" of the Independence group in Sweetwater Valley, southwestern Natrona County. Both contain large quantities of sodium carbonate and apparently derive the salt from the shales of the Green River formation. This source of the soda is further suggested by the fact that numerous springs which rise from these shales at various places in the Red Desert of Wyoming show considerable sodium carbonate in the water. The Green River sodas, however, differ decidedly from the sodas in the Independence alkali group in the absence of sodium sulphate. The well waters at Green River show only traces of sulphates, but in the sodas of the Independence alkali group sodium sulphate is present in considerable quantities. The first well (No. 1[a]) drilled on the Green River bottoms was a prospect well put down by the Green River Fuel and Oil Company, in which most of the citizens of Green River were interested. This well was drilled in 1896 to a depth of 692 feet. For the first 500 feet it was an 8-inch hole; for the remaining 192 feet a 6-inch hole. A flow of alkali water was struck at a depth of 125 feet. Below this the hole was dry to a depth of 685 feet, where artesian water was encountered in a white sandstone in the Wasatch formation and furnished a small flow at the surface. Although the quality of the water was known, nothing was done in the way of marketing the soda until some time afterward. In 1899 the title to this well reverted to B. Spinner, who owned the land.

In the winter of 1896–97 the Waters well (No. 2), an 8-inch hole, was drilled to a depth of 200 feet, and in April, 1897, the Spinner well (No. 3), a 6-inch hole, was drilled to a depth of 354 feet. In both wells soda was encountered at 125 to 200 feet below the surface.

In 1902 Mr. Spinner sold the old Green River Fuel and Oil Company's well and 40 acres of land to the Western Alkali Company. In 1903 this company drilled its first new well (No. 4), on the ground where the sal-soda plant was located. This was an 8-inch hole and went to a depth of 720 feet. In this well, as in well No. 1, artesian water was struck at about 685 feet. Both wells produced good soda in the first 200 feet and were cased by the company to be used permanently. Both wells, however, were finally abandoned because of defective casing. Another well (No. 5), put down to a depth of 705 feet, entered the same sand and supplied the same kind of water as the two wells just mentioned and was later abandoned for the same reason. Near

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[a] Numbers refer to corresponding numbers in figure 50.

the soda plant a shaft had been sunk to a depth of 114 feet. From the bottom of this shaft an 8-inch hole (No. 6) was drilled to a depth of about 200 feet and yielded a good quantity of soda; this well is still in use. Seven other wells have been drilled by the Western

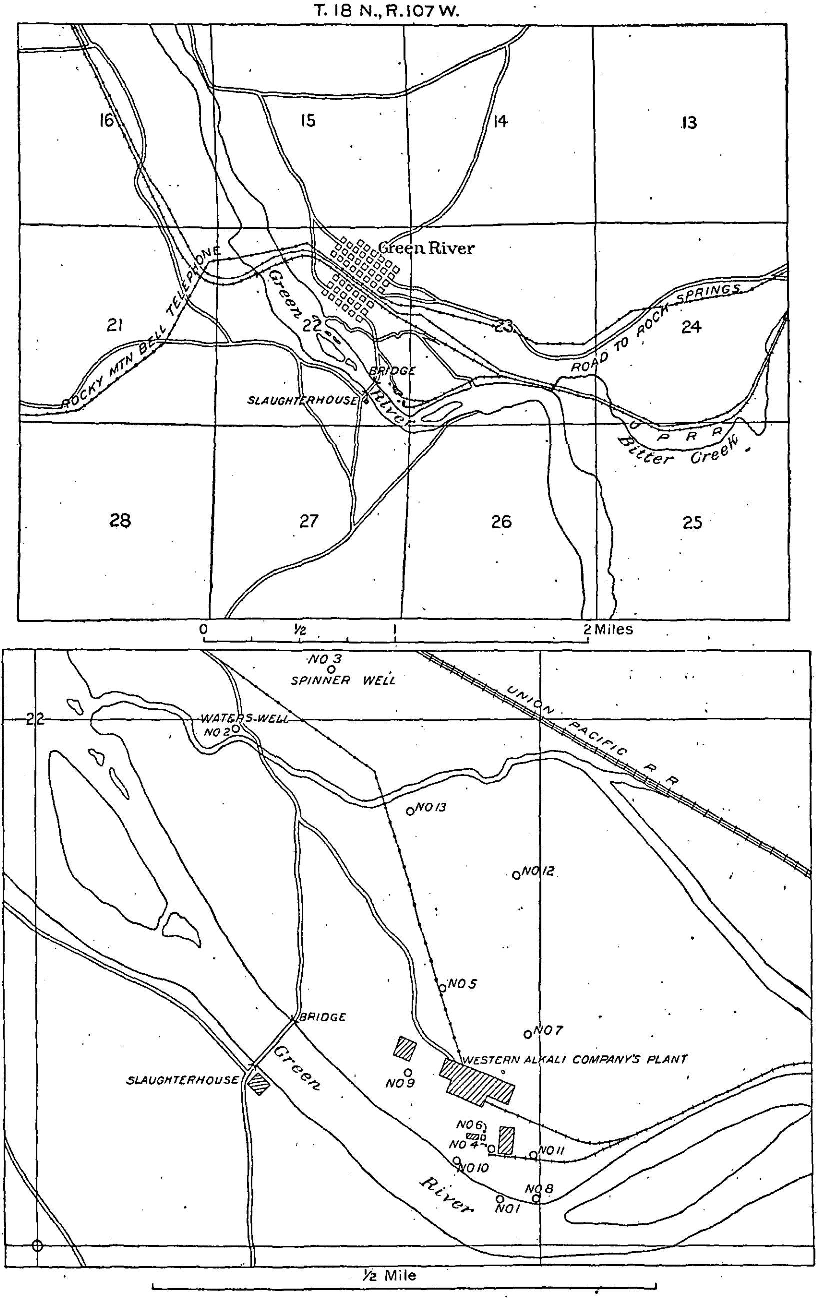

FIGURE 50.—Map showing location of Western Alkali Company's soda wells at Green River, Wyo.

Alkali Company during the past few years within an area of 2 acres. They range in depth from 150 to 300 feet and are 8 inches in diameter. The last well (No. 13) put down by the company was drilled in October, 1909, to a depth of 180 feet. Most of these wells produce good soda. There is considerable variation in the soda content of the water in the wells thus far drilled. The following features are common to all the wells: The wells must be cased from 65 to 100 feet in order to keep out the surface water; the soda belt ranges from 100 to 300 feet and apparently ceases below that depth; the artesian-water stratum, a fine grayish-white sandstone in the Wasatch formation, lies approximately 380 feet below the base of the soda belt or 680 feet below the surface of the water in Green River at Green River station. The location of the Western Alkali Company's wells is shown on the accompanying map (fig. 50).

The deepest well in Green River was drilled by the Sweetwater Brewing Company in November, 1909. Soda was encountered at the same horizon in this well as in the Western Alkali Company's wells, but no analysis was made of the water. The artesian-water stratum was struck at a depth of 765 feet and furnished a good flow of water with a pressure of 43½ pounds at the surface of the ground. This well is about half a mile from the old Green River Fuel and Oil Company's well. The formation penetrated in both of these wells is identically the same and the water encountered in the "soda belt," as well as the artesian water, is approximately of the same character in the two wells.

Mr. Hugo Gaensslen, general manager of the Sweetwater Brewing Company, has furnished the following statement concerning the well:

> Well is 780 feet deep, 10 inches in diameter for the first 190 feet, and cased that deep with 8¼-inch casing; balance of the way the well is not cased and is 8¼ inches in diameter. We did not keep an accurate log of the well for the reason that we knew practically what we had to contend with from knowledge acquired from wells the Western Alkali Company drilled. First 10 feet is surface soil; then a gravel bed of about 10 feet; and after that all the way down there is practically a solid bed of what we call shale, which stands up without casing. At about 150 feet we encountered a little water which was unfit for our use, which, however, we did not have analyzed and which we have cased off as stated above; balance of the hole was dry. Water of a fair flow, about 400 gallons per hour, and of a useful quality, was encountered at 765 feet, after going through about 2 feet of what appeared to be sandstone. Water comes from a sand bed, white, which we punched through for 15 feet and quit. Have not had water analyzed, but are using it about the brewery for boilers, condense water, and for cleaning and scrubbing. It is quite soft and the first two weeks was a good drinking water. We think, however, that some of the surface water is mixing with the lower flow and we intend, therefore, this summer to case the well down to the bottom and shut off everything above the water coming from the sand bed. This is the deepest well at Green River and no coal was encountered. The shale is practically of even hardness, as indicated by the drilling operations, but varies in color; it is of different tints, gray, yellow, blue, brown, green, up to almost black. A little gas was encountered about 120 feet down.

During the fall of 1909 only a part of the Western Alkali Company's wells were pumped. Three of the wells were supplying water the day the writer visited the plant. The company at this time was testing the wells to ascertain the effect of continuous pumping on the amount of salt or mineral held by the water and what interference, if any, there was between the various wells. Although a complete chemical test had been made of the waters from the separate wells, showing the variation in the salt content under various conditions over a period of several months, the company was not willing to supply any of this information and no conclusions concerning these results can be given here. It should be borne in mind, however, that conditions at the several wells are very different and give a wide range in results. Continuous pumping at some of the wells does not materially decrease the amount of salt in the water, but at other wells a few hours' pumping shows a remarkable decrease in the mineral content. In general there is a decrease in the quantity of salt held in solution as pumping continues, but if the well is allowed to stand idle for some time the water gradually regains its mineralization. Some wells recover their normal amounts of salt much more rapidly than others, and there is considerable difference in the mineral content and composition of the water at the different wells. The amount of water available from any well also depends in part on the treatment of the neighboring wells. It is reported that if only one is pumped the yield is greater for that well than when several wells are pumped at the same time. The deduction that these detailed facts would warrant can not be given here, as the company does not care to make its records public at the present time. The general range of mineralization of these waters in regard to the two chief minerals was given as follows: NaCl, 400 to 1,800 grains in a United States gallon; Na_2CO_3, 2,000 to 6,000 grains in a United States gallon. These values should be considered as maximum and minimum rather than averages.

In 1896 the Green River Fuel and Oil Company, while drilling its prospect well No. 1 at Green River, encountered a flow of alkaline water at a depth of 125 feet. A sample of this water sent to the University of Wyoming at Laramie proved to be a nearly saturated solution of sodium carbonate of greater purity than any found elsewhere in the State. On standing a few days a thick deposit of large crystals of hydrous sodium carbonate (sal soda) filled the bottom of the vessels. The salt thus formed was much purer than the commercial product and contained only traces of chlorides and sulphates. The water contained 8.9 per cent of sodium carbonate or 24 per cent of crystallized sal soda. It was reported by Robert Morris, of Cheyenne, that when 60,000 gallons was pumped from this well in twenty-four hours it lowered the well only an inch or two and did not appreciably lessen the strength of the soda solution. Not all the wells furnish so much sodium carbonate. A sample of the product of evaporation from one of the wells drilled at a later date gave the following results: Sodium carbonate (anhydrous), 48.2 per cent; sodium chloride, 51.6 per cent; undetermined, 0.2 per cent, with traces of magnesium and sulphates. According to another analysis, made by Herman Harms, of Salt Lake, the water shows a specific gravity of 1.10 at 59° F. and contains 246 grams of sodium carbonate crystallized and 6.12 grams of sodium chloride per liter.

Analysis of the Green River soda made by G. C. Wheeler, of Chicago, shows by the absence of any appreciable quantities of sulphates that this soda differs decidedly from all other waters and alkali deposits in the State. The analysis is as follows:

Analysis of Green River soda.

Silica	0.51
Iron and aluminum	.42
Calcium	.64
Magnesium	.27
Insoluble residue	.23
Water	22.57
Anhydrous carbonate of soda	75.36
	100.00

MANUFACTURE OF SODA AT GREEN RIVER.

SAL-SODA PROCESS.

The water is pumped from all or part of the wells by means of electric motors and carried in pipes to the main building, where the water from the separate wells is run into the same tank and allowed to mix. There are three large evaporating tanks that are used in turn as demand requires. The water is allowed to stand in the evaporating tank, which is provided with pipes through which steam is passed to facilitate evaporation, until the solution reaches the desired concentration. The concentrated solution is then run through pipes to one of the ten crystallizing vats, arranged in two parallel rows of five vats each, in an adjoining building, where it is allowed to cool until the crystallization is completed. The liquid residue is then run back into the "causticizers" in the main building and used in making caustic. The crystals are taken from the crystallizing vats and placed on drying tables, where they soon lose their crystalline form, breaking down into a fine white powder. This powder is then packed in 100-pound boxes and shipped to the eastern and western markets.

CAUSTIC PROCESS.

In the manufacture of caustic the water pumped from the wells, as well as the remaining water from the sal-soda crystallizing vats, is run into one of the two "causticizers" in the west end of the main building. These "causticizers" consist of large circular tanks 12 feet in diameter and 10 feet deep in which are perforated vessels containing caustic lime. Around these vessels the solution of sodium carbonate is agitated, and after "causticizing" the liquor is passed through four rectangular filters or iron settlers, where most of the lime is separated. The reaction is based on the fact that calcium carbonate is insoluble and that sodium carbonate and sodium hydroxide are soluble ($Na_2CO_3 + Ca(OH)_2 = 2Na(OH + CaCO_3)$.

The liquor after passing through these filters or iron settlers is allowed to stand for some time in the vat or settling tanks in order to let the finer particles of $CaCO_3$ settle. The upper part of the clear liquor is then let into a drum by vacuum and run into one of two storage tanks, 12 feet deep and 20 feet in diameter, where the liquor is allowed to stand for some time in order that all the remaining finer lime particles may settle. From these two tanks the clear liquor is drawn by vacuum into a third storage tank or settler, 12 feet deep and 20 feet in diameter. The liquor is now practically free from lime and the clear liquor from the third tank is run into one of the three salt settling pans, where waste steam heat is used to aid the evaporation of the solution and the settling of the salt as well as of part of the sulphur. From these salt settling pans the slightly concentrated liquor is run through two steam-heated low-pressure boilers, where further concentration takes place and the moisture is removed. The first boiler maintains a vacuum of 7 inches of mercury; the second a vacuum of 21 inches of mercury. From these boilers the concentrated liquor is run into a storage tank in the upper part of the building, and thence to the "end pots," large cast-iron pots set directly over a furnace, where all the remaining traces of water are driven off at a low red heat. The hydrate at this stage is as a rule nearly black. Sometimes small quantities of niter are added to the fused mass in order to whiten it. The hydrate is ladled from the "end pots" into sheet iron vessels or drums and shipped to Denver and other western cities.

PRODUCTION.

The Western Alkali Manufacturing Company produced in 1909 approximately 100 tons of caustic and 150 tons of washing soda.

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