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SALT RESOURCES OF THE UNITED STATES

BY

W. C. PHALEN

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SALT RESOURCES OF THE UNITED STATES.

By W. C. PHALEN.

INTRODUCTION.

In the search for deposits of soluble potash salts carried on by the Geological Survey under specific authority of Congress a great deal of important information on the salt resources of the United States has been collected. The bulletin containing this information as first prepared was divided into five parts, as follows: (1) Geology of the salt deposits of the United States; (2) theories (origin and formation) of saline deposition; (3) chemical composition of saline materials; (4) statistics of the production of salt in the United States; and (5) technology of the manufacture of salt.

The part relating to the technology of the manufacture of salt is omitted from the Geological Survey publication as more properly connected with the work of the Bureau of Mines. That part, which complements the present bulletin, has therefore been prepared for publication as Bulletin 146 of the Bureau of Mines, to which bureau application should be made for it.

SOURCES OF INFORMATION.

It was recognized that every known deposit of rock salt should be closely studied and tested from time to time in order to make a complete investigation of the possible occurrence of commercial deposits of potash salts in the United States; for deposits of ordinary rock salt may overlie, be included within, or underlie deposits of potash salts. A systematic study was therefore made in the summer of 1911 of the brines, bitterns, and deposits of rock salt in the States east of the Rocky Mountains and in localities considered most promising for potash. Hundreds of samples of brines, bitterns, rock salt, and calcium chloride, many of them sent in by drillers for oil, were collected for chemical examination; the geology of the occurrences of the brines and salt was investigated; records of deep wells were examined in the hope that some of them might be more complete than those already published by the different State surveys; and samples of the rocks passed through in the deep drillings were studied.

The field work extended over the western part of New York and included visits to the operating plants in Wyoming, Livingston, Genesee, and Tompkins counties. Every active salt plant in the Lower Peninsula of Michigan was visited. During the early part of the work the writer was accompanied by J. W. Turrentine, of the Bureau of Soils, United States Department of Agriculture. The brines of Midland, Saginaw, Bay, and Isabella counties, Mich., whose content of bromine in commercial quantity indicates partial desiccation of sea water and the occurrence of mother liquors, were sampled; also the brines of Malden, Kanawha County, and of Mason and Hartford, Mason County, W. Va.; those of Meigs County, Ohio, across Ohio River from Mason County, W. Va., and those of Pittsburgh, Pa.—all of which are or have been worked for bromine. Northern Ohio and Kansas were reviewed. As it was rumored early in 1911 that potash salts had been found near Goderich, western Ontario, Canada, that locality was visited and samples were obtained.

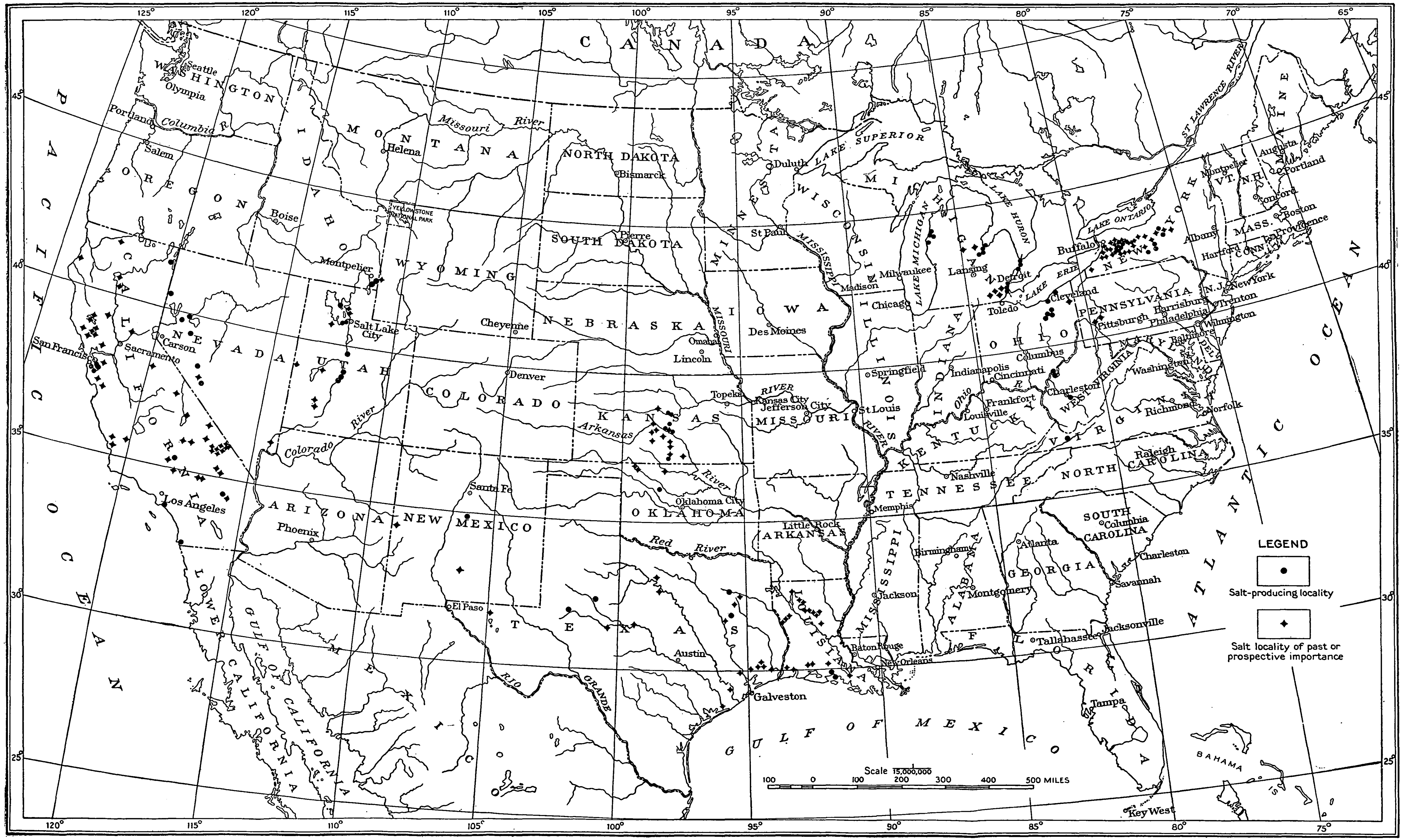
Similar field work was continued by the writer during the summer of 1912, principally by visits to the salt-producing districts in the Western States. The shores of Great Salt Lake were inspected, and the salt deposits to the south, in Sevier, Sanpete, and Juab counties, Utah, were sampled. Samples of salt and brine were obtained from the solar-salt plants on San Francisco Bay, Long Beach, and San Diego Bay; and the deposits in the Avawatz Mountains, San Bernardino County, Cal., were examined.

Practically all the analyses resulting from this work are given under the heading "Chemical composition of saline materials" (pp. 270–277).

The writer takes this opportunity to thank his numerous friends in the industry who have contributed so generously both time and information. In this connection specific mention should be made of his former colleagues in the United States Geological Survey, Messrs. H. S. Gale, R. B. Dole, and R. K. Bailey. Mr. Gale examined the report critically, as did Mr. Dole, who also scrutinized the analyses thoroughly and suggested many changes that have been incorporated in the report. Mr. Bailey recalculated all the chemical analyses and brought them to a uniform basis.

TYPES OF OCCURRENCE.

Salt is widely distributed and occurs in many places in beds of sufficient size to constitute true rock masses. It is also found in solution, as in salt springs and in the water of the ocean and of inland salt lakes or seas, as Great Salt Lake and the Dead Sea. Deposits of rock salt that are interstratified with rocks of various geologic horizons (see p. 193) have been formed by the gradual evaporation of bodies of sea water cut off from the main ocean. The salt water of inland salt lakes or seas, like Great Salt Lake and the Dead Sea, has



MAP SHOWING LOCATION OF SALT PLANTS IN THE UNITED STATES.

been concentrated by evaporation through lack of an outlet. The mineral matter of such inclosed bodies of salt water in general crystallizes out in the order in which the solution becomes saturated with the various salts. This order depends partly on the relative amounts of the salts in the water and partly on their solubility.

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Rock salt is of such universal occurrence that a list of the localities where it is found would include almost every country on the globe. In the United States extensive and valuable deposits of salt are found in central and western New York, in Pennsylvania, Ohio, Michigan, Virginia, Kansas, Louisiana, Texas, Nevada, Utah, Arizona, New Mexico, California, Idaho, Wyoming, and probably in several other States. Salt springs and wells abound in the neighborhood of the salt deposits, and these, as well as the waters of salt lakes and sea water, are used as sources of the commercial product.

The location of the producing salt plants in the United States is shown on the accompanying map (Pl. I).

MINERALOGY.[1]

Common or rock salt is known mineralogically as halite. It is the chloride of sodium, composed of 39.4 per cent chlorine, which in its free state is a gas, and 60.6 per cent of the metal sodium. Halite is rather brittle and has a conchoidal fracture. Its hardness is 2.5. Its specific gravity ranges from 2.1 to 2.6, that of pure crystals being 2.135. Its index of refraction is 1.5442. It is highly diathermous. It seldom occurs perfectly pure, being mixed with a variety of other saline minerals, among which are gypsum, anhydrite, and (in Germany) carnallite, kieserite, and polyhalite, or it is associated with shale and sandstone.

Halite is isometric in crystallization and usually forms cubes, which are commonly distorted or united in cavernous aggregations called hopper-shaped crystals. (See Pl. II.) It also occurs massive with granular to compact structure. Masses with perfect cubical cleavage are common as well as the fibrous variety, which is said to be pseudomorphous after gypsum. It has a vitreous luster, and when pure it is transparent and colorless. Impurities impart to it yellow, red, brown, blue, and purple hues and are responsible for its different degrees of translucency. It is readily soluble in water. (See table on pp. 274–275.) Its characteristic saline taste is known to all.

USES OF SALT.

Salt is largely used for culinary purposes and in the meat-packing, fish-curing, dairying, and other industries to preserve the products from deterioration. It is used extensively in refrigeration. The chlorination of gold consumes some salt. It is also used to form a

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[1] Dana, J. D., System of mineralogy, 6th ed., New York, pp. 154-156, 1892.

glaze on pottery, in enameling and pipe works, for salting cattle, in curing hides, making pickles, and in clearing oleomargarine. In the form of brine it is largely used in the chemical industries in the preparation of soda ash, caustic soda, and various other chemicals containing a sodium base.

GEOLOGY OF SALT DEPOSITS OF THE UNITED STATES.

GENERAL DISTRIBUTION AND CHARACTER.

Of the useful minerals found in the United States none perhaps occurs in greater abundance or is more widely distributed than common salt. It occurs in crystalline layers interbedded with other sediments, which may have been chemically precipitated, like gypsum, or which may be classified as ordinary clastic deposits, like sandstone and shale—the whole forming hills or even mountainous masses (see Pls. XIII, XIV, XV, and XVI); in the beds of dry, or nearly dry, lakes, marshes, or alkali flats (see Pl. XII, p. 142); or in the form of dissolved salt in natural brines that issue from salt springs or are found in salt lakes or ponds or in the ocean. Examples of all these modes of occurrence will be given in the descriptions of the salt resources of the different States in which salt is of present or of prospective commercial importance.

In the eastern and southern parts of the United States salt deposits do not appear at the surface as they do in many parts of the West. In New York, northern Pennsylvania, Michigan, Ohio, Kansas, Virginia, Louisiana, New Mexico, and eastern and northwestern Texas salt occurs in bedded deposits well below the surface, where it is protected from the solvent action of rain and ground water by a mantle of impervious strata. In the Western States, Idaho, Wyoming, western Texas, New Mexico, Arizona, Nevada, and California, many extensive salt deposits are exposed at the surface because of arid climatic conditions. Thus the United States may be divided into eastern and western parts with reference to its salt resources, the division being not only geographic but climatic.

The greater part of Nevada, large parts of Utah and California, and small parts of Oregon, Idaho, and Wyoming are included in the Great Basin region, so called, in which are the drainage basins of Lake Lahontan and Lake Bonneville, two Pleistocene lakes. The basins of these lakes have been studied by G. K. Gilbert[1] and I. C. Russell.[2] The conclusions of these geologists regarding the salines deposited from the waters of these lakes, their accumulation, their disappearance from the surface, and the possibility of finding them below the surface are discussed in subsequent pages of this bulletin.

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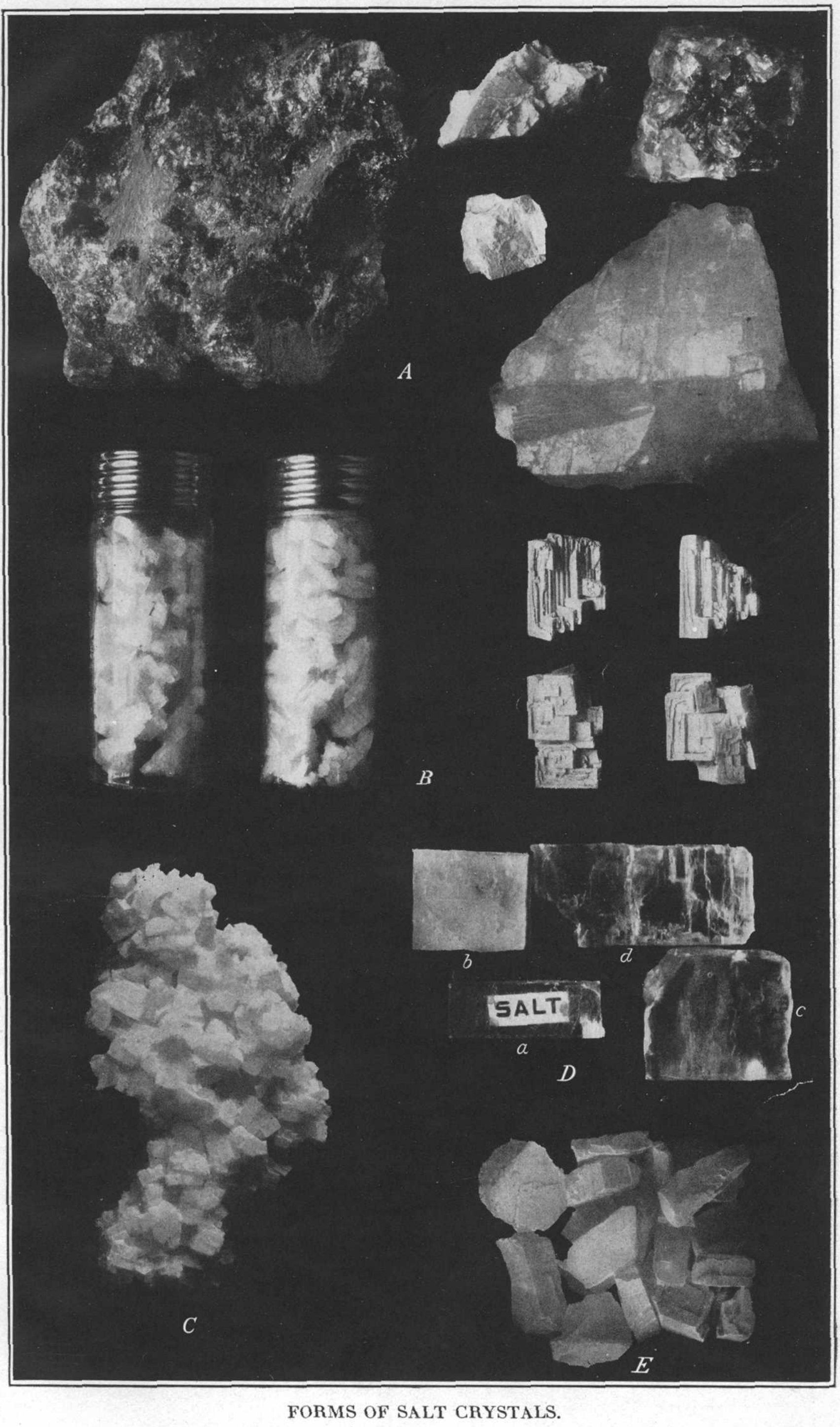
[1] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, 1890.

[2] Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U. S. Geol. Survey Mon. 11, 1885.



FORMS OF SALT CRYSTALS.

A. Rock salt including fragments of shale. *B*. Hopper-shaped crystals from the evaporating ponds of the Leslie Salt Co., Leslie, Cal. *C*. Perfect cubes of salt from Silver Peak Marsh, Nev. *D*. Salt crystals from Kansas: *a*, *b*, Rock salt from shaft of Standard Salt Co., Little River, Kans.; *c*, *d*, Salt showing perfect cubical cleavage, furnished by Bevis Rock Salt Co., Lyons, Kans. *E*. Large plate of rock salt from a mine in Genesee County, N. Y.

The climatic and geologic conditions pertaining to certain of the saline deposits of Arizona and New Mexico are similar to those of the Great Basin region, and the generalizations by Gilbert and Russell for that region hold for certain occurrences of salt in the two States mentioned.

NEW YORK.

HISTORY OF THE SALT INDUSTRY.

The salt industry is older in New York than in any other salt-producing State. Salt was probably made by the Indians from brine springs, the most important of which, near Syracuse, Onondaga County, were noted by missionaries among the Indians about the middle of the seventeenth century. Le Moyne, a French Jesuit, mentions the salt springs in connection with the Indians in his journal published in 1653. The Delawares are known to have sold salt to settlers in Canada and in northern and eastern New York as early as 1670. The manufacture of salt by white people near Syracuse began about 1788 or 1789. At first the brine was evaporated in kettles suspended over fires, but arches large enough to contain four ordinary potash kettles were soon introduced.

In 1797 the legislature of New York set apart 15,000 acres of land, the Onondaga Salt Springs Reservation surrounding the head of Onondaga Lake, and laws were made regulating the making of salt. The area of the reservation was reduced from time to time until 1908, when the control of the lands and wells was relinquished to the Onondaga Pipe Line Co. and the Mutual Pipe Line Co., of Syracuse, for the nominal sum of $15,000. The establishment of the reservation was followed by the formation of the Federal Co., which erected the largest salt-making plant of the period—32 kettles set in blocks of four each. At first the brine was pumped by hand from shallow wells, but as the wells enlarged horsepower and subsequently water power was used to lift the brine. Since the State government took possession of the reservation and appointed a superintendent, a record has been kept of all matters pertaining to its production of salt. The whole production from 1797 to 1896 was 365,434,887 bushels of 56 pounds.

Prior to 1846 the royalty charged the manufacturers by the State was variable, but since that year the uniform charge has been 1 cent a bushel; the net profit to the State to 1886 was $668,200, but since then there has been a small annual deficit.

It had long been believed by the geologists of the New York survey that the Onondaga salt springs were supplied by the leaching of beds of rock salt. In 1820 explorations with a deep drill were begun on the Onondaga Reservation in search of these beds, but they resulted in failure. In 1838 the State legislature appropriated a sum large enough to enable the superintendent to sink a shaft or well 600 feet deep, which likewise resulted in failure. The truth of the geologists' belief was demonstrated later by accident and in a locality where salt was least expected.

Rock salt was discovered in New York in 1865 at the village of Vincent, in western Ontario County. The importance of the find was not appreciated and it was not generally known until after the salt bed had been found in other places. Early in 1878 one of several test wells sunk in western New York in a search for oil encountered a bed of rock salt 70 feet thick at a depth of 1,279 feet a mile south of Wyoming. This well became known as the Pioneer well. Three years later, in March, 1881, works with the small capacity of 40 barrels a day were erected and salt was first made from artificial brine. Shortly after this discovery successful exploration took place at Leroy, north of Wyoming, where salt was made in the spring of 1884.

In the meantime progress was made in another part of the State. In August, 1881, a company of citizens of Warsaw began to sink a well near the Buffalo, Rochester & Pittsburgh Railway in the northern part of the town, and in October of that year a bed of salt and shale 111 feet thick was found at a depth of 1,520 feet. Eighty feet of the bed proved to be salt. An abundant supply of water with which artificial brines could be made was also encountered. It was soon shown that the artificial brine was fully saturated, of great purity, and could be produced practically in unlimited quantity. The development of the salt industry in this general locality was very rapid. In 1883, the year in which there was such a marked development in the Oatka Valley, salt was found in the Genesee Valley, where the salt bed was first reached in a well near the shaft of the Retsof salt mines, 10 miles directly east of the Pioneer well in the Oatka Valley. In September, 1885, a shaft 9 by 12 feet reached rock salt near Griegsville at a depth of 996 feet. Many wells and a few other shafts were later put down in the Genesee Valley.

The discovery of rock salt at Wyoming in 1878 revived interest in the search for the bed that geologists had asserted must exist in the higher land south of Syracuse, and in 1881 a well was sunk at Jamesville, 7 miles southeast of the head of Onondaga Lake. In 1882 another well was sunk at Cedarvale, 7½ miles southwest of the reservation. Rock salt was not found in either of these wells. In 1884 two wells were put down near the Onondaga salt springs, one by private parties and the other by the State. No rock salt was found in the Salina formation in either of these wells. In 1885 a test well was sunk at Ithaca to a depth of 3,185 feet in which salt was found and a careful record was made of it. (See p. 39.) The stratigraphy of the Ithaca well has been described by C. S. Prosser.[1] In 1886 a well

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[1] Am. Geologist, vol. 6, pp. 202-203, 1890.

was sunk at Morrisville, Madison County, in which rock salt was found. The Morrisville well marks the most easterly point at which rock salt has been found in the State and also the most northerly point east of Genesee River, with possibly a single exception.

In 1888 the Solvay Process Co., of Syracuse, in searching for a larger and cheaper supply of brine for its large soda-ash plant at Syracuse began to sink a well near the middle of the south end of the valley of Onondaga Creek in the town of Tully, 17 miles south of Syracuse. The well was abandoned after it had passed through 400 feet of glacial drift, and another was begun a quarter of a mile farther east, in which the drill encountered at a depth of 1,216 feet a bed of rock salt 45 feet thick. In 1889 ten new wells were put down; in 1890 ten more; and in 1891 nine more, all on the eastern side of the valley. In 1895 and 1896 eleven additional wells were drilled on the opposite side of the valley, making a total of 41 wells drilled to the salt bed in this locality by this company. Forty of these wells are connected by iron pipes with Tully Lakes. The water from the lakes flows by gravity to the salt and becomes saturated with it. This brine formerly flowed out through other pipes into a large main that conveyed it to Syracuse, where the works are 360 feet lower than the mouth of the lowest well, but because of the loss by this method the wells are now pumped. The geologic horizon of the mouths of these wells, all of which are close together, is the middle of the Hamilton formation.

In 1891 a well was sunk to the salt bed at Ludlowville, Tompkins County, and a second well was put down in 1892. In 1895 another well was drilled at Ithaca, north of the well put down in 1885. In 1893, 1894, and 1896 wells were sunk at Watkins, Schuyler County, and salt is now made at that place.

During the last few years New York has ranked second among the States in both quantity and value of the salt produced. The industry includes both the mining of rock salt and the evaporation of brine by the solar, open-pan, grainer, and vacuum-pan processes.

POSITION OF FIELD.

The Salina or salt-bearing formation outcrops in a belt approximately 12 miles wide at Niagara River, extends eastward across the central tier of counties to a point a little south of Oneida Lake. The outcrop then turns to the southeast, tapering gradually, and terminates in the vicinity of Schoharie River, Schoharie County. Its greatest width, about 20 miles, is at the foot of Cayuga and Seneca lakes. Salt mining is confined to the region south of this outcropping belt—that is, in the direction of the dip of the beds—as the salt beds, by reason of their solubility, can not exist at the surface in this region of abundant rainfall. These facts are brought out on the map (Pl. III), which shows the outcrop of the Salina formation and the places in the State where salt has been found in wells and shafts.

EXTENT OF DEPOSITS.

The district under which rock salt is known to exist comprises the corner of Genesee County south of Leroy, the eastern half of Wyoming County, nearly the whole of Livingston County, and the part of Ontario County west of Canandaigua Lake and chiefly south of the New York Central Railroad. There can be scarcely a doubt that rock salt exists west of Warsaw, but the early borings in Erie County seem to have been beyond the western limit of the salt deposits. No rock salt was found at the East Aurora well, but strong brine was obtained. At Gardenville, 7 miles from Buffalo, a well was sunk entirely through the Salina formation, but no rock salt was found. Likewise at Eden Valley and Gowanda, only brine was obtained in the early wells. Later reports, however, state that rock salt has been found in Erie County at Eden Valley, Springville, Perry, and Gowanda;[1] and in Cattaraugus County in a gas well between Cattaraugus and Gowanda.[2]

East of Canandaigua Lake the borings put down at Dundee, Watkins, Ithaca, Ludlowville, and Tully all reached the rock-salt beds. The area underlain by rock salt west of Canandaigua Lake is computed by I. P. Bishop[3] to be 1,100 square miles in areal extent. In view of discoveries made since Bishop's report was published, it is probable that his estimate is far too low. East of this lake the area underlain by salt must be fully as large as that west of it if not larger. The northern limit can be assigned only approximately, owing to the solution of the rock salt as it approaches the surface. The southern limit is not known and may never be accurately determined, as the cover of the Salina formation increases in thickness in that direction; but the salt is known to extend at least as far south as the vicinity of Pittsburgh, Pa. The persistence of the salt to the south in New York, however, is indicated by the wells at Ithaca, which reach the salt at a depth of 2,200 feet, and by test borings in northern Cattaraugus and Allegany counties, which encountered salt below 3,000 feet. The boring at Canaseraga, Allegany County, penetrated 75 feet of rock salt, beginning at a depth of 3,050 feet.[2]

The northern limit, as shown by the outcropping Salina strata, is approximately defined by a line drawn from a point south of Oneida Lake westward to Buffalo. To the south of this line deposits are

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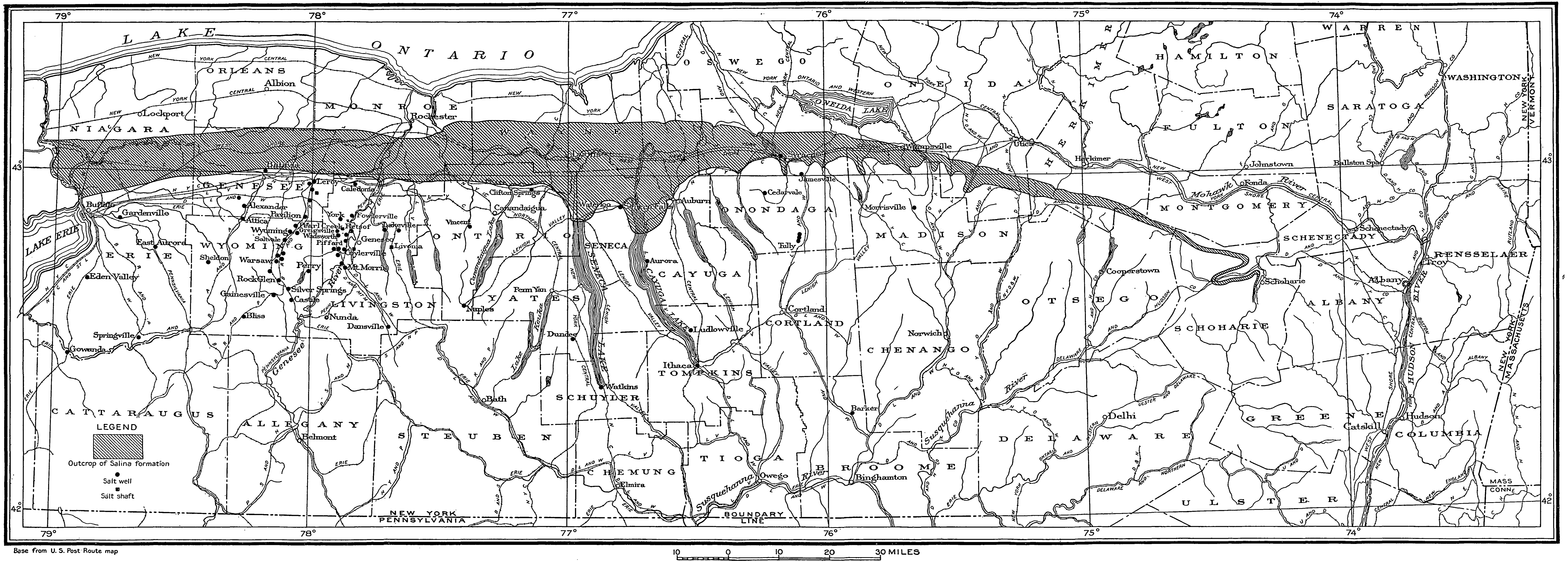
[1] Newland, D. H., New York State Mus. Bull. 166, p. 57, August, 1913.

[2] Newland, D. H., New York State Mus. Bull. 174, p. 66, December, 1914.

[3] New York State Geologist Rept., vol. 5, p. 34, 1885.



Base from U. S. Post Route map

MAP OF CENTRAL NEW YORK, SHOWING OUTCROP OF THE SALINA FORMATION AND LOCATIONS WHERE SALT OR BRINE HAS BEEN FOUND IN WELLS OR SHAFTS.

encountered at progressively increasing depths in accordance with the dip of the strata, which ranges from 40 to 50 feet a mile. The most easterly point where salt has been found is Morrisville, Madison County. Between this point and Lake Erie salt has been found in almost all the counties in the central tier of the State.

STRATIGRAPHY.

The salt beds of New York belong in the Salina formation of the Cayuga group of rocks, which in turn are in the Silurian system. To illustrate the position of these beds in the geologic columnar section of New York, the section of the Devonian and Silurian rocks is given below:

Major subdivisions of the Devonian and Silurian rocks of New York, showing position of Salina formation.[1]

Devonic	Chautauquan	Chemung beds.
		(Catskill sandstone, local facies.)
	Senecan	Portage beds.
		(Naples beds, Ithaca beds.)
		Oneonta beds, local facies.
		Genesee beds.
		Tully limestone.
	Erian	Hamilton beds.
		Marcellus beds.
	Ulsterian	Onondaga limestone.
		Schoharie grit.
	Oriskanian	Esopus grit.
		Oriskany sandstone.
		Port Ewen limestone.
	Helderbergian	Becraft limestone.
		New Scotland limestone.
		Kalkberg limestone.
		Coeymans limestone.
Ontaric or Siluric	Cayugan	Manlius limestone.
		Rondout waterlime.
		Cobleskill limestone.
		Salina beds.
	Niagaran	Guelph dolomite.
		Lockport dolomite.
		Clinton beds, including Rochester shale at top.
	Oswegan	Medina sandstone, including Oneida conglomerate.
		Oswego sandstone.

The Salina formation in central and western New York is now subdivided into the following members, beginning with the highest:

1. Bertie water lime:[2] Argillaceous magnesian limestone, used for the manufacture of natural cement in Erie County. (This is the upper horizon of abundant *Eurypterus*.)
2. Camillus shale: Workable gypsum deposits, shale, and dolomite.
3. Syracuse salt.
4. Vernon shale: Red, gray, and green shales and thin dolomites.
5. Pittsford shale: Shale interbedded with dolomite; contains a profusion of eurypterids.

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[1] Hartnagel, C. A., Classification of the geologic formations of the State of New York: New York State Museum Handbook No. 19, 1913, table 1, between pp. 24 and 25.

[2] The names here used are those in current use by the New York State Geological Survey.

In eastern New York the Wilbur limestone, below the cement beds of the Salina, carries a brief modified reappearance of the Niagaran fauna.[1] It will be observed, therefore, that the salt beds of New York are associated with deposits of gypsum, shale, dolomite, and limestone.

STRUCTURE.

It was stated that the Salina beds in which the salt deposits occur are lens shaped. The strike or line of surface exposure of the salt-bearing formation is eastward, approximately parallel with the shore of Lake Ontario, though because of the rough topography the line of outcrop is tortuous in detail.

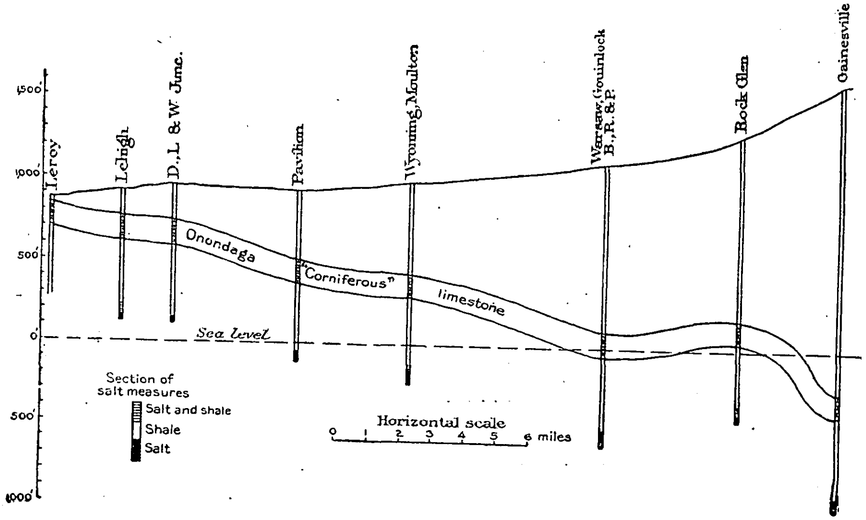

FIGURE 1.—Geologic section through the salt wells from Leroy to Gainesville Creek, N. Y., showing structure of Onondaga ("Corniferous") limestone and underlying salt bed. (After F. J. H. Merrill, New York State Mus. Bull. 11, 1893.)

The beds or lenses dip to the south at a low angle. Exposures and sections of deep records show that this dip is not continuous but is reversed at intervals, with consequent dip to the north. Over a large part of the salt district 60 feet a mile is considered a fair average of the dip, but it is very irregular and ranges from 100 feet or more to the south to almost as much to the north, where reverse dips have been noted. The structure is well shown in figure 1.

THE SALT BEDS.

The Salina formation contains not only the salt deposits of New York but also the gypsum deposits of the western part of the State. The gypsum deposits occur in the upper part of the Salina, in the

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[1] New York State Mus. Handbook 19, pp. 8, 18, and 19, ed. 1903; idem, pp. 51-53, ed. 1912.

member designated Camillus shale, occurring above the salt deposits. Evidence that the rocks were deposited in water which contained salt nearly to the point of complete saturation is found in the hopper-shaped forms that occur at several horizons and in the numerous cavities in the porous limestones, which it is now known were filled with salt. The Salina formation rests on rocks of the upper part of the Niagara group. From the point where these rocks terminate on the east the Salina rests on the lower part of the Niagara group, the Clinton formation. East of the line at which the Clinton formation ends the Salina rests on the beds designated as Frankfort shale by the New York State Survey (lower part of Lorraine shale), on which they continue to a point near Hudson River.

There is scarcely any well-defined division between the Salina formation and the magnesian limestone which overlies it. This magnesian limestone has been used extensively in the manufacture of hydraulic cement. It is known as the Rondout limestone or water lime.

The Salina beds as a whole have the form of an irregular lens, the maximum thickness of which is found between Oneida Creek and Cayuga Lake. From this region they diminish in thickness east and west, which fact has been determined by plotting the sections revealed by deep drillings. The areal distribution of the formation is indicated on the map (Pl. III) taken from a geologic map of the State survey. In the earlier studies of the Salina exposed at the surface no rock salt was found simply because this soluble substance can not remain at the surface in a region where the rainfall is considerable. Our knowledge of the condition and magnitude of the salt beds has been obtained entirely from deep wells and mine shafts, more than 200 of which are distributed over the entire area in which the salt beds are near enough to the surface to be reached practicably by drilling. If the salt outcropped, it would in general appear along a line a short distance north of the southern boundary of the Salina; north of this line it would be useless to expect to find rock salt by drilling. The outcrop of the Marcellus shale is about as far north as salt may be found on deep drilling. The Solvay wells must be located near the edge of the salt bed, and it also seems clear that the bed does not become thinner toward the north and gradually "peter out," as it does west of Seneca Lake, but that it ends abruptly as though part of it had been removed.

The thickness and character of the salt deposits is essentially the same throughout the district, the only material difference being in the thickness and the number of intercalated layers of rock. In many of the wells a thick layer of rock separates the salt bed into two parts, each of which is subdivided in turn into other and thinner layers. No one of these layers is continuous over the whole field, and wells only a few rods apart show marked differences in stratification.

In the Oatka Valley the total thickness of the rock salt beds, including the interstratified shales and limestones, is from 100 to 135 feet, at Silver Springs it is 145 feet, and at Castile 190 feet. The salt beds gradually thin out to the north and do not reach beyond the latitude of Batavia, Leroy, and Caledonia. In the Genesee Valley, in a well on the Retsof mine property, the total thickness of the salt-bearing strata was 124 feet, of which 80 feet was rock salt. At the West Bloomfield and Bristol wells in Ontario County only one bed 8 to 15 feet thick was found. At Naples the bottom of the well is in the second bed of salt 63 feet below the upper one. At Watkins several hundred feet of the salt strata were penetrated. From the top of the upper bed of salt in the Ithaca test well to the bottom of the seventh or lowest one is 470 feet, the salt in this column measuring 248 feet in thickness. The greatest thickness in the Solvay wells at Tully is 318 feet. At Morrisville, Madison County, it was only 12 feet.

Overlying the salt deposits are 250 to 300 feet of shales and magnesian limestones that contain the great deposits of gypsum found in Madison, Onondaga, Cayuga, Seneca, Ontario, Monroe, and Genesee counties.

The broader features of the structure of the salt beds have been outlined. To recapitulate: The beds are lens shaped, strike eastward, and have an average dip to the south of 60 feet a mile although the dip is reversed at intervals. Cross folding is marked in certain areas, giving strong dips east or west; but in general dips east or west are hardly appreciable. Besides the undulations, which are low in proportion to their width, there are many small but sharp anticlinal folds in which the rocks are fractured at the apex and at both sides of the base. In some places the sides are inclined 45°, but as a rule the slant is much less. Dislocations of the strata in overturns and vertical faults are encountered in places and also fissures and joints which penetrate to great depths, but these are common to all the formations.

In the district included in Livingston and Wyoming counties so many wells have been sunk to the salt beds that the data secured enable certain general statements to be made with a considerable degree of certainty. F. J. H. Merrill[1] has constructed a map showing the underground contours of the salt measures. The datum plane chosen for this map is 610 feet below the upper surface of the Onondaga ("Corniferous") limestone. This seemingly arbitrary datum is chosen because the salt beds vary greatly in thickness and position in the Salina formation, and it is necessary to assume a horizon

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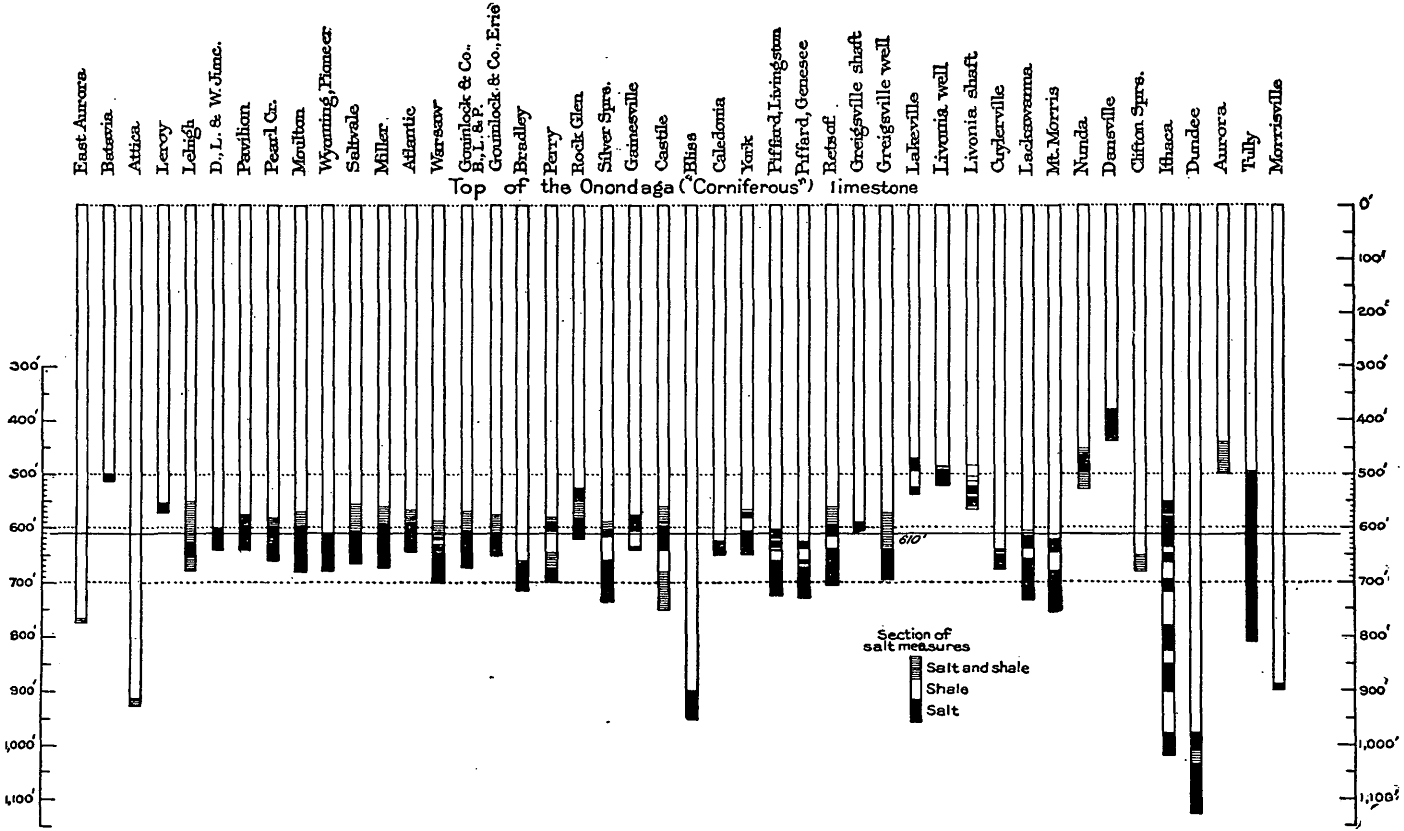
[1] New York State Mus. Bull. 11, p. 32, map, 1893.



DIAGRAMMATIC SECTIONS SHOWING DEPTHS OF ROCK SALT BELOW THE TOP OF THE ONONDAGA ("CORNIFEROUS") LIMESTONE IN NEW YORK.

After F. J. H. Merrill.

at which the salt may be expected to occur. The contour line at the altitude chosen intersects the principal salt bed in nearly every well shaft.[1]

Throughout the Oatka-Genesee district salt is usually found at levels varying from 550 to 750 feet below the upper surface of the Corniferous limestone. The exceptions to this are very few; the only ones * * * being the wells at Nunda and Bliss, in the former of which salt was found between 450 and 500 feet below the Corniferous, and in the latter it was first met at a depth of 900 feet. In the Ithaca well the lowest bed of rock salt was over 1,000 feet below the upper surface of the Corniferous. The testimony of the two latter wells would suggest that as a rule the wells and shafts of western New York have penetrated little more than halfway through the salt measures. The upper surface of the Corniferous limestone has been taken as the datum plane from which to determine the relative positions of the salt beds, because it is invariably recognized by the driller as soon as reached. Its persistent character and the abundance of chert distributed through it form a marked contrast with the comparatively soft shales and thin limestones which overlie it. From the underground contours as shown on the map [2] it will be seen that the dip of the strata in western New York is not directly to the south, but nearly southeast at the rate of about 60 feet to the mile. The section as plotted between Leroy and Gainesville Creek shows that the beds do not slope uniformly to the southeast but undulate in that direction.

RECORDS OF SALT WELLS AND SHAFTS.

The well records in the following pages have been taken from Bishop and Merrill in the references cited. Those by Bishop were obtained generally in the field; those quoted from Merrill were obtained in part in this way and in part from Englehardt and Prosser. Some of the records were obtained in the field by the writer. The arrangement in the text is geographic, from west to east. (See Pl. IV.)

Log of well at Gowanda, Cattaraugus County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	6	6
Shale	450	456
Sand, with oil and gas	4	460
Shale to "second sand"; more oil and gas	450	910
Shale	390	1,300
Hard rock (Corniferous and Helderberg)	400	1,700

[a] Bishop, I. P., New York State Geologist Fifth Ann. Rept., p. 17, 1885.

NOTE.—At 1,700 feet a vein of salt water was struck which filled the well and prevented further drilling. The brine is said to be very strong.

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[1] New York State Mus. Bull. 11, vol. 3, p. 32, 1893.
[2] Merrill, F. J. H., op. cit., map.

Log of well at Eden Valley, Erie County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shale	125	125
Hard rock, blue	200	325
Shale, black	300	625
Flint, lime, and sand	400	1,025
Brine in soft rock	50	1,075

[a] Bishop, I. P., op. cit., p. 17.

NOTE.—Salt water was struck at 1,025 feet.

Log of well at East Aurora, Erie County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shales, black and light colored	695	695
Limestone, Corniferous	165	860
From Corniferous to salt	605	1,465

[a] Bishop, I. P., op. cit., p. 18.

NOTE.—Strong brine was struck at 1,465 feet, which filled the well and ran out over the top.

Log of well at Gardenville, Erie County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Marcellus shales	60	60
Limestones (Upper and Lower Helderberg)	205	265
Shale to Niagara limestone	535	800

[a] Bishop, I. P., op. cit., p. 18.

NOTE.—Gas was found at the top of the Niagara and a few feet of shale containing brine a few feet above. No rock salt was found in the well.

Log of well of Lehigh Salt Mining Co., Lehigh, Genesee County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	50	50
Shale	100	150
Limestone, Corniferous, with flint	150	300
Limestone, hydraulic	30	330
Cement stone	20	350
Gypsum	100	450
Gypsum, shale, and limestone in layers 4 to 6 inches thick	250	700
Salt and shale	75	775
Rock salt	30	805

[a] Merrill, F. J. H., New York State Mus. Bull. 11, vol. 3, 1893.

Log of well at Batavia, Genesee County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Drift	40	40
Marcellus shale	60	100
Helderberg Limestone	150	250
Salina group (15 inches of salt at 600 feet)	500	750
Niagara	250	1,000
Medina	1,000	2,000

[a] Prosser, C. S., quoted by F. J. H. Merrill, New York State Mus. Bull. 11, vol. 3, 1893.

Logs of two wells at Leroy, Genesee County, N. Y.

Material.	Well No. 1.[a]		Well No. 2.[b]	
	Thickness.	Depth.	Thickness.	Depth.
	Feet.	*Feet.*	*Feet.*	*Feet.*
Soil, etc	23	23	22	22
Shale, Marcellus	10	33	11	33
Limestone, Corniferous	150	183	137	170
Water-lime (hydraulic limestone)	40	223	440	610
Rock, soft, saline shale	427	650		

[a] Merrill, F. J. H., op. cit.

[b] Bishop, I. P., New York State Geologist Fifth Ann. Rept., p. 19, 1885.

NOTE.—At 610 feet in the second well saturated brine was found in shale, mixed with particles of salt.

Log of well at junction of Buffalo, Rochester & Pittsburgh Railway with Delaware, Lackawanna & Western Railroad, Genesee County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Gravel	46	46
Shale	192	238
Limestone, Corniferous	146	384
Limestone, Lower Helderberg	454	838
Pure salt	40	878

[a] Bishop, I. P., op. cit., p. 20.

NOTE.—The drill passed directly from limestone to salt, there being no intervening shale, as in other wells. No salt was found in the shale below the main bed, though boring was continued with the expectation of finding it.

Log of well at Pavilion, Genesee County, N. Y.[a]

[Record furnished by M. E. Calkins.]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	51	51
Shale, Hamilton	374	425
Limestone, Corniferous	150	575
Limestone, Lower Helderberg	374	949
Shale	50	999
Salt bed	64	1,063
Shale	12	1,075

[a] Bishop, I. P., New York State Mus. Forty-fifth Ann. Rept., p. 54, 1892.

Log of well No. 2 of Pavilion Salt Co., Pavilion, Genesee County. N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	50	50
Limestone, soft	375	425
Limestone, Corniferous	150	575
Limestone, soft	375	950
Shale	50	1,000
Salt and shale mixed	19	1,019
Salt mixed with some shale	100	1,119

[a] Merrill, F. J. H., New York State Mus. Bull. 11, vol. 3, 1893.

NOTE.—Bottom in shale rock.

Log of well at Attica, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	200	200
Slate, Hamilton	375	575
Limestone, Corniferous	156	731
Limestone (Lower Helderberg), about	300	1,031
Slate	104	1,135

[a] Bishop, I. P., New York State Geologist Fifth Ann. Rept., p. 18, 1885.

NOTE.—At 1,490 feet some salt in rock till 1,500 feet. Total depth, 1,960 feet. For more details see Bishop's report.

Log of well at Pearl Creek, Wyoming County, N. Y.[a]

[Record furnished by Otis & Barton.]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	20	20
Shales, Hamilton, about	500	520
Limestone, Corniferous	90–100	620
Lower Helderberg(?), about	600	1,220
Salt and shale	20	1,240
Salt	55	1,295

[a] Bishop, I. P., New York State Mus. Forty-fifth Ann. Rept., p. 54, 1892.

Log of Moulton well, between Pearl Creek and Wyoming, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	3	3
Sand	50	53
Slate and soft rock	50	103
Shale	452	555
Limestone, Corniferous	152	707
Slate, indications of salt brine	60	767
Limestone, salt brine	323	1,090
Slate	34	1,124
Shale and rock salt	27	1,151
Rock salt	85	1,236
Slate	5	1,241

[a] Bishop, I. P., New York State Geologist Fifth Ann. Rept., p. 20, 1885

Log of Pioneer well, near Wyoming, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	40	40
Shales, bluish	40	80
Shales, black	220	300
Limestone	10	310
Slates of various colors	363	673
Limestone	100	773
Limestone, Corniferous; bitter water below	92	865
Shales, gypseous	405	1,270
Rock salt	70	1,340
Shale, red	190	1,530

[a] Merrill, F. J. H., New York State Mus. Bull. 11, vol. 3, 1893.

Log of well No. 1 of Crystal Salt Co., Saltvale, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Sand, gravel, and quicksand	136	136
Shale (?)	634	770
Limestone, Corniferous	146	916
Shale	15	931
Limestone, Upper and Lower	394	1,325
Shale and salt	50	1,375
Solid salt	61	1,436

[a] Bishop, I. P., op. cit., p. 21.

Log of Miller well, Warsaw, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shale, Lower Portage and Hamilton	935	935
Limestone, Corniferous	147	1,082
Shale	12	1,094
Limestone, Lower Helderberg	400	1,494
Shale and salt	30	1,524
Solid salt	85	1,609

[a] Bishop, I. P., op. cit., p. 21.

NOTE.—Depth to base of salt bed, 1,609 feet.

Log of well of Atlantic Salt Co., Warsaw, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface soil, clay, etc	26	26
Shale	874	900
Limestone, Corniferous	148	1,048
Limestone, shale, and salt	440	1,488
Rock salt	57	1,545
Shale, red (or sandstone)	104	1,649

[a] Bishop, I. P., op. cit., p. 21; also Merrill, F. J. H., Table of salt wells, New York State Mus. Bull. 11, 1893. The two records disagree in description of location and thickness of strata.

Log of well of Warsaw Salt Co., Warsaw, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface soil, clay	16	16
Shale	940	956
Limestone, Corniferous	156	1,112
Lower Helderberg and shale	430	1,542
Shale and salt mixed	30	1,572
Salt	6	1,578
Shale	10	1,588
Salt	70	1,658

[a] Merrill, F. J. H., op. cit.

Log of well of W. C. Gouinlock, Warsaw, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet*
Clay	17	17
Shales	1,011	1,028
Limestone, Corniferous	148	1,176
Shale	75	1,251
Limestones, Lower Helderberg	300	1,551
Shale	45	1,596
Salt and shale, mixed	37	1,633
Main salt bed	68	1,701

[a] Bishop, I. P., op. cit., p. 22.

Log of well of Gouinlock & Humphrey, on west side of the valley, Warsaw, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shales	1,230	1,230
Limestone, Corniferous	150	1,380
(Nature of strata not stated)	423	1,803
Salt and shale	19	1,822
Shale	3	1,825
Salt and shale	12	1,837
Salt	24	1,861
Shale, with a little salt	2	1,863
Salt	16	1,879

[a] Bishop, I. P., op. cit., p. 23.

Log of Bradley well, Warsaw, Wyoming County, N. Y.[a]

[Bishop calls this the well of the Eldridge Salt Co.; the designation here used is that of F. J. H. Merrill in New York State Mus. Bull. 11, 1893.]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	9	9
Shale (sandstone)	450	459
Slate	856	1,315
Limestone, Corniferous	225	1,540
Flint rock	70	1,610
Lower Helderberg	365	1,975
Salt	54	2,029
"Pocket"	10	2,039

[a] Bishop, I. P., op. cit., p. 23.

Log of well of Alex. Kerr, Bro. & Co., Rock Glen, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil, etc.	128½	128½
Sandstone and shale	1,361½	1,490
Limestone, Corniferous	140	1,630
Lower Helderberg	385	2,015
Salt	25	2,040
Shale	31	2,071
Salt	40	2,111

[a] Bishop, I. P., op. cit., p. 24.

Log of well at Perry, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Slate	1,462½	1,462½
Limestone	580	2,042½
Salt and shale	10	2,052½
Solid salt	15	2,067½
Slate, with little salt	40	2,107½
Salt and shale in about equal parts	30	2,137½
Solid salt	25	2,162½
Slate	18	2,180½

[a] Bishop, I. P., op. cit., p. 24.

Log of well of Duncan Salt Co., Silver Springs, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Gravel and quicksand	222	222
Slate and sandstones	1,299	1,521
Limestone, Corniferous	140	1,661
Limestone, Helderberg	320	1,981
Slate	128	2,109
Slate and shale, mixed	15	2,124
Pure salt	10	2,134
Slate	45	2,179
Salt, pure	75	2,254

[a] Bishop, I. P., op. cit., p. 25.

Log of typical well section near Silver Springs, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay, gravel, and quicksand	200	200
Blue stone	50	250
Shale or slate	1,200	1,450
Red rock	40	1,490
Flint rock with shells (Corniferous)	150	1,640
Limestone (soft)	200	1,840
Cement rock	250	2,090
Shale	80	2,170
Salt	100	2,270

[a] Furnished by superintendent of Worcester Salt Co., Silver Springs, N. Y.

Log of well at Castile, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	49	49
Sandstone; argillaceous; 175 feet or	180	229
Shale, blue, nearly uniform in color and hardness	786	1,015
Flint shell	10	1,025
Building stone, nearly like the first	650	1,675
Shale, black, nearly like coal; lower part much darker than upper (Marcellus shale)	100	1,775
Limestone, Corniferous	140	1,915
Alternate layers of hard and soft rock, two-thirds of which was as hard as flint and the rest shale	320	2,235
Soft slate saturated with brine	100	2,335
Salt and shale mixed; some salt crystals	35	2,370
Clear salt	45	2,415
Slate	40	2,455
Salt and slate, 5 feet of which was salt	70	2,525

[a] Bishop, I. P., op. cit., pp. 25-26.

Log of well of Bliss Salt & Oil Co., Bliss, Wyoming County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	55	55
To gas sand	580	635
First gas sand	40	675
Rock	525	1,200
Second gas and oil sand	100	1,300
Shale and black rock	400	1,700
Third gas sand	14	1,714
Black and white shale	286	2,000
Flint	100	2,100
Limerock and flint (solid)	800	2,900
Salt (very pure)	56	2,956
Limerock (solid).		

[a] Merrill, F. J. H., New York State Mus. Bull. 11, vol. 3, 1893.

Log of well at Caledonia, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface soil	6	6
Shale, Marcellus	20	26
Limestone, Corniferous	148	174
Gypsum and shale	50	224
Hydraulic lime and Helderberg	151	375
Shales and rock	225	600
Saline shale (brine at 600 feet)	50	650
Salt	25	675
Rock	73	748

[a] Bishop, I. P., op. cit., pp. 26-27.

Log of well of York Salt Co., York, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	52	52
Shale, Hamilton	128	180
Limestone, Corniferous	140	320
Limestone, Helderberg	330	650
Red shale	10	660
Blue and green shales	34	694
Salt and shales, mixed	6	700
Salt	10	710
Shale	27	737
Salt	41	778

[a] Bishop, I. P., op. cit., p. 27.

Log of well of Livingston Salt Co., Piffard, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil, etc	158	158
Shale	77	235
Limestone, Corniferous	150	385
Lower Helderberg and shales	453	838
Salt	18	856
Shale	6	862
Salt	11	873
Shale	4	877
Salt	2	879
Shale	20	899
Salt	62	961

[a] Bishop, I. P., op. cit., p. 27.

Log of well of Genesee Salt Co., Piffard, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	72	72
Gravel, strongly alkaline water	3	75
Clay (end of drive pipe)	2	77
Shale, blue, strongly alkaline water	13	90
Shale, blue	160	250
Shale, black	15	265
Shale, black, and lime	10	275
Solid lime, Corniferous	10	285
Decomposed mica	....	....
Solid lime, Corniferous, gas and oil	45	330
Lime and shale, gas and oil	2	332
Lime and shale, gas and oil	2	334
Lime, Corniferous, some oil, little gas	91	425
Oil or pebble rock (Bradford oil-bearing rock)	12	437
Shell in lime (end of first casing)	8	445
Lime	16	461
Shale, blue or gray	40	501
Salt shale and salt (second casing to 510 feet)	217	718
Saline shale (cased to 725 feet)	7	725
Salt shales, first rock salt at 880 feet	162	887
Rock salt	5	892
Slate rock	30	922
Rock salt	8	930
Soft slate	12	942
Rock salt	55	997
Slate	5	1,002

[a] Furnished by superintendent of company.

NOTE.—First flow of brine (65° salimeter) at 718 feet rose to about 60 feet from the surface. The brine at 725 feet registered 75° salimeter.

Log of well of Genesee Salt Co., Piffard, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay and gravel	64	64
Limestone and shale	186	250
Limestone, Corniferous	142	392
Slate	3	395
Gray lime (water lime)	313	708
Slate and shale	167	875
Rock salt	13	888
Shale	24	912
Rock salt	6	918
Shale	7	925
Rock salt	53	983
Shale	4	987

[a] Merrill, F. J. H., New York State Mus. Bull. 11, vol. 3, 1893.

NOTE.—Brine of 68° salimeter at 708 feet.

Log of well a short distance above Genesee Co.'s works, Piffard, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
To rock salt	936	936
Rock salt	2	938
Shale	4	942
Rock salt	12	954
Shale	28	982
Rock salt	6	988
Shale	9	997
Rock salt	54	1,051

[a] Bishop, I. P., New York State Geologist Fifth Ann. Rept., p. 28, 1885.

Log of well of Retsof Mining Co., Piffard, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Encrinal limestone	8	8
Hamilton shale (Moscow shale)	40	48
Dark shales	93	141
Limestone	8	149
Ludlow shale (Hamilton shale)	216	365
Limestone	4	369
Marcellus shale	39	408
Limestone, Corniferous	2	410
Shale	1	411
Limestone, Corniferous	140	551
Limestone, Onondaga	1	552
Hydraulic limestone (water lime)	13	565
Sandstone	14	579
Gypsum	4	583
Hydraulic limestone	25	608
Gypsum	47	655
Magnesian limestone (water lime)	63	718
Hydraulic limestone	14	732
Shales, blue	25	757
Limestone, Helderberg	10	767
Shales, blue	12	779
Limestone, Helderberg	17	796
Limestone and sandstone	31	827
Hydraulic limestone	10	837
Limestone and cement	15	852
Hydraulic limestone	6	858
Shale, blue	19	877
Shale, red	12	889
Limestone	41	930
Shale, red	5	935
Shale, blue	12	947
Limestone	12	959
Salt shale	51	1,010
Rock salt	2	1,012

[a] Merrill, F. J. H., New York State Mus. Bull. 11, vol. 3, 1893.

Log of well of Retsof Mining Co., Piffard, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shale and slate	28	28
Shale, Hamilton	373	401
Limestone, Corniferous	146	547
Shale (water lime)	68	615
Helderberg (Upper and Lower)	322	937
Shale	80	1,017
Salt	4	1,021
Shale	12	1,033
Salt	18	1,051
Shale	32	1,083
Salt	58	1,141

[a] Merrill, F. J. H., op. cit.

NOTE.—First well sunk on the property where the shaft is now.

Log of the main hoisting shaft, Retsof Mining Co., Retsof, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shale	133	133
Lime	8	141
Shale	232	373
Lime	4	377
Shale	23	400
Lime	3	403
Corniferous	142	545
Cement	13	558
Sandstone	4	562
Cement	7	569
Sandstone	14	583
Gypsum	4	587
Cement	26	613
Gypsum	47	660
Magnesium limestone and sand	63	723
Cement	14	737
Shale, blue	25	762
Cement	10	772
Shale, blue	12	784
Cement, Helderberg	17	801
"Mixture"	31	832
Cement	10	842
Lime, cement, and sand	15	857
Cement	6	863
Shale, blue	19	882
Shale, red	12	894
Shale, blue	41	935
Shale, red	5	940
Shale, blue	12	952
Lime	12	964
Salt and shale	32	996
Foot of shaft in rock salt	21	1,017

[a] Obtained through the courtesy of Mr. Frank Rundio, general superintendent of Retsof Mining Co.

Log of well at Greigsville, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Alluvial deposit, sand, clay, etc	60	60
Rocks belonging to the Hamilton group	112	172
Limestone	10	182
Marcellus shale, etc	260	442
Limestone, Corniferous	150	592
Limestone, Onondaga	10	602
Water lime	40	642
Shale, gypseous	75	717
Shale, red	12	729
Limestone	12	741
Shale, green and red alternating	269	1,010
First salt vein, followed by shale	2	1,012
Second salt vein, with shale below	4	1,016
Third salt vein, with shale below	19	1,035
Fourth salt vein	58	1,093
Shale between salt veins	45	1,138

[a] Merrill, F. J. H., New York State Mus. Bull. 11, vol. 3, 1893.

Log of well three-quarters of a mile south of Greigsville, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Alluvium	105	105
Hamilton shales	145	250
Limestone	12	262
Marcellus (etc.) shale	182	444
Limestone, Corniferous	148	592
Limestone, Onondaga	10	602
Water lime	78	680
Shale, gypseous	90	770
Shale, green and red	275	1,045
First salt bed	19	1,064
Second salt bed	6	1,070
Third salt bed	6	1,076
Fourth salt bed	6	1,082
With shale between veins	63	1,145

[a] Merrill, F. J. H., op. cit.

Log of well of Phoenix Salt Co., Cuylerville, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil, etc	184	184
Shales, Hamilton	286	470
Limestone, Corniferous	140	610
Water lime and shale	500	1,110
Salt	4	1,114
Shale	3	1,117
Salt	28	1,145

[a] Bishop, I. P., New York State Geologist Fifth Ann. Rept., p. 30, 1885.

Log of well of Lackawanna Salt Co., Mount Morris, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shale, Hamilton	600	600
Limestone, Corniferous	140	740
Lower Helderberg limestone and shale	463	1,203
Salt and shale, mixed	12	1,215
Salt, pure	23	1,238
Hard rock	20	1,258
Salt	75	1,333

[a] Bishop, I. P., op. cit., p. 30.

Log of well of Royal Salt Co., Mount Morris, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	191	191
Shale	479	670
Limestone, Corniferous	150	820
Water lime	50	870
Lower Helderberg	250	1,120
Salina shale	170	1,290
Salt and shale, mixed	4	1,294
Salt	20	1,314
Slate	35	1,349
Salt (drill stopped in salt)	73	1,422

[a] Bishop, I. P., op. cit., p. 31.

Log of well of Conesus Lake Salt & Mining Co., Lakeville, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	54	54
Shale, lower part bituminous; with gas and some oil	454	508
Limestone, Corniferous	140	648
Limestone, Helderberg	325	973
Shale	5	978
Salt (very clear)	25	1,003
Soft shale	30	1,033
Salt	20	1,053

[a] Bishop, I. P., op. cit., p. 31.

Log of Livonia well, bored by Mr. Townsend, half a mile north of Livonia, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Gravel	90	90
Sand and clay	250	340
Slate rock	65	405
Nature of strata not stated	6	411
Sandstone	10	421
Slate rock	284	705
Flint rock	140	845
Limestone	345	1,190
Slate and salt	5	1,195
Salt	32½	1,227½

[a] Merrill, F. J. H., New York State Mus. Bull. 11, vol. 3, 1893.

Log of Livonia shaft, Livonia, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Drift	64	64
Hamilton shales and limestones	748	812
Marcellus shales and limestones	54	866
Limestone, Corniferous, cherty	135	1,001
Water lime	23	1,024
Gypseous shales and limestones (first salt in thin veins)	324	1,348
Shales and limestones with small amounts of salt and gypsum (first salt bed 8 inches to 3 feet thick)	21	1,369
Shale	4	1,373
Shale, with salt in seams and veins	2	1,375
Crystalline salt	2	1,377
Shale	1	1,378
Salt, with fragments of shale	11	1,389
Salt	13	1,402
Limestone	6	1,408
Shale	1½	1,409½
Salt, with fragments of shale	15½	1,425
Limestone	2	1,427
Shale, with thin layers of salt	4	1,431
Bottom of shaft	31½	1,462½

[a] Merrill, F. J. H., op. cit.

Log of well on Reed farm, Livonia, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay, gravel, and sand	56	56
Shale	464	520
Sand rock	10	530
Slate (shale?)	302	832
Limestone, Corniferous	133	965
Hydraulic lime	45	1,010
Limerock	313½	1,323½
Shale and salt	11½	1,335
Pure salt	35	1,370
Salt and shale	8	1,378
Pure salt	15	1,393
Soft shale	114	1,507

[a] Bishop, I. P., New York State Mus. Forty-fifth Ann. Rept., p. 57, 1892. [Furnished by D. D. Luther.]

Log of well at Nunda, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shale, blue	65	65
Shale, black, with some gas	468	533
Sandstone, argillaceous	10	543
Slate, light-colored, with a small show of oil	473	1,016
Hard shell-rock	8	1,024
Slate	544	1,568
Iron pyrites	40	1,608
Limestone, Corniferous	210	1,818
Slate	182	2,000
Sandrock	60	2,060
Salt and shale, mixed	10	2,070
Pure salt	35	2,105
Salt and shale, mixed	35	2,140
Black shale without salt	85	2,225

[a] Bishop, I. P., New York State Geologist Fifth Ann. Rept., p. 26, 1885.

Log of well of Dansville Oil, Gas & Mining Co., Dansville, Livingston County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	20	20
Gravel	10	30
Shale, hard, gritty	70	100
Gritty slate	20	120
Dark sand like Bradford	15	135
Slate and shale	1,565	1,700
Hard limestone (dark color)	80	1,780
Hard "granite" (Corniferous)	80	1,860
Limestone, hard	40	1,900
Limestone, very hard	200	2,100
Solid salt (dry rock)	60	2,160
Limestone, hard	70	2,230
Crooked hole	10	2,240

[a] Merrill, F. J. H., New York State Mus. Bull. 11, vol. 3, 1893.

Log of well at Muttonville, near Bristol, Ontario County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shale, about	550	550
Limestone, about	450	[b] 1,000

[a] Bishop, I. P., New York State Geologist Fifth Ann. Rept., p. 32, 1885.
[b] Then more than 300 feet of shale and salt, with rock salt at the bottom.

Log of well at Clifton Springs, Ontario County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Limestone, Corniferous	70	70
Limestone	6	76
Limestone, Corniferous	65	141
Hard sandrock	12	153
Slates and shales	497	650
Salt (reported but not there)	20	670
Shale and slate	40	710

[a] Merrill, F. J. H., New York State Mus. Bull. 11, vol. 3, 1893.

Log of George G. Hill salt well, Watkins, Schuyler County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Unrecorded strata	1,880	1,880
Gray shale	125	2,005
Salt (1)	265	2,270
Limestone with occasional layers of shale	40	2,310
Salt (2)	28	2,338
Brown shale	40	2,378
Salt (3)	72	2,450
Brown shale	57	2,507
Salt (4)	10	2,517
Brown shale	20	2,537
Salt (5)	23	2,560
Brown shale	70	2,630
Salt (6)	50	2,680
Limestone and shales	130	2,810
Salt (7)	10	2,820
Very hard limestone	100	2,920
"Slate" limestone and shale	395	3,315

[a] Kindle, E. M., U. S. Geol. Survey Bull. 260, p. 568, 1905.

NOTE.—The record at Watkins shows the salt to be distributed throughout 815 feet of the Salina formation.

Log of well No. 6, International Salt Co., Watkins, Schuyler County, N. Y.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Drive pipe, 8-inch	26	26
Shale	20	46
Limestone, water	15	61
Shale	50	111
Limestone, water	20	131
Shale	100	231
Limestone	10	241
Shale	659	900
Shale; gas at 1,039 feet	139	1,039
Shale and limestone; black water at 1,200 feet	201	1,240
Limestone	100	1,340
Sand	10	1,350
Limestone	10	1,360
Sand	20	1,380
Limestone	200	1,580
Sand	12	1,592
Limestone; casing, 6¼ inch, to 1,620 feet	28	1,620
Shale and lime shells; salt water at 1,660 feet	50	1,670
Sand and lime shells; black water at 1,877 feet	26	1,696
Shale and lime shells	82	1,778
Salt	100	1,878

NOTE.—The International Salt Co. has seven wells from which artificial brines are obtained for the manufacture of salt. The wells are distributed alongside the plant near the edge of Lake Seneca, and are located a hundred feet or more apart in the following order from north to south, Nos. 1, 7, 6, 4, 2, 5, 3. The first four were drilled about 1893, No. 5 a little later, and Nos. 6 and 7 about 1903 (?). The depths of the wells are as given on page 38.

Log of well No. 7, International Salt Co., Watkins, Schuyler County, N. Y.

Material	Thickness.	Depth.
	Feet.	*Feet.*
Drive pipe, 10-inch	22	22
Shale	24	46
Limestone, water	15	61
Shale	50	111
Limestone, water	20	131
Shale	100	231
Limestone	10	241
Shale	659	900
Shale; gas at 1,040 feet	340	1,240
Limestone	100	1,340
Sand	10	1,350
Limestone	10	1,360
Sand	20	1,380
Limestone	200	1,580
Sand	12	1,592
Limestone	28	1,620
Shale and lime shells; salt water at 1,660 feet	50	1,670
Sand and lime shells; black water at 1,677 feet (6¼-inch casing to 1,696 feet)	26	1,696
Shale and lime shells	83	1,779
Salt	96	1,875

NOTE.—10-inch hole to 660 feet, and 8-inch hole from 660 to 1,696 feet.

Depths of wells of International Salt Co., Watkins, N. Y.

	Depth to salt.	Total depth.
	Feet.	*Feet.*
1	1,760	1,854
2	1,775	1,830
3	1,780	1,870
4	1,769	1,890
5	1,780	1,883
6	1,778	1,878
7	1,779	1,875

Log of well at Aurora, Cayuga County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	5	5
Blue clay	10	15
Gravel and shale	95	110
Slate	245	355
Fine black sand	20	375
Slate (cased off at 485 feet)	110	485
Slate	15	500
Limestone, Corniferous	175	675
Slate (?) (strong flow of 24° brine, at 500 feet)	30	705
Limestone (?) (sand)	25	730
Slate	100	830
Gypsum (strong brine at 840 feet)	108	938
Salt rock (later found to be salt shale)	60	998
Shale	45	1,043
Gypsum	25	1,068

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[a] Bishop, I. P., New York State Geologist Fifth Ann. Rept., pp. 33-34, 1885.

Log of well No. 1 of Remington Salt Co., near Ithaca, Tompkins County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Lime, Portage	130	130
Shale, Genesee	125	255
Limestone, Tully	30	285
Hamilton shale	1,360	1,645
Marcellus	80	1,725
Limestone, Corniferous	75	1,800
Sandstone, Oriskany	22	1,822
Lower Helderberg	125	1,947
Salt, Onondaga	148	2,095
Salt	42	2,137
Limerock	8	2,145
Salt	44	2,189
Rock	3	2,192

[a] Record furnished by superintendent.

NOTE.—Piping, 20 feet; 6¼-inch casing, 452 feet; 3½-inch tubing, 2,183 feet.

Log of well at Ithaca, Tompkins County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shales, Lower Portage	340	340
Shale, Genesee	100	440
Limestone, Tully	30	470
Hamilton group	1,142	1,612
Marcellus shale	82	1,694
Limestone, Corniferous	78	1,772
Sandstone, Oriskany	13	1,785
Limestone, Lower Helderberg	115	1,900
Shale	344	2,244
First rock salt	24	2,268
Shale	6	2,274
Second rock salt	54	2,328
Shale	12	2,340
Third rock salt	17	2,357
Shale	31	2,388
Fourth rock salt	21	2,409
Shale	67	2,476
Fifth rock salt	42	2,518
Shale	24	2,542
Sixth rock salt	48	2,590
Shale	82	2,672
Seventh rock salt	42	2,714
Shale, green	308	3,022
Shale, mottled red and green	6	3,028
Shale, green	157	3,185

[a] Prosser, C. S. (quoted by F. J. H. Merrill), New York State Mus. Bull. 11, vol. 3, 1893.

Log of well No. 3, International Salt Co., near Meyers, Tompkins County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Light shale	965	965
Marcellus black shale	90	1,055
Corniferous limestone	78	1,133
Oriskany sandstone	30	1,163
Helderberg limestone	111	1,274
Limestone and shale	226	1,500

[a] Record furnished by the superintendent of the plant, Mr. James Cooney.

Log of well No. 4 [?], International Salt Co., near Meyers, Tompkins County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Light shale	900	900
Marcellus black shale	105	1,005
Corniferous limestone	55	1,060
Oriskany sandstone	32	1,092
Helderberg limestone	108	1,200
Limestone and shale	230	1,430
Salt	30	1,460
Limestone	30	1,490
Salt	63	1,553

[a] Record furnished by the superintendent of the plant, Mr. James Cooney.

(Two different records were marked as from well No. 4.)

Log of well No. 4 [?], International Salt Co., near Meyers, Tompkins County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Light shale	870	870
Marcellus shale	79	949
Corniferous limestone	80	1,029
Oriskany limestone	25	1,054
Helderberg limestone	106	1,160
Limestone and shale	208	1,368

[a] Record furnished by the superintendent of the plant, Mr. James Cooney.

(Two different records were marked as from well No. 4.)

Log of deep State well of 1884, Syracuse, Onondaga County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Red shales, followed by sand, gravel, etc	578	578
Limestone and shales, Niagara	72	650
Limestones and shales	345	995
Clinton iron ore	5	1,000
Shales	5	1,005
Shales, magnesian limestone; quartz particles first noticed	3	1,008
Shales, alternating with quartz and sand	67	1,075
Red-brown sandstone alternating with gray, brown, green, etc., with shale	374	1,449
Sandstone of various colors predominating with some shale and slate mixed in layers	520	1,969

[a] Merrill, F. J. H., New York State Mus. Bull. 11, vol. 3, 1893.

NOTE.—For details in regard to this and the Gale well (p. 41), see New York State Geologist Ann. Rept. for 1884.

Log of well of Solvay Process Co., Cardiff, Onondaga County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shales, Hamilton	244	244
Limestone, Corniferous	148	392
Upper and Lower Helderberg	352	744
Red shales	100	844

[a] Merrill, F. J. H., op. cit.

Log of well at Jamesville, Onondaga County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Water lime and gypseous shales	587	587
Red shales	453	[b] 1,040

[a] Merrill, F. J. H., op. cit.

[b] Stopped in red shales.

Log of well of Solvay Process Co., Tully, Onondaga County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shales, Hamilton	678	678
Shales, Marcellus	40	718
Limestone, Corniferous	150	868
Water lime	50	918
Limestone, Helderberg	294	1,212
Rock salt	47	1,259

[a] Merrill, F. J. H., op. cit.

Log of Gale well, Green Point, Onondaga County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Red shale	536	536
Limestone and shale, Niagara	69	605
Limestone and shale	371	976
Clinton ore	10	986
Shales with some limestone	10	996
Dirty brown and gray sand-mixed quartz first noticed	4	1,000
Shales, sandstone, and quartz alternating	55	1,055
Sandstones and shales of various colors mixed with quartz, etc., to bottom of well	545	1,600

[a] Merrill, F. J. H., op. cit.

Log of well at Morrisville, Madison County, N. Y.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shales, Hamilton	340	340
Shales, Marcellus	31	371
Limestone, Corniferous	70	441
Limestone, Lower Helderberg	209	650
Limestone, hydraulic	325	975
Shale, light gray	43	1,018
Shale, dark red	5	1,023
Marl, green and blue	87	1,110
Marl, green and blue, with 30 feet of limestone	149	1,259
Rock salt	10-12	1,271
Marl, red and green variegated	129	1,400
Marl, red	60	1,460
Marl, green and blue	105	1,565
Shale, red	225	1,790
Shale, blue, and limestone (Niagara formation)	59	1,849
Shale, blue	22	1,871
Shale, blue, and limestone (Clinton)	15	1,886

[a] Prosser, C. S., quoted by F. J. H. Merrill, op. cit.

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Note.—Newland has continued to prepare annual reports similar to those cited.

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——— Montezuma brine springs: New York Geol. Survey Ann. Rept., 1838, pp. 270-272, 1839.

——— Salt wells or borings of Onondaga: New York Geol. Survey Ann. Rept., 1838, pp. 262-270, 284-285, 1839; idem, 1840, pp. 139-147, 1841.

——— Hopper-shaped caritiles in Onondaga salt group; Rock salt: Geology of New York, pt. 3, pp. 102, 280-283, 287, 1842.

——— Salt boring in Broome County: Geology of New York, pt. 3, pp. 295-296, 1842.

Whitlock, H. P., Halite (rock salt): New York State Mus. Bull. 58, pp. 63-64, 1902.

MICHIGAN.

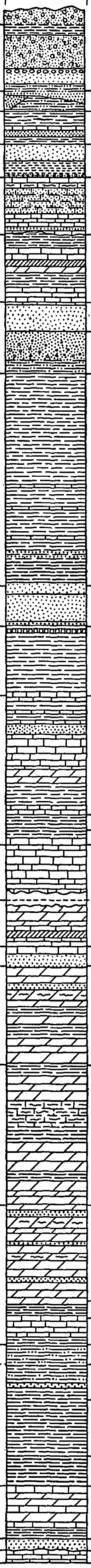
For some years Michigan has ranked first among the States in both quantity and value of the salt produced. The salt is derived from two distinct sources—rock salt and natural brines—and is obtained by open-pan, grainer, and vacuum-pan methods of evaporation. The industry based on rock salt is of much greater importance than that based on natural brine.

POSITION OF FIELDS.

Salt is produced in three distinct parts of the State. The districts (see Pl. I, p. 12) are (1) in the southeastern part of the State along Detroit and St. Clair rivers; (2) in approximately the central part of the Lower Peninsula, especially in the Saginaw Valley, and (3) along the western shore of the Lower Peninsula.

STRATIGRAPHY AND STRUCTURE.

The salt produced in the southeastern part of the State and along the western shore is derived from rock-salt beds in the Salina formation, underlying the Monroe group (Silurian); that produced in the Saginaw Valley comes from natural brines in the Marshall sandstone (Mississippian). These brines are of importance also as sources of bromine and calcium chloride, as well as of other calcium and mag-

System and series.		Group and formation.		Columnar section.	Thickness.	Character of rock.
Quaternary.	Recent.					Sand, gravel, boulder clay.
	Pleistocene.	Wisconsin and earlier drift sheets.			1,110–0	Pink clay along Lake Superior. Till, boulder clay, in some places very sandy, in others clayey and dark. A gray and red till may in some places be distinguished, an older and a younger.
Carboniferous.	Pennsylvanian.				110–0	Light-reddish sandstone and sandy shales.
		Saginaw formation.			400	White sandstone, coal seams, black and white shales; then bands of limestone and of siderite rare, rarely broken up and found in fragments of the sandstone.
		Parma sandstone.			170–0	White sandstone and conglomerates of small white quartz pebbles; brine and sulphates.
	Mississippian.	Grand Rapids group.	Bayport limestone.		235–50	Limestones, light and bluish, cherty; also calcareous sandstones.
			Michigan formation.		300–0	Dark or bluish limestones and dolomites with gypsum and blue or black shales; rarely reddish or greenish shales and dark or red sandstones.
		Marshall sandstone.			560–to	White sandstone, often pyritic; brine or fresh water; sulphates low.
					260	White and red sandstones, peanut conglomerates, sandy shales, whetstones, and blur shales; much carbonate of iron and mica in the formation; generally a red shale at the top and bottom.
		Coldwater shale.			1,000–800	Blue shale, with nodules of carbonate of iron, especially at the top; sandstone; very subordinate streaks of fine-grained limestone, especially on the west side; black shales at the base.
		Berea sandstone.				White sandstone; brine and salt, even near the surface.
Devonian.	Upper Devonian.	Antrim shale.			480–140+	Shale, mainly black, everywhere black at the base, with huge round balls of calcite; blue and black shales toward the top.
	Middle Devonian.	Traverse formation.			660 to	Bluish limestones, dolomites, and shales; base a blue or black shale; top generally limestone and rarely reddish.
					50	
					60	
		Dundee limestone.			253 to 65–	Limestone, buff and light brown, fiercely effervescent, somewhat cherty.
Silurian.		Monroe group.	Detroit River dolomite.		275 to 0 a--200 b--20 c--50 d--47	Dolomites, mainly; some limestone; gypsum or anhydrite also occurs, with celestite and sulphur.
			Sylvania sandstone.		440? to 30	White sandstone, very pure, passing toward the north into calcareous sand and limestone.
			Bass Islands dolomite.		200? 100+ 100– 100–	Dolomites, at some levels sandy, at others oolitic, often cherty; shaly in places; anhydrite abundant in the lower parts of the salt basin; celestite.
		Salina formation.			960 to 0	Salt, anhydrite, dolomites, calcareous marls, red and green, more rarely blue and black, shales.
		Niagara group.			600 to 270	White dolomites; peculiar whiteness characteristic, in places cherty, and with a little quartz sand which locally occurs in beds; pure limestone rare.
					83 to 0	Blue shale.
					130 to 0	Reddish limestones and shales of iron ore.
					100 to 0	Red shales; in places sandy or green shales.
Ordovician.		Utica and later Ordovician shales.			150 to 0?	Shales; red and blue and sandy; gradual transition at base.
					343 to 215	Shales, blue, locally black in streaks, especially toward base.
					80 to 50	Black shales.
		Trenton (?) and older limestones.			271 to 100?	Limestone and dolomite; blue and shaly, or solid shale at base.
		St. Peter sandstone.			18 to 0	White friable sandstone, or represented by red clay.
		"Calciferous."				Residual top of underlying formation.

COLUMNAR SECTION OF STRATA IN LOWER PENINSULA OF MICHIGAN.

Adapted from A. C. Lane.

nesium compounds. The positions of the rock-salt beds and the brine-bearing horizon in the geologic column of the State and their relations to the overlying and underlying beds are shown in Plate V.

The Lower Peninsula of Michigan is a syncline or basin. The salt beds that are worked in the southeastern part of it dip northwest toward the center of the State and outcrop again on the shore of Lake Michigan and the Strait of Mackinac. The salt beds that are worked at varying depths along Detroit and St. Clair rivers lie very much deeper in the central part of the State, but as they approach the shore of Lake Michigan they again rise and are worked by means of deep wells in the vicinity of Manistee and Ludington. The major structural features of the Lower Peninsula are brought out in figure 2.

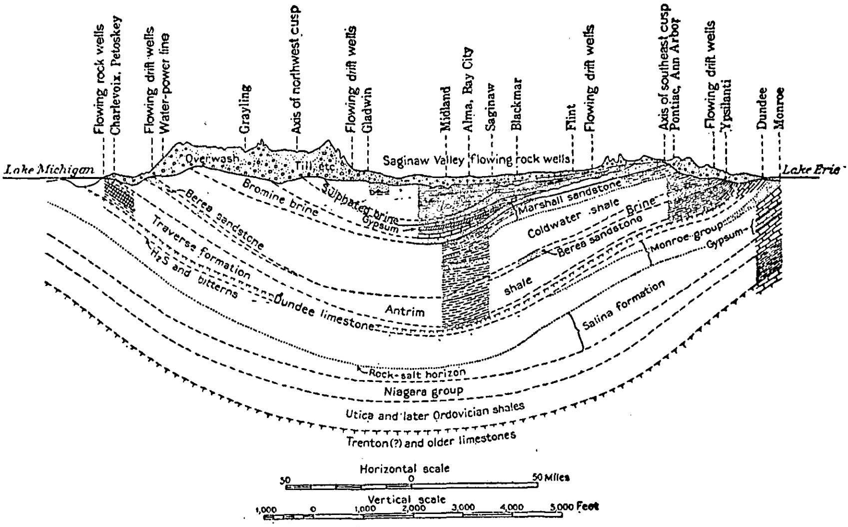


FIGURE 2.—Cross section of the lower Michigan basin. (After A. C. Lane, U. S. Geol. Survey Water-Supply Paper 114, 1905, with modifications.)

MONROE GROUP AND SALINA FORMATION.

CHARACTER AND EXTENT.

The rock salt of the Lower Peninsula of Michigan is found in beds underlying the Monroe group and consisting of Silurian rocks now generally accepted as belonging to the Salina formation, although in the earlier reports they were included in the Monroe. (See Pl. VI.)

The term Monroe was introduced into geologic nomenclature in 1893[1] by M. E. Wadsworth and A. C. Lane, being applied to rocks underlying the Dundee limestone and overlying (whether directly or indirectly not indicated) 650 to 2,000 feet of dolomite, salt, and anhydrite containing the fourth brine. As later defined,[2] the term

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[1] Wadsworth, M. E., Michigan Geol. Survey Rept. for 1891 and 1892, p. 66, 1893.

[2] Lane, A. C., The geology of Lower Michigan with reference to deep borings: Michigan Geol. Survey, vol. 5, pt. 2, pp. 26–28, 1895; Notes on the geological section of Michigan: Michigan Geol. Survey Ann. Rept. for 1908, p. 57, 1909.

was made to include all the Silurian rocks above the Niagara, as it was found difficult to separate the Salina from the beds above, owing to the fact that the latest salt bed is not always at the same horizon, and it is particularly difficult to know where to draw the line where no salt exists. The Monroe as thus defined was described[1] "as extending from the limestones of the overlying Dundee down to the lowest gypsiferous beds and as consisting mainly of buff dolomites and calcareous and argillaceous marls associated with anhydrite and rock salt."

The present generally accepted definition of Monroe, however, restricts the name to the rocks overlying the salt-bearing beds and underlying the Dundee limestone, including 1,200 feet or more of strictly marine strata, chiefly dolomite, divided into Detroit River dolomite (275 feet thick) at the top, Sylvania sandstone (440 feet thick) in the middle, and Bass Islands dolomite (500 feet thick) at the base; the salt-bearing deposits, which are considered by Grabau and others to be of nonmarine origin and lithologically resemble as well as occupy the stratigraphic position of the Salina formation of New York, are considered as representing the western accumulations of the Salina sea.

What Lane says regarding the Monroe beds (the name at that time being used by him to include not only the Monroe group, as now generally accepted, but the underlying Salina formation as well) is of peculiar interest with reference to the subject of salt in general, and in Michigan and Ohio in particular. It is therefore given below in full.[2]

> The period of the Monroe beds is that of the Salina and Lower Helderberg. At that time Michigan was covered by an excessively salt sea which stretched from Wisconsin to New York, was bounded by a continent on the north and east, on the west by low land in Wisconsin (the edge of the Helderberg is found barely extending to just north of Milwaukee), and on the south by a great bar, or reef, or flat in Ohio, which seems to have been just awash. This is indicated by the prevalence in the Ohio Helderberg not only of ripple marks, but also of mud cracks and of brecciated and conglomeratic layers. If we imagine tides like those of the Bay of Fundy rushing over this flat, producing this breccia and conglomerate and bringing fresh supplies of water to the inclosed sea, and furthermore that the sea was exposed to a hot sun and received but little accession of fresh water from rivers—this latter is shown to be true by the scarcity of mud and sand—we have the conditions of the Helderberg or Monroe deposits, conditions which are evidently favorable to the formation of a sea charged with salts. * * *
>
> If a line be drawn (on the Lower Peninsula of Michigan) leaving Muskegon and Wyandotte on its northeast side and Monroe and Kalamazoo on the southwest, we may say that south of this line no rock salt has been discovered in this formation, although concentration proceeded far enough to lead to the deposition of sulphate of lime and the concentration of brines. This region then belongs with Ohio. But north of this

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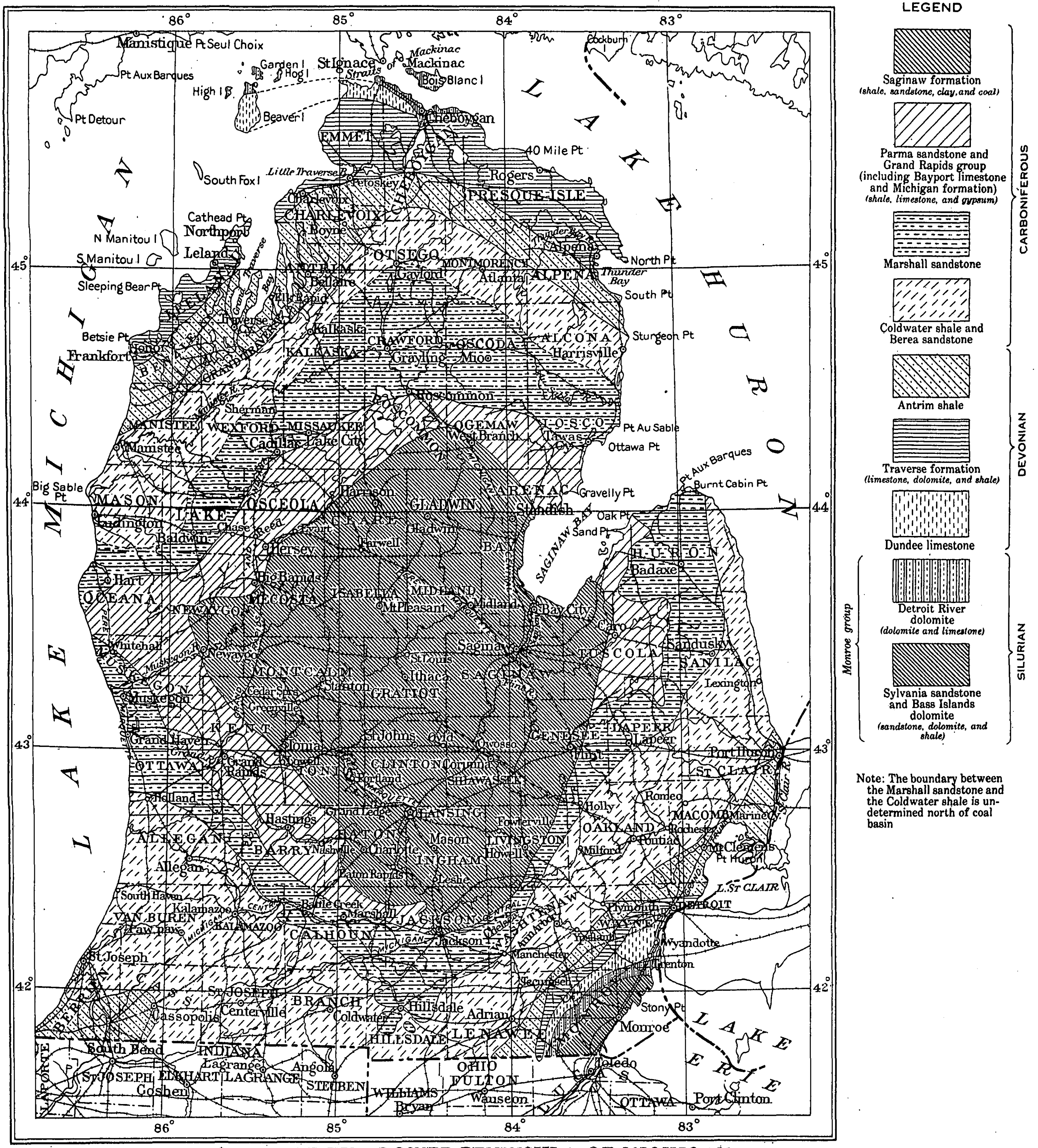
[1] Lane, A. C., The geology of Lower Michigan with reference to deep borings: Michigan Geol. Survey, vol. 5, pt. 2, p. 27, 1895.

[2] Idem, pp. 27-28.



GEOLOGIC MAP OF THE LOWER PENINSULA OF MICHIGAN

Scale $\frac{1}{2,500,000}$

25 0 25 50 75 100 Miles

1918

After A. C. Lane, with modifications

line it is probable that this formation yields rock salt almost universally. The thickness of rock salt at Wyandotte and along St. Clair River is over a hundred feet, and at Royal Oak it appears to be over a thousand.

These figures need excite no incredulity, as there are vastly thicker deposits in Germany. They only excite the query whether somewhere there may be found deposits of those salts which, being most soluble, are latest to crystallize, like those deposits which have made Stassfurt the storehouse of the world's chemical industries. Such analyses as those of Sand Beach [Huron County [1]] indicate a concentration of sea water nearly to the point of precipitation of the Stassfurt salts. Such deposits, if they occurred, would be expected in the upper part of the formation.

These salt deposits should rise again, proceeding to the north, and, in fact, just north of the Strait of Mackinac gypsum beds do outcrop, while at St. Ignace a thin bed of salt is reported only 400 feet below the surface. At Alpena they are about 1,200 feet below the surface. Near Cheboygan they should be sooner reached. The salt industry will doubtless, in time, work north.

The upper beds outcropping in Monroe County are ash-colored and brecciated, in some places marked with acicular crystals (gypsum), which readily weather out and leave cavities.

Thick as this formation is, we can not sharply subdivide it, although, as I have said, it doubtless includes the series called Salina in New York, as well as the Helderberg. However, in the section between Monroe and Goderich we may perhaps divide it as follows, in descending order:

At the top a series of dolomites or gypseous marls, marking a time of desiccation, underlain by limestone frequently passing into a calcareous sandstone; beneath this sandstone some more beds, gypseous or even salty, marking a second time of desiccation, and after 200 feet or more of somewhat gypsiferous dolomites, a rapid succession of thick salt beds, marking the first and greatest period of desiccation. The boundary line between this formation and the Niagara underlying it is far from well marked.

To recapitulate, the thickness of the Monroe group, as judged by borings, has been given as 1,200 feet. The beds are stated by Lane to have been deposited in an interior sea extending from New York to eastern Wisconsin and exposed to arid conditions—a hot sun and only slight accession of fresh water from rivers. Shallow-water conditions prevailed in places, especially in Ohio, where the existence of a bar, reef, or flat permitted ripple marks and mud cracks to form. In southeastern Michigan three periods of desiccation have been recognized, the first and greatest is represented by heavy beds of rock salt aggregating in thickness some 900 feet; the second, preceding the formation of the Sylvania sandstone (the middle formation of the Monroe group) is marked by gypseous or salty dolomites; and above the Sylvania, at the top of the Monroe, is evidence of a third period of desiccation, during which there were deposited dolomites and gypseous marls.

In the records of wells in the southeastern part of the Lower Peninsula at Britton, Milan, Romulus, and Wyandotte there is an increasing thickness to the northeast between the beds of the rock salt and what is regarded as the top of the underlying Niagara group. Northward the salt beds seem to occur higher up in the geologic

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[1] Lane, A. C., op. cit., p. 82.

column, and gypsum often occurs above the Sylvania sandstone. Salt occurs below the Sylvania, usually within 450 feet.

The salt-bearing formation itself, the Salina, has the following thicknesses and occurs at the indicated depths below the surface at the following places in southeastern Michigan:

Depth below surface and thickness of the Salina formation in southeastern Michigan.

Locality.	Thickness.	Depth.
	Feet.	*Feet.*
Britton	370	1,180-1,550
Milan	520	1,025-1,545
Strasburg	485	485
Trenton	491	850-1,341
Wyandotte	780	730-1,510

In general, it will be seen that the thickness of the formation increases to the north, which increase holds good into Canada. To the southeast the salt disappears. Thus wells drilled at Trenton show the exact edge of the salt-producing area to be there, as salt occurs in only one of them.

As already stated, it is hard to draw the line of the top of the Salina where no salt exists. There are only lithologic grounds and stratigraphic position for identifying it with the Salina of New York, and it is altogether unlikely that the top can be drawn consistently on such grounds. At present the top of the nearest salt or gypsum bed, 400 feet below the Sylvania sandstone, is regarded as the top of the Salina. This procedure gives fairly consistent results.

DEPTH TO SALT BEDS.

In the southeastern part of Michigan and to the north along St. Clair River a great many drill holes have been sunk to the salt-bearing horizons. Records of these are given in the reports of the Michigan Geological Survey, chiefly in the publications already cited. The depths to the salt beds are given in the accompanying table:

Depths to salt beds in eastern Michigan.

Location.	Well and formation.	Depth.
		Feet.
Marine City	No. 1	1,604-1,637.
Do	No. 2 (first bed)	1,634-1,735+.
Do	No. 3	1,622-1,637. 1,642-1,662. 1,672-1,737.
Do	No. 4	1,570-1,590. 1,600-1,630.
2½ miles north of Marine City	No. 6	1,600.
Probably west of Marine City	No. 7	1,620-1,650. 1,675-1,775.
Petrolia, Ontario, 18 miles from Port Huron	Monroe group	1,199-1,251.
Port Huron	No. 12 (Monroe group and Salina formation).	Just above 1,600. At 1,600. Above and below 1,700.
Port Lambton, Ontario, 5 miles northeast of Algonac, Mich.		1,710-1,720.
Royal Oak	No. 2	Highest, 1,543-1,640. Lowest, 2,315-2,475.
St. Clair		1,630-1,660.
5 miles below St. Clair		1,500.
Half a mile east of St. Clair	Monroe group	1,620-1,650.
Wyandotte	Bands of salt	730-1,235.

In the southwestern part of the State no rock salt occurs, but to the north at Ludington and Manistee rock salt was struck. At Frankfort, still farther to the north, in Benzie County, wells have been put down deep enough to go through the Salina, but they did not strike salt and not even a very strong brine. It is very likely that the location of Frankfort was just without the borders of the Salina sea. Likewise the St. Ignace and Cheboygan wells show no salt. As showing the character of the material which a typical well goes through in this region, the following log may be given:

Log of well put down by J. S. Stearns, at Ludington, Mason County, Mich.[a]

Material.	Thickness.	Depth.
Pleistocene:	*Feet.*	*Feet.*
Sand	198	198
Clay, pink, calcareous	68	266
Gravel	94	360
Clay, pink, calcareous	155	515
Gravel	61	576
Limestone; 15 feet of porous granular limestone and salt water 35 feet below the casing	74	650
Coldwater:		
Shale, blue	550	1,200
Antrim:		
Shale, black	200	1,400
Traverse group:		
Limestone, brown	25	1,425
Shale, blue	35	1,460
Limestone, brown, oily, with hydrogen sulphide	40	1,500
Limestone, pure (Dundee?)	250	1,750
Dolomite, brown, sandy	160	1,910
Shale, calcareous	90	2,000
Monroe group:		
Dolomite	25	2,025
Limestone	25	2,050
Dolomite	25	2,075
Sandstone, Sylvania (?)	100	2,175
Dolomite, sandy, and anhydrite	121	2,296
Salt	8	2,304

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[a] Lane, A. C., Notes on the geological section of Michigan: Michigan Geol. Survey Ann. Rept. for 1908, p. 94, 1909.

NOTE.—10-inch casing, 204 feet; water (temperature, 53° F.) at about 300 feet; 8-inch casing to rock.

At Manistee there are a number of wells, the depths of which are 300 to 400 feet shallower than that of the Stearns well just given. The depth to the salt, as shown by some of the records of the Ludington and Manistee wells, are as follows:

Depths to salt at Ludington and Manistee, Mich.

Location.	Well.	Depth to salt.
		Feet.
Ludington	No. 1	2,195
1 mile south of Ludington		2,242-2,260
Ludington	No. 3	1,965-2,001
Manistee	No. 1	1,978-1,985 1,988-2,012
Do	No. 2	1,900-1,904(?) 1,912-1,942
Do	No. 3	1,988
Stronach		1,930-1,964

Alpena, in the northeastern part of the Lower Peninsula on the shore of Thunder Bay, an arm of Lake Huron, is another area in which rock salt has been found in some quantity but has not yet been developed. There are five beds of salt, which aggregate about 300 feet in total thickness and include streaks of gypsum and anhydrite.

MARSHALL SANDSTONE.

The brines of the Saginaw Valley occur in the Marshall sandstone of the Mississippian series, which yields the brine utilized so extensively in the manufacture of salt, bromine, and calcium and magnesium salts. Wells have been put down to the brine-bearing horizon at Bay City, Saginaw, Midland, Mount Pleasant, St. Charles, and perhaps elsewhere. The description, by Lane, of the Marshall sandstone is as follows:

> Next beneath the Grand Rapids group occurs a series of sandstones usually very easy to recognize in a general way. The lower part of the formation and the beds immediately underlying it are rich in fossils. It is a fact that the Grand Rapids group is underlain by sandstone which often grades into the shales beneath. It varies in thickness, which is generally from 50 to 100 feet. It is fine grained, calcareous, friable, and gray or slightly greenish in hue, and in contrast with the Parma sandstone finer grained and darker. This appears to be its common character, but at Napoleon, Stony Point, and elsewhere it is thicker and coarser. Its upper boundary is generally sharper than the lower. It is of economic importance where it outcrops and is the source of building stone, flagstone, grindstones, and, where covered in Saginaw Valley, also the source of the brines of Saginaw, Bay City, Midland, and other places. It is the second salt horizon.[1]

In a later report Lane speaks of the upper Marshall or Napoleon sandstone and gives the following record of the rocks at Mount Pleasant:

Log of well at Mount Pleasant, Isabella County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface deposits and glacial till	400	400
Coal measures with particles of coal at 410, 430, and 560 feet	220	620
Unrecorded strata	190	810
Sandstone, Parma, calcareous and water bearing, with 10 to 20 feet of limestone	30	840
Unrecorded strata	130	970
Limestone, Maxville (as at Bayport)	80	1,050
Michigan series with gypsum (as at Alabaster)	358	1,408
Sandstone, Marshall	142	1,550

[a] Michigan Geol. Survey Ann. Rept. for 1903, pp. 293-294, 1905.

A detailed description of the Marshall sandstone and its variations from place to place is also given by Lane in a later report,[2] and in

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[1] Lane, A. C., The geology of Lower Michigan with reference to deep borings: Michigan Geol. Survey, vol. 5, pt. 2, pp. 17-19, 1895.

[2] Lane, A. C., Notes on the geological section of Michigan: Michigan Geol. Survey Ann. Rept. for 1908, pp. 79-83, 1909.

the geologic column accompanying that report (p. 43) the Marshall is classified as the upper and lower Marshall sandstone under the single heading Napoleon sandstone.

WELL RECORDS.

The following are selected records of deep wells in the different salt-producing districts of Michigan, and they furnish in detail the bases of some of the general statements already made. In general, the arrangement is from north to south.

Log of well of Lewis Sands at Manistee, Manistee County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface sand	640	640
Shale, black, soft, some red (black water at 980 feet)	340	980
Limerock	510	1,490
Clay and shale	110	1,600
Limerock	378	1,978
Salt	7	1,985
Shale	3	1,988
Salt	24	2,012

[a] Lane, A. C., The geology of Lower Michigan with reference to deep borings: Michigan Geol. Survey, vol. 5, pt. 2, pl. 30, 1895.

Log of Canfield & Wheeler well, Manistee, Manistee County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Sand, with streaks of gravel	93	93
Reddish-gray clay	2	95
Sand	107	202
Gray clay	94	296
Dark-reddish clay	2	298
Quicksand	3	301
Clay, some sand	54	355
Gravel	3	358
Clay, sand, and gravel	36	394
Reddish clay, gravel, and some sand	181	575
Dark clay and gravel	5	580
Dark shaly stuff	15	595
Light shaly stuff	7	602
Shale and gravel	113	715
Sandrock, with streaks of shale and lime in places	160	875
Shale, and streaks of hard lime	200	1,075
Blue shale	380	1,455
Sticky grayish-brown shale	100	1,555
Shaly lime	20	1,575
Limerock	29	1,604
Shale and lime	51	1,655
Lime streaks, dark and light	40	1,695
White lime	10	1,705
Lime and shale, hard	20	1,725
Limestone, shaly and sticky, dark buff	15	1,740
Limestone	5	1,745
Shale, limy	7	1,752
Very hard spots and softer streaks of lime	28	1,780
Very hard streaks, with streaks of softer material	23	1,803
Dolomite, dark gray or drab	32	1,835
Dolomite, dark drab, very hard	10	1,845
Limerock, gray, with hard thin streaks	3	1,848
Softer material that is cut very fast	10	1,858
Limerock, soft	7	1,865
Hard and soft streaks; 92° brine	10	1,875
Limerock, massive, 93° brine	25	1,900
Supposed salt; 96° brine	4	1,904
Unrecorded strata	8	1,912
Rock salt	30	1,942
Limestone, hard	5	1,947

[a] Lane, A. C., op. cit., pl. 31.

Log of well of Wheeler, Magill & Co., Manistee, Manistee County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface rock	614	614
Shale, black (black water at 960 feet)	346	960
Limerock, soft and hard	530	1,490
Shale, argillaceous	110	1,600
Limestone, sandy	305	1,905
Not designated in record	83	1,988
Salt to hard rock below	38	2,026

[a] Lane, A. C., op. cit., pl. 82.

Log of well at East Lake, Manistee County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Sand and gravel	104	104
Clay	3	107
Sand	70	177
Clay	1	178
Sand	23	201
Gray clay	51	252
Reddish-gray clay, very tough	257	509
Hardpan of sand and gravel	13	522
Sand and gravel, mostly quicksand	21	543
Reddish clay	37	580
Blue clay	2	582
Whitish-blue clay	4	586
Soft blue shale	2	588
Hard shale	1	589
Blue shale	2	591
Sand	4	595
Blue shale	5	600
Slate	1	601
Hard white shale	120	721
Brown shale	90	811
Black slate rock	58	869
Gray lime rock	10	879
Hard black limerock	86	965
Hard white limerock	31	996
Brown limerock	80	1,076
Very little gypsum.		
White limestone	59	1,135
White limerock	15	1,150
Blackish-blue limerock	132	1,282
Gypsum	10	1,292
Gypsum and lime	58	1,350
Brown limerock	106	1,456
Crumbly, caving rock	62	1,518
Sticky blue shale	69	1,587
Hard brown limerock	88	1,675
Softer brown limerock	44	1,719
Hard brown limerock	4	1,723
Soft rock or part brown shale	17	1,740
Hard limerock	5	1,745
Soft limerock	3	1,748
Hard limerock	19	1,767
Gypsum	1	1,768
Gray lime	27	1,795
Soft gray lime	1	1,796
Hard gray lime	18	1,814
Blue shale	15	1,829
Hard sticky rock	3	1,832
Soft slate rock	5	1,837
Hard slate rock	10	1,847
Crevice about	1	1,848
Hard limerock	60	1,908
Honeycombed limerock	1	1,909
Hard limerock	27	1,936
Soft limerock	14	1,950
Soft dark limerock	8	1,958
Hard gray limerock	19	1,977
Shell lime and gypsum	9	1,986
Soft blue lime	2	1,988
Salt	20	2,008
Rock	1	2,009
Salt mixed with small pieces of rock and shale	6	2,015
Rock	4	[b]2,019

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[a] On land owned at present by R. G. Peters Co.

[b] Total depth given as 2,024 feet 10 inches.

Log of well of plant of R. G. Peters Salt Co., 500 feet from East Lake station, Manistee County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Blue calcareous shale	593	593
Calcareous shale	207	800
Limestone	675	1,475
Calcareous shale	12	1,487
Limestone	118	1,605
Limestone containing sponge spicules	33	1,638
Calcareous shale containing sponge spicules	14	1,652
Calcareous shale	6	1,658
Limestone	22	1,680
Limestone, rather impure	10	1,690
Limestone, very sandy	90	1,780
Calcareous sandstone	30	1,810
Limestone	110	1,920
Siliceous and ferruginous limestone	20	1,940
Shaly limestone	24	1,964

[a] Petrographic examinations by W. H. Fry, U. S. Dept. Agr., Bur. Soils.

Log of well of Stronach Lumber Co., southeast of Manistee, Manistee County, Mich.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface sand	570	570
Shale, water vein	380	950
Shale and shell of sand	20	970
Hard and soft limerock	480	1,450
Blue clay and shale	175	1,625
Limerock and some mica, flinty	305	1,930
Salt	34	1,964
Hard limerock	8	1,972

[a] Lane, A. C., The geology of Lower Michigan with reference to deep borings: Michigan Geol. Survey, vol. 5, pt. 2, pl. 65, 1895.

Log of well of Stearns Salt & Lumber Co., Ludington, Mason County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Reddish sand	94	94
Coarse gravel	6	100
Reddish sand	52	152
Hardpan	35	187
Clay	56	243
Whitish sand	2	245
Clay	49	294
Hardpan and gravel	20	314
Hardpan	96	410
Fine sand	107	[a] 517
Calcareous sandstone	3	520
Calcareous and shaly sandstone	13	533
Calcareous shale	40	573
Calcareous and sandy shale	30	603
Calcareous shale	5	608
Sandy calcareous shale	1	609
Buff calcareous and sandy shale	6	615
Calcareous shale	223	838
Sandy calcareous shale	373	1,211
Calcareous shale	179	1,390
Limestone, impure	73	1,463
Fairly pure limestone	338	1,801
Dolomitic limestone	134	1,935
Calcareous mudstone	86	2,021
Limestone	260	2,281
Salt	9	2,290

[a] Petrographic examinations of the material below 517 feet were made by W. H. Fry, Bureau of Soils, United States Department of Agriculture, and the notations in the record below that depth differ from those in the original draft of the record furnished the writer.

Log of well No. 1 of Pere Marquette Lumber Co., Ludington, Mason County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Sand	30	30
Marl, shells, and pine sticks	5	35
Sand	21	56
Soft clay	4	60
Hard clay	20	80
Hardpan	10	90
Coarse sand and small stones	18	108
Sand and gravel	9	117
Sand	42	159
Sand and gravel	24	183
Sand with clay	17	200
Sand	5	205
Clay	4	209
Clay and gravel	5	214
Clay and sand	27	241
Hardpan	32	273
Clay	11	284
Clay and gravel	8	292
Clay	15	307
Clay and gravel	53	360
Clay	37	397
Clay and sand	15	412
Hard clay	52	464
Hardpan and gravel	12	476
Gravel	16	492
Gravel and sand	6	498
Sand	18	516
Gravel and clay shale	12	528
Blue shale	35	563
Limestone	15	578
Red shale and marl	8	586
Shale	8	594
Limestone	5	599
Blue shale	601	1,200
Black slate or hard shale, with pyrite	165	1,365
Blue shale and limestone	70	1,435
Black sandy limestone, with strata of gypsum	45	1,480
Limestone	60	1,540
Limestone and gypsum	20	1,560
Limestone, hard, with grit above, and softer, with less grit below	240	1,800
Blue shale	58	1,858
Salt (either salt or soft salt rock), 90° brine	4	1,862
Limestone, very sticky, 70° to 80° brine	100	1,962
Limestone, very hard, 20° brine	40	2,002
Dolomite, with soft streaks, 50° to 56° brine	138	2,140
Hard gray limestone	55	2,195
Rock salt	18	2,213
Limestone, 2 feet of rock salt	7	2,220

[a] Lane, A. C., op. cit., pl. 27.

Log of well No. 2, Ludington, Mason County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface rock	540	540
Shale	950	1,490
Limestone, sand, etc	752	2,242
Salt	18	2,260

[a] Lane, A. C., op. cit., pl. 28.

Log of well No. 3, Ludington, Mason County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Sand, streaks of gravel and one of clay	200	200
Clay	97	297
Quicksand	3	300
Clay, with some sand and gravel	300	600
Clay and shale, with layers of limestone	115	715
Sandy, contains iron	160	875
Laminated clay, soft micaceous sandstone in upper part; lower part not sharply distinguished from Portage	200	1,075
Whitish and greenish limy shales, with nodular kidney vein ore and strata of crystalline and fossiliferous limestone	500	1,575
Black shale, hard and massive	20	1,595
Buff magnesian limestones	160	1,755
Limestone, hard	150	1,905
Limestone, clayey and magnesian	60	1,965
Limestone and marl, clayey and magnesian, with gypsum and rock salt	36	2,001

[a] Lane, A. C., op. cit., pl. 29.

Log of well of Port Huron Salt Co., Port Huron, St. Clair County, Mich.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shale, black, bituminous	300	300
Limestone, bluish gray, dolomitic	15	315
Limestone, mixed bluish and gray dolomitic	50	365
Shale, bluish, calcareous, somewhat plastic	70	435
Even more shaly and plastic	135	570
Fragments, light brown, sharp, clear	30	600
More granular, brownish	50	650
Similar, with a little dark shaly matter	20	670
Same, but sandy and granular	55	725
Almost similar but a shade darker	65	790
Dolomite in light-buff chips and white grains of anhydrite	25	815
Granular, and dark brown	40	855
Similar, with few specks of gypsum	15	870
Similar to previous sample	10	880
Mainly anhydrite	5	885
Dolomite	30	915
Limestone, dolomitic	30	945
Limestone, dolomitic, light buff	40	985
Dolomite, brown	15	1,000
Dolomite, light buff	5	1,005
Limestone, dolomitic, mixed dark and brown, bituminous	25	1,030
Limestone, dark, dolomitic	85	1,115
Slightly brighter, with some anhydrite	10	1,125
Dolomite	40	1,165
Cherty dolomite	20	1,185
Largely a white cherty dolomite	25	1,210
Dolomite, light buff	5	1,215
Limestone, darker, dolomitic	5	1,220
Limestone, light, dolomitic, some anhydrite	45	1,265
Limestone, darker, dolomitic	20	1,285
Dolomite, dark, thin-bedded	15	1,300
Dolomite, lighter	5	1,305
Limestone, slate-colored, dolomitic	20	1,325
Limestone, bluish slate-colored, dolomitic	20	1,345
Limestone, dark bluish gray and varicolored, dolomitic	20	1,365
Limestone, dark, dolomitic, more granular	5	1,370
Limestone, brownish, dolomitic	38	1,408
Yellow, sharp change in color	8	1,416
Dolomite, dark slate-colored	77	1,493
Anhydrite, dark slate-colored	3	1,496
Salt, brownish	6	1,502
Dark slate-colored, with impure salt and anhydrite	4	1,506
Salt, brownish	28	1,534
Anhydrite, blue and brown, dolomitic	10	1,544
Salt, gray	30	1,574
Salt, brown	5	1,579
Anhydrite, blue and brown, dolomitic	4	1,583
Anhydrite, buff, dolomitic	17	1,600
Anhydrite, bluish gray, slaty	15	1,615
Salt, white	14	1,629
Salt, brownish	11	1,640

Log of well of Port Huron Salt Co., Port Huron, St. Clair County, Mich.—Contd.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Salt, clear, white, coarsely crystalline	26	1,666
Salt, white and brown	29	1,695
Anhydrite, dark gray slate-colored	5	1,700
Salt, clear white	25	1,725
Salt, brownish, impure	10	1,735
Salt, grayish, with bands of anhydrite	25	1,760
Salt, dark gray, and anhydrite	20	1,780
Dolomite, varicolored	25	1,805
Dolomite, varicolored, with anhydrite	20	1,825
Dolomite, buff	30	1,855
Salt, slate-colored, and anhydrite	5	1,860
Salt, clear white	10	1,870
Dolomite, buff	5	1,875
Salt, nearly clear	10	1,885
Salt, mixed green and reddish and colorless, and anhydrite	30	1,915
Clay, gritty, plastic	5	1,920
Anhydrite, slate-colored	62	1,982
Salt, nearly clear white	66	2,048
Salt, gray, with anhydrite	212	2,260
Impure dolomite at	....	2,260

Log of well No. 12, Port Huron, St. Clair County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface, mostly clay	102	102
Black slate and shale	83	185
Top limestone	105	290
Soapstone, with seams of limestone	225	515
Limestone	133	648
Slight indications of salt	10	658
Gray dolomitic limestone	27	685
Unrecorded strata	10	695
Light-gray calcareous marl, very small residue	21	716
Light-gray calcareous marl	10	726
Light-gray marly limestone	24	750
Light-gray hard limestone	20	770
Gray hard dolomite	40	810
Bluish-black marl, argillaceous and gypseous	50	860
Hard gray dolomite	43	903
Dark gray limestone	17	920
Bluish-black argillaceous marl	45	965
Grayish dolomite	15	980
Unrecorded strata	90	1,070
Soft argillaceous marl	10	1,080
Unrecorded strata	70	1,150
Dark brown gray, calcareous sandstone	15	1,165
Hard grayish-white, calcareous sandstone	50	1,215
Unrecorded strata	10	1,225
Drab to bluish black, argillaceous marl	20	1,245
Dirty yellow drab hard dolomite	10	1,255
Grayish-white calcareous gypsum	45	1,300
Soft yellow-drab dolomitic limestone	100	1,400
Grayish-white calcareous gypsum	35	1,435
Grayish dolomite	35	1,470
Grayish-white argillaceous marl	20	1,490
Grayish-yellow dolomite	10	1,500
Black and reddish calcareous clay	35	1,535
Little salt and shale	20	1,555
Alternating layers of salt, shale, and limestone	....	1,700+

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[a] Lane, A. C., op. cit., pl. 57.

Log of well No. 1, Marine City, St. Clair County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface rock	50	50
Clay	150	200
Hardpan	30	230
Slate, black, bituminous, containing pyrite	70	300
Slate, dark and light drab	20	320
Slate, black, bituminous	20	340
Shale, dark drab, bituminous	10	350
Shale, drab, bituminous, somewhat calcareous	10	360
Limestone, argillaceous, dolomitic	50	410
Limestone, light bluish gray to drab	40	450
Limestone, light gray	20	470
Limestone, light gray, with little talc and slate	20	490
Limestone, light and dark gray	10	500
Limestone, soft, argillaceous	50	550
Limestone, dark drab	10	560
Rock, calcareous, argillaceous, gritless	75	635
Limestone, light yellowish gray	95	730
Limestone, light gray	40	770
Dolomite	30	800
Dolomite, light brownish drab	30	830
Dolomite, light gray	25	855
Dolomite, light drab	25	880
Limestone, hard, dolomitic, light gray	25	905
Limestone, dolomitic, with fragments of slate, little anhydrite	30	935
Limestone, dolomitic	30	965
Limestone, dolomitic, light drab	15	980
Limestone, dolomitic, drab, even textured	10	990
Limestone, dolomitic, dark drab	70	1,060
Limestone, arenaceous	70	1,130
Limestone, light drab	30	1,160
Limestone, light gray, carries some gypsum	60	1,220
Limestone, dolomitic, dark drab	5	1,225
Limestone, dolomitic, hard, light gray	20	1,245
Limestone, dolomitic, very dark drab	25	1,270
Limestone, dolomitic, light drab	23	1,293
Gypsum, drab and white	11	1,304
Gypsum, calcareous, dark drab	26	1,330
Gypsum, calcareous, dark drab, possibly argillaceous, with anhydrite	35	1,365
Gypsum, calcareous, dark drab, contains anhydrite	25	1,390
Limestone, dolomitic, light and dark drab, large residue of slate, anhydrite, gypsum, silica, and some organic matter	75	1,465
Limestone, dolomitic, light drab, large residue of gypsum	20	1,485
Limestone, gypseous, light drab, large residue of gypsum	53	1,538
Clay, calcareous	41	1,579
Anhydrite	20	1,599
Gypsum, white and dark drab	5	1,604
Rock salt	33	1,637
Limestone, gypseous	4	1,641

[a] Lane, A. C., op. cit., pl. 33.

NOTE.—The gypsum is anhydrite.

Log of well No. 2, Marine City, St. Clair County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface rock	210	210
Brownish-black argillaceous slate	200	410
Hard gray limestone	45	455
Hard gray limestone, with fragments of slate	15	470
Bluish-gray argillaceous shale	166	636
Bluish-gray argillaceous limestone	4	640
Light-gray siliceous limestone	100	740
[Not named in record]	96	836
Gray dolomitic limestone	10	846
Dark-gray hard limestone	34	880
Dark chocolate colored dolomitic limestone	10	890
[Not named in record]	110	1,000
Dark-gray dolomitic limestone	10	1,010
Dark-gray dolomitic limestone, medium residue	20	1,030
Hard gray dolomitic limestone	25	1,055
Hard gray dolomitic limestone, medium siliceous residue	20	1,075
Hard light-gray and gray arenaceous dolomitic limestone	10	1,085
Grayish-white calcareous sandstone	25	1,110
Hard grayish, calcareous sandstone	50	1,160
[Not named in record]	455	1,615
Rock	19	1,634
Salt (stopped in salt)	101	1,735

[a] Lane, A. C., op. cit., pl. 34.

Log of well No. 3, Marine City, St. Clair County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	155	155
Hardpan	27	182
Black shale	20	202
Gas rock, dark	10	212
[Not named in record]	148	360
Black slate	10	370
Dark slate, with streaks of limestone	70	440
Sandy shale, hard	40	480
White shale, sticky	25	505
White shale, very hard	10	515
White shale	25	540
Light pucker shale (alum?), with narrow streaks of lime	60	600
Limestone	40	640
Shale rock, sticky	60	700
Shale, very black	30	730
Black limestone	20	750
Black limestone, sulphur water	60	810
Hard limestone	100	910
Hard limestone	82	992
Limestone with pockets of sandstone	200	1,192
Limestone, some sandstone, and a showing of gypsum	33	1,225
Sandy limestone, with streaks of gypsum	60	1,285
Hard limestone	280	1,565
Light-colored shale (anhydrite?)	40	1,605
Hard limestone	17	1,622
Salt	15	1,637
Limestone	5	1,642
Salt	20	1,662
Limestone	10	1,673
Salt	65	1,727

[a] Lane, A. C., op. cit., pl. 35.

Log of well No. 4, Marine City, St. Clair County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Earth	150	150
Gravel	50	200
Dark brown and black slate	200	400
Limestone, light gray	75	475
Calcareous argillaceous shale	95	570
Hard light-drab slate	15	585
Calcareous argillaceous shale	40	625
Gypseous argillaceous limestone	40	665
Light-drab gypseous limestone	35	700
Hard grayish-white limestone	25	725
Limestone	25	750
Brownish-gray dolomitic marl	60	810
Dolomitic limestone, drab	10	820
Calcareous anhydrite	30	850
Dolomitic gypseous marl, drab	10	860
Dolomitic gypseous marl, grayish	10	870
Dolomitic limestone	10	880
Dolomitic limestone, drab and light gray	90	970
Dolomitic limestone, yellowish to buff	30	1,000
Arenaceous dolomitic limestone	130	1,130
Dolomitic limestone, buff	60	1,190
Dolomitic limestone, light gray	30	1,220
Dolomitic limestone, bluish gray	50	1,270
Dolomitic limestone, bluish gray, large residue of gypsum	60	1,330
Arenaceous dolomitic limestone	20	1,350
Calcareous gypsum, light bluish gray	50	1,400
Dolomitic limestone	30	1,430
Dolomitic limestone, bluish gray	20	1,450
Dolomitic limestone, gray	60	1,510
Gypseous limestone, dark drab	10	1,520
Calcareous clay, grayish	30	1,550
Dolomitic limestone, dark drab; small residue of gypsum	10	1,560
Dolomitic limestone, dark drab, large residue of gypsum	10	1,570
Rock salt	20	1,590
Dolomitic limestone shale residue of gypsum and anhydrite	10	1,600
Rock salt	30	1,630

[a] Lane, A. C., op. cit., pl. 36.

Log of well No. 5, Marine City, St. Clair County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	150	150
Gravel stones	5	155
Clay	30	185
Hardpan	45	230
Brown shale	70	300
Black slate	160	460
Brown calcareous slate	5	465
Hard siliceous gray limestone	45	510
Calcareous argillaceous shale	230	740
Light-gray limestone	50	790
Hard light-gray limestone	25	815
Soft light-gray argillaceous limestone	10	825
Buff gypseous limestone	55	880
Soft light-gray limestone, small residue	20	900
Soft light-gray limestone, small residue of anhydrite	30	930
Hard gray dolomite	65	995
Hard dark-gray dolomite	15	1,010
Grayish-drab dolomite	55	1,065
Dark-buff arenaceous limestone	25	1,090
Dark-buff calcareous sandstone	35	1,125
Dark-buff arenaceous limestone	82	1,207
Chocolate-buff dolomite	93	1,300
Grayish-drab soft dolomite	10	1,310
Gypseous dolomite, dark drab to yellow	30	1,340
Gypseous dolomite, light gray and yellow	20	1,360
Gray calcareous gypsum	100	1,460
Gray dolomite; small residue of silica and gypsum	10	1,470

[a] Lane, A. C., op. cit., pl. 37.

Log of well No. 6, 2½ miles north of Marine City, St. Clair County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	40	40
Hard blue argillaceous limestone	60	100
Calcareous clay	70	170
Dark-drab slate	30	200
Calcareous marl	10	210
[Not named in record]	490	700
Hard gray limestone	10	710
Hard light-gray limestone	40	750
Medium-hard light-gray limestone	60	810
Soft grayish-white marly limestone	20	830
Hard light-gray limestone	50	880
Buff calcareous marl, with yellow spots	30	910
Medium-soft grayish-white limestone	30	940
Hard light-gray dolomite	10	950
Soft light-gray marly limestone	10	960
Soft gray marly limestone	50	1,010
Medium-hard light-gray limestone	50	1,060
Dark-buff friable limestone	20	1,080
Dark-buff friable arenaceous limestone	30	1,110
Grayish-white calcareous sandstone	80	1,190
Grayish-drab arenaceous marly limestone	130	1,320
Bluish-gray calcareous clay	80	1,400
Dark-gray gypseous marl	40	1,440
Hard grayish limestone, with yellow specks	20	1,460
Dark-gray marly limestone	60	1,520
[Not named in record]	100	1,620
Salt.		

[a] Lane, A. C., op. cit., pl. 38.

Log of well No. 7, Marine City, St. Clair County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Blue clay	145	145
Gravel	6	151
Boulders	4	155
Hardpan, quite black	40	195
Light shale, quite hard	20	215
Dark shale, quite hard	25	240
Light shale, soft	100	340
Black slate, quite hard	250	590
White shale, soft	25	615
Blue shale	50	665
Hard limestone	50	715
Sticky blue shale	60	775
Black shale	50	825
Black limestone	30	855
Black rock, like oil rock	75	930
Hard gray limerock	100	1,030
Hard brown limerock	80	1,110
White shale (anhydrite?)	60	1,170
Sandrock, with streaks of limerock	200	1,370
Hard limerock, brown	50	1,420
Hard gray limerock	50	1,470
Blue shale, somewhat sticky	75	1,545
Black sand	50	1,595
Hard gray limerock	25	1,620
Solid salt	30	1,650
Hard limerock, grayish blue	25	1,675
Salt	100	1,775
Hard limerock	2	1,777

[a] Lane, A. C., op. cit., pl. 39.

Log of well No. 2, Royal Oak, Oakland County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	40	40
Gravel	5	45
Clay	25	70
Quicksand and gravel	94	164
Black shale	141	305
Limestone	85	390
Brown shale	130	520
Limestone, containing salt water	316	836
White sand	154	990
Limestone	115	1,105
Very gritty hard limestone	20	1,125
Dark sandrock, gray	15	1,140
Blue hard gritty limestone	35	1,175
Very soft light-colored lime	40	1,215
Same kind of rock	45	1,260
Hard, close bluish limerock	145	1,405
Hard gray sandrock	5	1,410
Hard limerock	10	1,420
Hard gritty limerock	45	1,465
Rotten lime or shale	78	1,543
Solid rock salt	97	1,640
Hard shale	10	1,650
Nice quality of salt	45	1,695
Slate, rotten lime, or shale, marly	40	1,735
Salt	57	1,792
Hard blue lime	18	1,810
Shale	10	1,820
Salt	80	1,900
Soft gray lime	10	1,910
Hard lime	95	2,005
Salt	15	2,020
Slate	95	2,115
Salt	35	2,150
Slate	15	2,165
Salt	20	2,185
Slate	15	2,200
Salt	100	2,300
Slate	15	2,315
Salt	160	2,475
Hard blue lime	27	2,502

[a] Lane, A. C., op. cit., pl. 9.

Log of well of Detroit Natural Gas Co., Detroit, Wayne County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Gravel and gas	100	100
Gravel	25	125
Black slate	8	133
Hard shale	7	140
Black slate; gas and water at 165 feet	52	192
Shelly sandstone	34	226
Limestone	14	240
Soapstone	160	400
Hard slates and limestone	75	475
White sandstone, quite hard	105	580
Limestone (ended in limestone)	190	770

[a] Lane, A. C., op. cit., pl. 15.

Log of well of Morton Salt Co., Ecorse, Wayne County, Mich.[a]

Material.	Thickness.	Depth.
Pleistocene:	*Feet.*	*Feet.*
Surface deposit	62	62
Silurian:		
Monroe above Sylvania:		
Dolomite, light buff, with sulphur in places	75	137
Dolomite, bituminous; sulphur and pyrite in places	60	197
Sylvania:		
Quartz sand	65	262
Dolomite	20	287
Dolomite, siliceous	35	312
Sand	35	352
Dolomite, sandy	10	362
Monroe below Sylvania(?):		
Dolomite, cherty	50	412
Dolomite, dove-colored	20	432
Dolomite, bluish	30	462
Dolomite, brown	15	477
Dolomite, light	15	492
Dolomite, dark	[b] 35	527
Dolomite, light	25	552
Beginning of Salina:		
Gypsum, impure	45	597
Dolomite	20	617
Dolomite, bluish, and anhydrite	175	[c] 792
Salt, blue and brown [d]	50	842
Dolomite	80	922
Dolomite, with anhydrite	10	932
Anhydrite, with salt	10	942
Dolomite	5	947
Salt, gray and white	15	962
Dolomite, anhydrite, clay	100	1,062
Anhydrite, almost solid	5	1,067
Dolomite, with anhydrite	50	1,117
Salt, dolomite, and anhydrite	5	1,122
Salt	201	1,323

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[a] Lane, A. C., Notes on the geological section of Michigan: Michigan Geol. Survey Ann. Rept. for 1908, p. 97, 1909.

[b] Given as 40 feet in original report.

[c] First salt at 730 feet.

[d] "This is the most likely to contain potash."

Log of well No. 9 of Pennsylvania Salt Co., Wyandotte, Wayne County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface	2	2
Clay	50	52
Lime	148	200
Sand	200	400
Lime	160	560
Gypsum	12	572
Lime	48	620
Slate	80	700
Lime	90	790
Salt	25	815
Lime	105	920
Salt	30	950
Slate	100	1,050
Lime	35	1,085
Salt	80	1,165
Lime	10	1,175
Salt	95	1,270
Lime	11	1,281

[a] Furnished by the Pennsylvania Salt Co.

Log of well at Wyandotte, Wayne County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay and gravel	75	75
Dark limestone	15	90
Light-brown limestone	10	100
Gray limestone	25	125
Brown sand with slate	30	155
Brown sand and lime	5	160
Brown and white limestone	70	230
Freestone	60	290
White and brown limestone	70	360
Gray limestone	5	365
Shelly limestone	30	395
Brown limestone	5	400
Muddy limestone	30	430
Very dark limestone	104	534
Limestone and slate	66	600
Slate and soapstone	15	615
Limestone and slate	75	690
White limestone and shale	40	730
White lime and salt, mixed	70	800
Pure white salt	30	830
Salt and lime, shelly	40	870
Light-brown limestone	30	900
Light-brown shaly limestone	20	920
Dark-brown shaly limestone	20	940
Pure salt	15	955
Salt and lime	5	960
Pure salt	5	965
Salt and lime shell	5	970
Lime and slate, shaly	75	1,045
Pure limestone	10	1,055
Slate and brown limestone	5	1,060
Pure brown limestone	20	1,080
Pure brown salt	10	1,090
Pure white salt	100	1,190
Salt and brown limestone	45	1,235
Dark shaly limestone	5	1,240
Dark limestone	90	1,330
Very dark limestone	5	1,335
Brown limestone	5	1,340
Blue limestone	10	1,350
Brown limestone	10	1,360
Brown limestone, very hard	5	1,365
Hard dark limestone	5	1,370
Brown and blue limestone, mixed	5	1,375
White and blue limestone, mixed	50	1,425

[a] Lane, A. C., The geology of lower Michigan with reference to deep borings: Michigan Geol. Survey, vol. 5, pt. 2, pl. 56, 1895.

Log of well at Wyandotte, Wayne County, Mich.—Continued.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
White crystalline limestone	15	1,440
Brown and white limestone	35	1,475
Fine brown limestone	35	1,510
Limestone	350	1,860
Slate	10	1,870
Limestone	20	1,890
Red rock	110	2,000
Black slate	20	2,020
Red rock	80	2,100
Slate	95	2,195
Red rock	5	2,200
Gray sand	10	2,210
Slate	40	2,250
Dark grayish shale	250	2,500

NOTE.—The strata from 730 to 1,500 feet were provisionally assigned by Lane to the Salina.

Log of well at Alpena, Alpena County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Limestone and fossiliferous bluish-green shales	20	20
Light-colored limestones, fossiliferous	60	80
Limestone	320	400
Blue shale, Hamilton, with well-marked fossils	80	480
Limestone, variable hardness and color	120	600
Limestone, dolomitic, light colored	425	1,025

[a] Lane, A. C., op. cit., pl. 5.

NOTE.—Salt found a little below 1,000 feet.

Log of well at Petrolia, Ontario, Canada.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Yellow clay	12	12
Blue clay	108	120
Blue lime	65	185
Blue shale	120	305
Blue lime	10	315
Gray soapstone	30	345
Blue lime	30	375
Hard white lime	100	475
Rotten, porous limestone	15	490
[Not named in record]	578	1,068
Hard gray dolomitic limestone	4	1,072
Dolomitic limestone	4	1,076
Yellowish-buff calcareous sandstone	26	1,102
Arenaceous dolomitic limestone	5	1,107
Pinkish-gray calcareous argillaceous sandstone	26	1,133
Grayish-white calcareous sandstone	21	1,154
Grayish-white arenaceous limestone	13	1,167
Grayish-white argillaceous arenaceous limestone	10	1,177
Calcareous sandstone, gray and buff	16	1,193
Gray calcareous salty rock	6	1,199
Grayish-white impure salt	52	1,251
Grayish dolomitic sandstone	63	1,314

[a] Lane, A. C., op. cit., pl. 46.

Log of well at Port Lambton, Ontario, Canada.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Blue clay	140	140
Hardpan and boulders	50	190
Slate and shale	270	460
Limestone	100	560
Calcareous clay rock and gypsum	150	710
Hard fine-grained limestone	50	760
Soft, porous limestone	70	830
Gray dolomite, dirty yellow from 980 feet to 990 feet	200	1,030
Gray arenaceous limestone	100	1,130
Yellowish arenaceous limestone	70	1,200
Light-gray calcareous limestone	20	1,220
Dirty-yellow calcareous sandstone	30	1,250
Dark yellow-buff ferruginous dolomite	120	1,370
Bluish-gray dolomitic limestone	40	1,410
Calcareous gypsum	40	1,450
Grayish drab to buff dolomite	100	1,550
Gypseous limestone	10	1,560
Calcareous gypseous clay	10	1,570
Argillaceous (limestone) dolomite	100	1,670
Calcareous sandstone	40	1,710
Calcareous clay shale (salty taste)	10	1,720
Soft bluish-gray limestone	....	....

[a] Lane, A. C., op. cit., pl. 58.

Log of well of Peter MacEwan estate, Goderich, Ontario, Canada.

Material.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Clay, gravel, and boulders	78	9	78	9
Dolomite	278	3	357	0
Limestone	276	0	633	0
Dolomite, with seams of gypsum	243	0	876	0
Variegated marl	121	0	997	0
Rock salt, first bed	30	11	1,027	11
Dolomite, with marls	32	1	1,060	0
Rock salt, second bed	25	4	1,085	4
Dolomite	6	10	1,092	2
Rock salt, third bed	34	10	1,127	0
Marl, with dolomite	80	7	1,207	7
Rock salt, fourth bed	15	5	1,223	0
Dolomite and anhydrite	7	0	1,230	0
Rock salt, fifth bed	13	6	1,243	6
Marl, soft, with anhydrite	135	6	1,379	0
Rock salt, sixth bed	6	0	1,385	0
Marl, soft, with dolomite and anhydrite	132	0	1,517	0

Log of well No. 1, Bay City, Bay County, Mich.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Sand and clay	85	85
Hardpan	35	120
Shale, blue	300	420
Shale, sandy	145	565
Limestone, Carboniferous (?)	20	585
Sandrock; brine 45 feet to 55 feet	50	635
Shale, sandy	25	660
Shale, blue	40	700
Gypsum, white	12	712
Shale, blue	108	820
Limerock, hard	10	830
Sandstone, brine to 100° (Marshall)	90	920
Shale, white	35	955
Shale, red	100	1,055
Shale, blue	50	1,105
Limestone	40	1,145
Shale, hard, blue	75	1,220
Limestone, blue	65	1,285
Shale, white	105	1,390
Sand shale	120	1,510
Shale, blue	20	1,530

[a] Lane, A. C., op. cit., pl. 6.

Log of well No. 1, Bay City, Bay County, Mich.—Continued.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Limestone, hard	18	1,548
Shale, blue	200	1,748
Shale, white	50	1,798
Shale, black	35	1,833
Limestone, black	65	1,898
Sandstone, brine-bearing	15	1,913
Shale, white (Berea)	70	1,983
Limestone, hard	50	2,033
Sand, soft, black	15	2,048
Shale, hard, blue at 2,067 feet; black, oily, 15 to 20 feet thick at 2,085 feet	45	2,093
Limestone, very hard	25	2,118
Sandstone	15	2,133
Limestone, gray	8	2,141
Sandrock, with 100° salt brine (Berea grit)	165	2,306
Shale, white	65	2,371
Shale, black, oily, sandy	214	2,585
Limestone, black, hard	100	2,685
Limerock, gray	90	2,775
Shale, blue, quite hard	47	2,822
Limestone, sandy, very hard	30	2,852
Limerock	13	2,865

Log of well of Saginaw Plate Glass Co., West Saginaw, Saginaw County, Mich.[a]

Material.	Thickness.	Depth.
Pleistocene:	*Feet.*	*Feet.*
Sand, fine	5	5
Clay, red, plastic	20	25
Clay, blue	53	78
Gravel, with water	2	80
Till, hardpan, with coal	21	101
Saginaw formation:		
Shale, dark (Lower Verne coal horizon?)	14	115
Fire clay, light, and dark shale	7	122
Shale, blue	17	139
Shale, black	15	154
Coal, large (Saginaw seam? or Middle Rider)	[b] 7	161
Shale, white, black impressions	4	165
Shale, dark (Saginaw coal horizon?)	8	173
Shale, blue	5	178
Shale, blue, white and brittle	½	178½
Shale, dark gray	19½	198
Shale, very dark (Lower Rider coal horizon?)	13	211
Shale, dark	9	220
Shale, gray	79	299
Shale, light and dark (Lower coal horizon?)	9	308
Shales, with siderite	56	364
Shale, very dark (Bangor Rider coal horizon?)	12	376
Shale, blue	19	395
Sandstone, micaceous	9	404
Shale, very dark, almost coal (Bangor coal?)	21	425
Shale, dark	49	474
Parma conglomerate and sandstone:		
Transition sandstone	[c] 24	498
Sandrock	23	521
Sandrock, conglomeratic	14	535
Bayport or Maxville sandstone:		
Limestone	81	616
Michigan series:		
Black and dark shale	35	651
Gypsum	25	676
Dolomite	12	688
Shale, blue	58	746
Limestone, gray	5	751
Shale, dark, sandy	9	760
Limestone, gray	14	774
Limestone, blue	21	795
Shale, sandy	14	809
Dolomite	11	820
Upper Marshall sandstone and brine 83° to 94° salimeter	78	898
Lower Marshall:		
Clay, red	2	900

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[a] Lane, A. C., Notes on the geological section of Michigan: Michigan Geol. Survey Ann. Rept. for 1908, pp. 102-104, 1909.

[b] 6 feet in original report.

[c] 22 feet in original report.

Log of well No. 15 of Dow Chemical Co., Midland, Mich.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Sand, clay, and gravel	200	200
Brown shale		203
Blue, white, and brown shale		211-370
Light-gray water-bearing sand		380
Water-bearing sand	120	500
Blue and white shale	190	690
Dark-gray sand; salt water		700
Sandstone	220	920
Brown shale and streaks of sand	120	1,040
Hard brown shale and sand		1,042-1,160
Salt sand	75	1,235
Streaks of red rock	10	1,245
Salt sand	63	1,308

Log of well No. 14 of Dow Chemical Co., Midland, Mich.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Gravel and sand	15	15
Hard clay	155	170
Gravel with some water	5	175
Clay	45	220
Quicksand	20	240
Clay	5	245
Gravel, no water	15	260
Blue shale	65	325
Sandstone, with big flow of water	45	370
Sandstone	250	620
Sandstone, with streaks of shale	150	770
Mostly sandstone	240	1,010
Sandstone, with streaks of shale and shale gas	105	1,115
Sandstone and shale	40	1,155
Brine rock	147	1,302

Log of Meyer well, Midland, Mich.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Sand and gravel	193	193
Black shale	207	400
Sandstone	100	500
Black shale	200	700
Light shale	90	790
Sandstone	45	835
Limestone	25	860
Black shale	90	950
Light shale	200	1,150
Limestone	27	1,177
Salt sand	23	1,200
Salt sand, with streak of limestone	10	1,210
Salt sand	85	1,295
Red shale	5	1,300

The Marshall sandstone, which is the brine-bearing bed, ranges in thickness from 100 feet to nearly 150 feet in the vicinity of Midland as revealed in the numerous wells put down in this locality. Its top ranges from about 1,150 to 1,250 feet in depth, and its base from 1,275 to 1,360 feet.

Well of Dow Chemical Co., Mount Pleasant, Isabella County, Mich.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Gravel, glacial overwash	80	80
Till, blue	20	100
Quicksand	20	120
Till, blue	160	280
Porous bed, with water; coarse gravel on top, fine sand below	74	354
Clay, red	26	380
Till, ground moraine, with broken coal measures	55	435
Shale, black, with streaks of coal at 410, 435, and 560 feet; sandstone, limestone, or carbonate of iron and fire clay, mostly less than 5 feet thick	185	620
Sandrock, fine white, with mineral water	90	710
Sandrock, gravelly, with a strong flow of water not too salt	80	790
Limestone, shale and red	30	820
Limestone, white	30	850
Limestone, white, with very salt water	120	970
Limestone, white, fiercely effervescing	55	1,025
Shale	5	1,030
Sandstone	20	1,050
Dolomite, with shale	75	1,125
Anhydrite and dolomite	100	1,225
Anhydrite and nearly pure gypsum	45	1,270
Dolomite, shale, and anhydrite	103	1,373
Top of Marshall sandstone (?)		
Sandstone	8	1,381
Shale	5	1,386
Sandstone	4	1,390
Shale	15	1,405
Sandstone, dark, with heavy brine	58	1,463

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OHIO.

Ohio has ranked third among the States in recent years in both quantity and value of salt produced. The raw material is derived from both salt beds and natural brines, and the product is made by the most common processes of evaporation—the grainer and the vacuum-pan processes. No rock salt is mined. Considerable brine obtained from the beds of rock salt is utilized in the manufacture of soda. Bromine and calcium chloride also are obtained from the natural brines.

POSITION OF FIELDS.

Ohio salt comes from two districts, one in the northeastern and the other in the southeastern part of the State. Both occurrences are distinct geologically as well as geographically. Their locations are indicated on the general map (Pl. I, p. 12), but their details are better shown in figure 3. The southeastern field is an extension of the field in West Virginia, which lies on the opposite side of Ohio River.

DEPOSITS IN NORTHEASTERN OHIO.[1]

EXTENT.

Thus far the production of salt in northeastern Ohio has been restricted to Cuyahoga, Summit, Medina, Lake, and Wayne counties, though salt as such is not produced in Lake County, the brines obtained by the Diamond Alkali Co., at Fairport Harbor, being made into other sodium compounds. The salt deposits are not limited to this area, and the extension of the beds farther east is shown by the accompanying log of the Hadsell well near Cortland, the correlations in which are those of Bownocker.[2]

Log of Hadsell well, near Cortland, Trumbull County, Ohio.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Drift	40	40
Shale	60	100
Berea grit	160	260
Shales, Bedford and Ohio	2,396	2,656
Limestones, Corniferous and Monroe	583	3,239
Salina formation:		
Rock salt	12	3,251
Limestone	5	3,256
Rock salt	2	3,258
Limestone	3	3,261
Rock salt	10	3,271
Limestone	49	3,320
Rock salt	29	3,349
Limestone	10	3,359
Rock salt	52	3,411
Shale, white	18	3,429
Limestone	36	3,465
Rock salt	10	3,475
Limestone	50	3,525
Shale, white	15	3,540
Rock salt	30	3,570
Limestone	10	3,580
Rock salt	3	3,583
Shale, white	90	3,673
Limestone	5	3,678
Shale, blue	32	3,710

This record shows 148 feet of rock salt. If the alternating strata of limestone, like those farther west, have many large holes filled with salt, then the total quantity is much in excess of that contained

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[1] Bownocker, J. A., Salt deposits and the salt industry in Ohio: Ohio Geol. Survey, 4th ser., Bull. 8, 1906.

[2] Idem, p. 39.

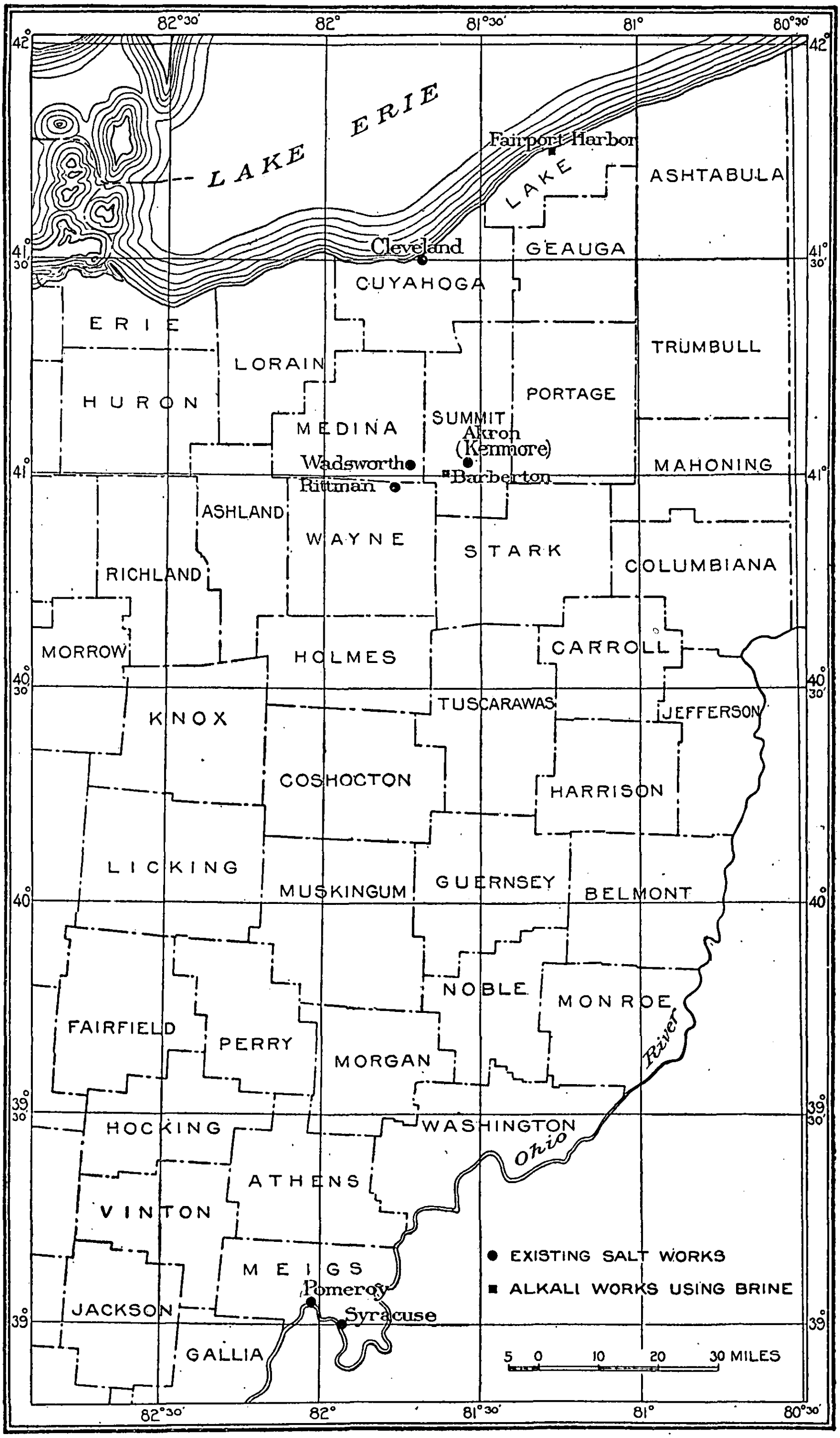

FIGURE 3.—Map of eastern Ohio showing location of salt works and alkali works using brine.

in the 148 feet. The record shows that the salt strata extend to the eastern limit of the State, and, although the well records in New York do not warrant the assertion, yet the presumption that the salt beds of the main New York field are continuations of those of Ohio is strong, as comparatively recent records have shown the existence of rock salt in Erie and Cattaraugus counties, N. Y., in localities where it was formerly not known. To the south the limit of the salt deposits has not been determined, because the strata dip to the south and east, and hence the salt horizon lies so deep that it has not been reached by the drill. Westward the limit has not been determined. It can not extend as far as Sandusky, according to the following record, but of course too much weight must not be attached to the evidence afforded by a single well.

Log of well at Sandusky, Erie County, Ohio.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Drift	10	10
Limestone, Corniferous	100	110
Limestone, Monroe and Niagara	970	1,080
Shale, Niagara, and Clinton formation	105	1,185
Shale, Medina	175	1,360
Shale and limestone, Cincinnati	500	1,860
Shale, Utica	310	2,170
Strata not recorded	40	2,210
Limestone, Trenton, at		2,210

[a] Ohio Geol. Survey, vol. 6, p. 195, 1888.

The Monroe and Niagara were found to contain layers of gypsum but none of salt. However, when the area beneath which salt has been demonstrated to exist and the number and thickness of the salt beds are considered, the conclusion is warranted that northeastern Ohio contains enough salt to last an indefinite period at the present rate of consumption.

STRATIGRAPHY.

The salt horizon in the northeastern part of Ohio lies beneath the Monroe formation and in the Salina formation of the Silurian system. It would appear that the salt-bearing beds from which the artificial brine (brine formed by allowing water to come into contact with the salt beds) is obtained in this part of the State are not extensions of those of southeastern Michigan, although the salt in northeastern Ohio occurs at the same geologic horizon as that along the Detroit and St. Clair rivers in Michigan. The reason for this has been explained under Michigan, and, briefly, is due to supposed shallow water in the ancient sea.

It will be observed that in the first Ohio record given above, Bownocker has classified the beds containing rock salt in northeastern Ohio as belonging to the Salina formation. This formation is not known to outcrop anywhere in the State of Ohio, but that the deposits in northeastern Ohio which contain the rock salt are a southwestward extension of the Salina formation of New York is now generally accepted. In the past some confusion has arisen from the fact that the earlier definitions of the Monroe included the salt-bearing beds, the name being used to include all rocks between the Dundee limestone above and the Niagara below. The present generally accepted definition of Monroe, however, restricts that name to the strictly marine deposits overlying the salt-bearing deposits (which according to Grabau and others are nonmarine) and underlying the Dundee limestone, and the salt-bearing deposits, which lithologically resemble as well as occupy the stratigraphic position of the Salina formation of New York, are considered as unquestionably representing the western accumulation of the Salina sea, although they are not everywhere easily separable from the overlying Monroe deposits, especially where no rock salt is present.

BRINE HORIZON IN SOUTHEASTERN OHIO.

STRATIGRAPHY AND STRUCTURE.

The surface rocks in the Ohio Valley at Pomeroy lie at the summit of the Conemaugh formation, also known as the "Lower Barren Coal Measures." [1]

The depths of the wells from which the brine is obtained have undergone great variation. At first the wells were shallow, reported at about 300 feet. This reached the horizon of the first Cow Run sand, an important source of petroleum in Washington and Morgan counties. Later the wells were deepened until a larger supply of brine was obtained. When this proved inadequate, the wells were again deepened.

The following skeleton record of a well belonging to the Buckeye Salt Co. is interesting. The well head is 25 feet below the Pomeroy or No. 8 coal.

Log of well near Pomeroy, Meigs County, Ohio.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Conductor	58	58
Shale	492	550
Sand, white and gray	320	870
Sand, white and slate	90	960
Big Salt sand	170	1,130
Sand and white shale	365	1,495
Strata unrecorded	50	1,545
Berea grit	25	1,570
Strata unrecorded	20	1,590

NOTE.—Brines were struck at 320 feet, density 6° B.; at 710 feet, density 9° B.; at 980 feet, density 9° B.; and at 1,550 feet, density 16° B.

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[1] Prosser, C. S., Revised nomenclature of the Ohio geological formations: Ohio Geol. Survey, 4th ser., Bull. 7, p. 25, 1905.

A record furnished by the Liverpool Salt & Coal Co. is as follows:

Log of well at Hartford, Mason County, W. Va.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface to "Horseneck"	300	300
"Horseneck" (containing oil and gas)	50	350
Chiefly shale	110	460
First Cow Run sand (much water, no oil)	40	500
Shale, etc	250	750
Second Cow Run sand	40	790
Shale, etc	210	1,000
First salt sand	50	1,050
Shale	55	1,105
Second salt sand	60	1,165

NOTE.—The names of the sands are those of the driller.

As soon as the second salt sand was reached the brine rose in the well to a height 600 feet below the surface. In all, the well was drilled to a depth of 1,359½ feet but soon partly filled up, and the rest of the record was not procurable. It was the intention to go to the Berea, but the volume of water prevented this unless another line of casing was put in. A very small coal was reported in the record but its exact position was not given.

CHARACTER OF BRINE.

In the well at Pomeroy the brine found in the Berea is much denser than that found in the overlying rocks. The quantity, however, was small, and the well is pumped from the horizon of the Big Salt sand (Pottsville). The Buckeye Salt Co. has five wells, whose depths range from 1,089 to 1,590 feet; the deepest well penetrates the Berea. The Excelsior Co. has four wells, whose depths range from 1,100 to 1,200 feet. Wells drilled farther east to the same geologic horizon are deeper, as the rocks dip in that direction.

When drilling was begun in this territory the water is said to have risen nearly to the well heads and in some wells to have actually overflowed. As pumping progressed the reservoirs of brine were lowered, and the tubing was consequently extended deeper into the wells, following the brine in its descent.

For many years the Excelsior works have pumped from the 750-foot level. The brine is said to rise slightly when the wells in the neighboring plants are not in action. The density of the brine increases in the direction of the dip of the rocks—that is, to the southeast. This is shown in the following table:

Increase of density with depth of natural brine at Pomeroy, Ohio.

	Density of brine.	Temperature of brine.
	° B.	*° F.*
Pomeroy Salt Works, west end of Pomeroy	8	61.5
Excelsior Salt Co., east end of Pomeroy	8.5	63
Syracuse Salt, Bromine & Calcium Works (not now operated)	10.5	62.5

According to Bownocker [1] the variation in density is due to the heavier brines seeking the lower level. The differences in temperature result in part from the different conditions under which the measurements were made, it not being possible in all cases to ascertain the temperature directly at the well head. The variation is due also in part to the greater depth of the wells to the southeast.

The quantity of brine that has been taken from these rocks is enormous, much more than the rocks could at any one time contain. This great excess has doubtless been derived from surrounding territory. The brine-bearing strata dip toward Pomeroy from the northwest. As the brine has been pumped from the wells, the supply has been renewed from the rocks lying at a higher level.

WELL RECORDS.

Log of well No. 4, Union Salt Co., Cleveland, Cuyahoga County, Ohio.[a]

Material.	Thickness.	Depth.
Drift:	*Feet.*	*Feet.*
Sand	15	....
Quicksand	6	21
Blue clay	129	150
Sand and clay	9	159
Quicksand	76	235
Sand and gravel	6	241
Gravel and clay	26	267
Ohio shales	723	990
Corniferous, Monroe, and Niagara [b] formations:		
Limestone	390	1,380
Sandstone, white	33	1,413
Limestone	11	1,424
Sandstone, white	16	1,440
Limestone	315	1,755
Limestone and rock salt	10	1,765
Salina formation:		
Rock salt	16	1,781
Limestone	16	1,797
Rock salt	19	1,816
Limestone	4	1,820
Rock salt	59	1,879
Limestone	21	1,900
Rock salt	37	1,937
Limestone	4	1,911
Rock salt	37	1,978
Slate	13	1,994

[a] Bownocker, J. A., op. cit., p. 35.

[b] Obviously an oversight, as the Niagara underlies the salt-bearing Salina formation.

NOTE.—Total depth by steel-line measurement, 2,006½ feet; 316 feet of 10-inch casing; 379 feet of 8¼-inch casing.

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[1] Op. cit. p. 26.

Log of well of Union Salt Co., Newburg, Cuyahoga County, Ohio.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Drift	40	40
Ohio and Bedford shales	1,310	1,350
Corniferous and Monroe formations:		
Limestone	310	1,660
Sand; contains lime	40	1,700
Limestone	290	1,990
Salina formation:		
Rock salt and shale	164	2,154
Shale	15	2,169
Limestone	81	2,250
Rock salt	50	2,300
Shale, blue	40	2,340
Sand	20	2,360
Shale	18	2,378
Limestone	22	2,400
Rock salt	20	2,420
Shale	10	2,430
Limestone	40	2,470
Rock salt	5	2,475
Shale	8	2,483
Niagara formation:		
Limestone	167	2,650
Oil and sand	8	2,658
Limestone	22	2,680
Oil sand	6	2,686
Clinton formation:		
Limestone	64	2,750

[a] Ohio Geol. Survey, vol. 6, p. 352, 1888.

Log of well No. 2, Cleveland Salt Co., Cleveland, Cuyahoga County, Ohio.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Shales and limestone	1,821	
Rock salt	10	1,831
Limestone	5	1,836
Rock salt	5	1,841
Limestone	5	1,846
Rock salt	10	1,856
Limestone	22	1,878
Rock salt	72	1,950
Limestone	2	1,952

[a] Bownocker, J. A., op. cit., p. 36.

Log of well of Cleveland Salt Co., Cleveland, Cuyahoga County, Ohio.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
First gravel	481	481
Clay	7	488
Rock	30	518
Shale, white	182	700
Shale, black	330	1,030
Lime, black	50	1,080
Lime, brown	220	1,300
Lime, sandy	90	1,390
Lime (bitter water increasing to 1,470 feet rose to 97 feet, the level of Lake Erie)	50	1,440
Sand	185	1,625
Lime, brown, very hard	85	1,710
Lime, white (6-inch casing seated at 1,730 feet)	111	1,821
Salt and lime	14	1,835
Salt, white	15	1,850
Lime	5	1,855
Lime and salt	10	1,865
Lime	10	1,875
Salt (3-inch tubing ended at 1,954 feet)	80	1,955
Lime	4	1,959

[a] Record furnished by the Cleveland Salt Co.

Log of well No. 1, Colonial Salt Co., Kenmore, Summit County, Ohio.

Material.	Thick-ness.	Depth.
	Feet.	*Feet.*
Strata not recorded	377	377
Slate, white	323	700
Slate, black	200	900
Sandstone	200	1,100
Slate, white	175	1,275
Slate, black	125	1,400
Lime shells	250	1,650
Slate	300	1,950
Lime	110	2,060
Lime, light	255	2,315
Sand and water	35	2,350
Lime and bittern	6	2,356
Sand and lime	8	2,364
Sandstone	46	2,410
Sand	58	2,468
Lime	8	*a* 2,376
Lime	205	2,581
To top salt	5	2,586
Salt	7	2,593
Lime	6	2,599
Salt	44	2,643
Lime	26	2,669
Salt	45	2,714
Lime	10	2,724
Salt	50	2,774

a Depth by tape at this point, 2,388 feet.

NOTE.—Total depth by tape, 2,903 feet. There is an interval of 236 feet from the top of the bittern-bearing horizon at 2,350 feet to the top of the salt at 2,586 feet.

Log of well No. 2, Colonial Salt Co., Kenmore, Summit County, Ohio.

Material.	Thick-ness.	Depth.
	Feet.	*Feet.*
Brown clay and sand	6	6
Quicksand	1	7
Clay	5	12
Gravel	16	28
Clay and gravel	47	75
Slate	5	80
Slate, white	90	170
Lime shells	100	270
Black slate	400	670
White slate	500	1,170
Lime, brown	80	1,250
Sand, white	200	1,450
Slate, white	300	1,750
Slate, black	150	1,900
Lime, black	90	1,990
Slate and lime	62	2,052
Blue lime and salt water	316	2,368
Blue lime	30	2,398
White lime	106	2.504
Brown lime	106	2,610
White lime	28	2,638
Red lime	67	2,705
Salt	9	2,714
Lime to second vein	9	2,723
Salt	44	2,767
Lime	6	2,773

NOTE.—Depth of hole by drilling, 2,773 feet; by tape, 2,726 feet. There is an interval of 337 feet between the top of the bittern-bearing horizon at 2,368 feet and the top of the salt at 2,705 feet.

Log of well No. 3, Colonial Salt Co., Kenmore, Summit County, Ohio.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Brown sand	6	6
Quicksand	1	7
Clay	5	12
Gravel	16	28
Clay	47	75
Slate	4	79
8⅝-inch casing		345
To water		2,361
To 6-inch casing by tape		2,400
Finished casing		2,420
Amount of 6-inch casing used		2,420
Lime, white	24	2,444
Bittern water	91	2,535
Light bittern	10	2,545
Brown lime	138	2,673
Light lime	24	2,697
Struck salt		2,715
Bottom salt	6	2,721
Lime	5	2,726
Salt	44	2,770
Lime	9	2,779

NOTE.—Total depth by tape, 2,779 feet. There is apparently an interval of 271 feet from the top of the bittern-bearing horizon at 2,444 feet to the top of the salt at 2,715 feet. If the bittern were encountered at 2,361 feet, which is a possible interpretation of this record, the interval would be 344 feet. The latter figure and the corresponding elevation are more in harmony with the records of wells Nos. 1 and 2.

Log of well No. 4, Colonial Salt Co., Kenmore, Summit County, Ohio.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Strata unrecorded	2,065	2,065
Limestone	100	2,165
Dark lime	50	2,215
Light lime	20	2,235
Dark lime	25	2,260
Sand and lime	100	2,360
Water	11	2,371
Lime	33	2,404
Lime and sand	6	2,410
Sandstone	30	2,440
Dark-gray sandstone? [probably limestone]	30	2,470
Light gray	6	2,476
Brown lime	21	2,497
Light lime	18	2,515
Brown lime	30	2,545
Light gray [limestone]	25	2,570
Shut down—bad cable	5	2,575
Brown lime	50	2,625
Gray lime	40	2,665
Dark lime	65	2,730
Salt	10	2,740
Lime	9	2,749
Salt	40	2,789
Lime	15	2,804
Salt	29	2,833

NOTE.—There is apparently an interval of 380 feet between water at 2,360 feet and the top of the salt at 2,740 feet.

Log of well No. 6, Colonial Salt Co., Kenmore, Summit County, Ohio.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Sand, clay, gravel, quicksand, and slate, some water	115	115
Slate (lime and shells at 240; but trace of gas at 265 feet)	155	270
Slate (8⅝ inch casing 376¾ feet)	70	340
Slate and shell	320	660
Slate	515	1,175
Slate and shells	155	1,330
Slate	154	1,484
Shale	311	1,795
Slate	323	2,118
Limestone	14	2,132
Lime (water at 2,398 feet)	272	2,404
Lime	57	2,461
Water-bearing beds	13	2,474
Lime	23	2,497
Lime, soft	12	2,509
Lime, hard	14	[a] 2,523
Limestone	15	2,547
Lime	115	[b] 2,662
Lime	67	2,752
Salt	7	2,759
Lime	4	2,763
Salt	37	2,800
Lime	22	2,822
Salt	30	2,852
Stone	4	2,856

[a] Depth at this point by steel tape, 2,532 feet; subsequent record corrected by 9 feet.
[b] Depth at this point by steel tape, 2,662 feet; subsequent record corrected by 23 feet.

NOTE.—Drilled in 1902; 84 feet of drive pipe. Total depth by steel tape, 2,857 feet. There is an interval of 354 feet between the water at 2,398 feet and the top of the salt at 2,752 feet.

Log of well No. 9 of Colonial Salt Co, Kenmore, Summit County, Ohio.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Loam, black	30	30
Gravel	70	100
Shale	10	110
To top of Berea grit	270	380
Strata unrecorded	10	390
Slate, white	360	750
Shale, brown	1,125	1,875
Shale, white	175	2,050
Shale, brown	125	2,175
Lime (bittern at 2,555 feet)	380	2,555
Lime, sandy	73	2,628
Lime	182	2,810
Salt	3	2,813
Lime	8	2,821
Salt	38	2,859
Lime	20	2,879
Salt	43	2,922
Lime	3	2,925
Salt	32	2,957
Slate, white	53	3,010
Salt	25	3,035
Lime	55	3,090
Shells, lime	45	3,135
Salt	20	3,155
Lime	180	3,335
Lime shells	15	3,350
Lime, black	50	3,400
Lime, brown	40	3,440
Second water-bearing beds	10	3,450
Sandstone	35	3,485
Sand and limestone	70	3,555
Lime, white	25	3,580
Lime, blue	20	3,600
Lime, white	58	3,658
Slate, green	85	3,743
Lime shells	20	3,763
Lime and sand (contains oil and gas)	5	3,768

Log of well No. 9 of Colonial Salt Co., Kenmore, Summit County, Ohio—Continued.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Lime	5	3,773
Sand, red	5	3,778
Slate, black	27	3,805
Sand, Clinton	5	3,810
Medina red rock	8	3,818
Sand, Clinton	4	3,822
Sand, pink, Clinton	11	3,833
Red rock	13	3,846
Sand, white	5	3,851
Slate, dark	10	3,861
Lime and slate	12	3,873
Slate, black	97	3,970
Red rock	114	4,084

NOTE.—Ten-inch drive pipe, 110 feet; 6⅝-inch casing, 2,630 feet; finished April 18, 1912; first plug at 3,748 feet; second plug at 3,620 feet; third plug at 3,050 feet. There is an interval of 255 feet between the bittern at 2,555 feet and the top of the salt at 2,810 feet.

Log of well of Colonial Salt Co., Kenmore, Summit County, Ohio.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Drift (water at 110 feet)	115	115
Slate and shells	1,943	2,058
Limestone (water at 2,398 and 2,465 feet)	694	2,752
Salt	7	2,759
Limestone	4	2,763
Salt	37	2,800
Limestone	22	2,822
Salt	30	2,852
Limestone	4	2,856

[a] Bownocker, J. A., op. cit., p. 37.

[illegible]

Section of well on H. R. Boyden farm, sec. 66, Northfield Township, Summit County, Ohio.

[Record furnished by Henry S. Chapman, Cleveland, Ohio.]

	Depth (feet).
Ten-inch drive pipe	40
Berea grit (with light gas)	140–145
8¼-inch casing (on shell)	250
Shale, with gas pockets	270–315
Top of lime	1,660
Salt water	2,100
6⅝-inch casing (in lime)	2,250
Dry salt	2,350–2,420
Brown lime shells	2,421
Hard brown lime	2,860
Newburg sand (top showing oil)	2,969–2,979
Salt water	2,980
Hard brown lime	3,100–3,170
Bottom big lime (white and hard)	3,221
Shale (black and soft)	3,222–3,240
White sand (hard) first	3,240–3,260
Black shale (soft)	3,260–3,290
White sand (hard) second	3,290–3,320
Green slate (soft)	3,320–3,335
Red sand (soft) with showing of gas estimated at 30,000 cubic feet at 3,387 feet	3,335–3,393
Red slate (soft) "ox-blood"	3,393–3,398
Clinton white sand (dry)	3,398–3,411
Medina shale (soft, red)	3,411–3,511
Bottom of well	3,607

NOTE.—The "Clinton" drilled very hard, some towers making only 3 feet. Bottom of sand was coarser and softer. Well was plugged above and below red sand and "Clinton."

Section of well on Nellie S. Chapman farm, sec. 46, Northfield Township, Summit County, Ohio.

[Record furnished by Henry S. Chapman, Cleveland, Ohio.]

	Depth (feet).		Depth (feet).
Ten-inch casing	40	$5\frac{3}{16}$-inch casing	3, 342
Berea grit	115–165	White sand	3, 406
$8\frac{1}{4}$-inch casing	180	Slate and shale	3, 421
Shale, with gas pockets	250	Green shale	3, 429
Top of lime	1, 782	White sand with showing of oil	3, 444
Salt water	2, 114	Gray sand	3, 455
$6\frac{5}{8}$-inch casing	2, 342	Clinton (gas at top with some oil and increasing in gas downward)	3, 494–3, 519
Dry salt	2, 480–2, 580	Shale	3, 520
Hard brown lime	2, 990	Stopped drilling in shale	3, 551
Newburg sand	3, 080–3, 104		
Salt water	3, 105		
White lime	3, 285–3, 321		
Shale	3, 325		

NOTE.—Well completed May 27, 1912. The well was shot and tested 150,000 cubic feet of gas together with 1 barrel of oil. The gas is now used for local consumption.

Log of well No. 1, Ohio Salt Co., Rittman, Wayne County, Ohio.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	40	40
Quicksand and gravel	133	173
Gray sand (Berea)	20	193
Bedford and Ohio shales:		
Shale, black	1,007	1,200
Shale, red	50	1,250
Slate and shells	250	1,500
Shale, brown	535	2,035
Corniferous and Monroe formations:		
Limestone	268	2,303
Sandstone, gray	30	2,333
Shelly limestones	225	2,558
Salina formation:		
Rock salt	66	2,624

[a] Bownocker, J. A., op. cit., p. 32.

Skeleton log of deep well, Ohio Salt Co., Rittman, Wayne County, Ohio.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Ten-inch drive pipe		167
$8\frac{1}{4}$-inch casing		230
Lime		2,015
Water-bearing beds		2,284
$6\frac{1}{4}$-inch casing		2,384
Salt		2,540
Through salt		2,615
Second water-bearing beds		3,140
Through lime		3,295
$5\frac{3}{16}$-inch casing		3,314
Little lime		3,354
Clinton sand		3,412
Sand with show of oil on top	20	3,432
Red rock	10	3,442
Slate	20	3,462
Hard white sand with little gas	25	3,487
Slate and shells	38	3,525
Medina sand	43	3,568
Red rock	282	3,850
Sandy lime	170	4,020
Lime and shells	130	4,150
Lime and slate	170	4,320
Slate	280	4,600

NOTE.—The "pencil cave" was found at 4,600 feet. Drilled 6 weeks and made only 65 feet.

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——— Salt deposits and the salt industry in Ohio: Ohio Geol. Survey, 4th ser., Bull. 8, 42 pp., 1906. Reviews the salt industry in Ohio and describes present operations. Includes notes on the composition of the brines, the geologic horizon of the salt beds, and well records.

CARNEY, FRANK, The economic mineral products of Ohio: Denison Univ. Sci. Lab. Bull., vol. 16, pp. 137–181, December, 1910.

WEST VIRGINIA.

West Virginia is an important producer of salt from natural brines, which occur in part in Carboniferous sandstones. These brines also furnish bromine and calcium chloride.

POSITION OF FIELDS.

The natural brines now utilized are found along Ohio and Kanawha rivers. The Ohio River field is an extension of the area in Ohio. Mason and Hartford, located in Mason County, are the centers of the industry in this part of the State. Malden, 6 miles above Charleston, is the site of the salt, bromine, and calcium-chloride industry on Kanawha River.

OHIO RIVER AREA.

The Ohio River area is geologically a part of the Pomeroy district of Ohio. Mason, one of the centers of the industry in West Virginia, is located nearly opposite Pomeroy, Ohio, and Hartford is a short distance farther up the river. The geology of the brines pumped at Pomeroy, Ohio, has already been discussed.

KANAWHA RIVER AREA.

The record of a well drilled for gas on Cool Spring Branch of Burning Springs Hollow, 2 or 3 miles from Malden, or 9 miles above Charleston, throws some light on the geologic horizon from which brines are obtained on Kanawha River near Charleston. According to I. C. White,[1] the well was begun about 100 feet below the horizon of the Campbell Creek coal bed, which is in the Kanawha formation of the Pottsville group (Pennsylvanian).

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[1] White, I. C., Petroleum and natural-gas precise levels: West Virginia Geol. Survey, vol. 1, p. 272, 1899.

The log of the well is as follows:

Log of Edwards well No. 1, near Malden, Kanawha County, W. Va.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Conductor	53	53
Coal, trace.		
Sand, hard, white	100	153
Slate, gray	8	161
Sand, gray, strong smell of oil	40	201
Slate, dark	25	226
Sand, hard, white; top of "Salt sand"	174	400
Coal, splint	6	406
Sand, hard, white, salty	200	606
Slate, white	10	616
Limestone, white (shale)	50	666
Slate, white	40	706
Sand, hard, white	125	831
Sand, hard, white, flinty, salt	130	961
Slate, black	2	963
Sand, hard, white	50	1,013
Sand, hard, blue; base of "Salt sand"	50	1,063
Limestone, blue, "Greenbrier" or "Long Running rock"; gas in bottom	300	1,363
Red rock, sandy, shaly	50	1,413
Unrecorded	187	1,600
Sand, coarse, heavily charged with light oil	2	1,602
Slate, blue	250	1,852
Slate, black	75	1,927
Slate, blue, shading into dark blue	323	2,250
Slate, shelly, with puffs of gas in last 50 feet	100	2,350
Slate, blue	50	2,400
Sand, shelly, with slight increase of gas	50	2,450
Slate, blue, very soft	92	2,542

The horizon at which the well was begun, it is thought, is not very far from the surface at the wells near Malden. According to White, the Salt sand in this record is 837 feet thick, and from it is obtained the brine which yields the salt and bromine produced in the plant at Malden. As White has used the term Salt sand it appears to be approximately the equivalent of the Pottsville group. The brines come from the Pottsville.

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GRIMSLEY, G. P., Iron ores, salt, and sandstones: West Virginia Geol. Survey, vol. 4, pp. 286–354, 1909.

PENNSYLVANIA.

Salt, bromine, and calcium chloride have been obtained in the North Side, Pittsburgh, Pa. Early in 1914, however, the industry in Pittsburgh was discontinued, owing to the fact that the natural brines became so dilute that it was no longer profitable to work them.

GEOLOGY.

At the plant where salt was produced four wells were in operation, the record of one of which is given below. This well, one of the deepest in Pennsylvania, reached a depth of 4,089½ feet and penetrated nearly 4,000 feet of beds that do not outcrop in the immediate territory. The brine is obtained in this well at a depth of 1,405 feet from a sand designated in the record as Salt sand. This sand is probably in the Pocono formation, which is of Mississippian age, and may possibly correspond with the Berea sandstone.[1] The record of this deep well follows:

Log of the John A. Beck No. 4 gas well, at Pittsburgh, Allegheny County, Pa.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Ashes and clay	20	20
Gravel	49	69
Slate (water at 95 feet)	30	99
Sand (drive pipe, 75 feet)	40	139
Slate	81	220
Sand	50	270
Slate	15	285
Lime	5	290
Slate	89	379
Coal	7	386
Slate (10-inch casing, 390 feet)	50	436
Lime	30	466
Slate	10	476
Sand	30	506
Slate	10	516
Lime	15	531
Sand	45	576
Slate	121	700
Sand	10	710
Slate (8¼-inch casing, 840 feet)	35	745
Sand, Big Injun	319	1,064
Slate	10	1,074
Sand	70	1,144
Slate	15	1,159
Sand	20	1,179
Slate	5	1,184
Sand	20	1,204
Slate and shell	46	1,395
Salt sand (salt water at 1,405 feet)	95	1,490
Sand	30	1,520
Slate	10	1,530
Sand	115	1,645
Slate (6⅝-inch casing, 1,645 feet)	5	1,650
Sand (little gas at 1,655 feet)	10	1,660
Slate	50	1,710
Sand	30	1,740
Slate	20	1,760
Sand (Gordon Stray?)	10	1,780
Slate	5	1,785
Red rock	5	1,790
Sand (Gordon?)	30	1,820
Slate	35	1,855
Sand	10	1,865
Slate and shell	60	1,925
Sand, Fifth	23	1,948
Slate and shell	82	2,030
Sand	10	2,040
Slate and shell	310	2,350
Sand	30	2,380
Slate	110	2,490
Sand	40	2,530
Slate	35	2,565
Sand	40	2,605
Slate	195	2,800
Sand	20	2,820
Slate	580	3,400
Sand	40	3,440
Slate and shell	560	4,000
Sand	40	4,040
Slate and shell	49½	4,089½

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[1] Munn, M. J., Oil and gas fields of the Carnegie quadrangle, Pa.: U. S. Geol. Survey Bull. 456, pp. 11-12, 1911.

PROBABLE SOUTHWARD EXTENSION OF THE SALINA FORMATION IN PENNSYLVANIA.

Two records of very deep wells are in the possession of the Survey which indicate that the salt-bearing formation of New York State, the Salina, probably continues southward into Pennsylvania. One of these records is that of the Derrick City or Bradford City well, drilled by the Bradford Deep Well Co., 4 miles northeast of Bradford, McKean County, Pa., in 1912 and 1913. The second deep well, known as the McDonald well, is located about 4 miles northwest of McDonald, Washington County, Pa., or 14 miles southwest of Pittsburgh.

The Bradford well reached a depth of 5,820 feet and four beds of salt are recorded as having been encountered, which range in thickness from 10 to 47 feet. The top of the highest salt bed is at a depth of 4,490 feet; the base of the lowest is at 4,713 feet; the salt-bearing beds therefore extend through a total thickness of 223 feet.

In the McDonald well, salt water was encountered at a depth of approximately 6,825 feet, and rock salt was found in the interval between 6,825 feet and 7,175 feet, or approximately 350 feet.

The record of the Bradford City well has been kindly furnished to the Survey by the Bradford Deep Well Co. and is given below:

Log of the Bradford deep well, near Bradford, McKean County, Pa.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
No record given of material to a depth of 1,230 feet		
Slate, light	90	1,320
Slate, black	110	1,430
Slate, light	37	1,467
Sand (in 2 layers, with 2 feet of black slate between)	23	1,490
Shale, soft, dark	60	1,550
Sand shells, hard, dark	20	1,570
Shale, light, soft	70	1,640
Sand shells, hard, dark	10	1,650
Shale, soft, dark	30	1,680
Sand shells, hard, dark	40	1,720
Slate, light, soft	10	1,730
Shale, soft, brown	10	1,740
Sand shells, hard, brown	10	1,750
Lime shells, hard and light	50	1,800
Slate, soft, light	70	1,870
Shales, brown	30	1,900
Slate and lime shells, hard, variegated	200	2,100
Lime, hard, light	50	2,150
Slate and lime, light and of medium hardness	50	2,200
Slate and lime, dark and of medium hardness	30	2,230
Slate, soft, light	35	2,265
Slate and shells, fairly light and hard	35	2,300
Lime and slate, hard, light	43	2,343
Slate, soft, light	57	2,400
Lime shells, hard, dark	30	2,430
Sand shells, hard, dark	16	2,446
Shells and slate, hard, light	24	2,470
Shale, soft, brown	20	2,490
Sand shells, hard, brown	25	2,515
Slate, soft, dark	25	2,540
Shale, soft, dark	120	2,660
Slate and shells	25	2,685
Slate, soft, black	43	2,728
Sandstone (shells), hard, black	22	2,750
Slate, shells, and shale, soft, brown	83	2,833
Sand shells, hard, brown	12	2,845
Shale, soft, brown	155	3,000
Slate, soft, black	100	3,100

Log of the Bradford deep well, near Bradford, McKean County, Pa.—Continued.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Slate, soft, white	50	3,150
Slate, soft, black	250	3,400
Shale, soft, black and brown	20	3,420
Sand shale, soft, black, and brown	155	3,575
Slate and shale, soft, black	75	3,650
Slate and shale, soft, brown	19	3,669
"Pencil cave," soft, black	31	3,700
Shale, soft, black	80	3,780
Shale, soft, brown	20	3,800
Lime shells, hard, dark	30	3,830
Shale, soft, brown, and black	235	4,065
Sand, hard, black (small showing of gas from 4,065 feet to 4,095 feet)	30	4,095
Lime, hard, black	20	4,115
Flint, very hard, dark, and light	20	4,135
Sand, very hard and white; showing of oil	20	4,155
Lime, very hard, dark	10	4,165
Sandy lime, very hard, light	10	4,175
Lime, very hard, dark, and light	40	4,215
Sandy lime, very hard, dark (gas pocket from 4,225 feet to 4,235 feet)	20	4,235
Lime, very hard, dark	30	4,265
Shale, soft, dark	5	4,270
Lime and gypsum	10	4,280
Lime, hard, dark	140	4,420
Lime, hard and variegated	70	4,490
Pure salt, soft, white	30	4,520
Sandy lime, fairly soft, light (showing of black oil from 4,520 feet to 4,535 feet)	15	4,535
Lime and slate, fairly soft, light	15	4,550
Lime, hard, dark, and brown	46	4,596
Salt, white, and soft	10	4,606
Lime, hard, brown	20	4,626
Lime, very hard, gray	12	4,638
Salt, soft, white	47	4,685
Lime, hard, brown	8	4,693
Salt and "lava," soft, white	20	4,713
Slate and "lava," soft, gray	127	4,840
Slate, soft, white	20	4,860
Slate and shells, hard, dark	40	4,900
Lime, shells, hard and dark	30	4,930
Lime, hard and dark	15	4,945
Shale and shells, dark	5	4,950
Slate, soft, light and dark	15	4,965
Shale, soft, dark brown	45	5,010
Lime, hard, dark gray	65	5,075
Lime, shells, and slate, black	10	5,085
Lime, hard, dark gray or black	70	5,155
Shale, black	15	5,170
Sand, very hard, gray	15	5,185
Lime, very hard, black	15	5,200
Sand, very hard, light to dark gray (small showing of oil)	46	5,246
Lime, hard, dark	4	5,250
Sandy lime, hard, brown	10	5,260
Lime, hard, dark	10	5,270
Sandy, hard, brown	10	5,280
Lime, hard, dark gray	40	5.320
Sand, hard, light to dark gray	22	5,342
Sand, soft, dark	3	5,345
Sand, shells, dark	9	5,354
Sand, hard, gray	6	5,360
Sand, soft, dark	25	5,385
Sand and shale, dark	35	5,420
Shale, soft, blue and black	40	5,460
Sand, shells, white, hard, and dark gray	35	5,495
Slate and shells, very soft, gray to brown	55	5,550
Sand, very hard, gray	10	5,560
The red Medina sand, very hard and red	40	5,600
The red Medina sand, soft, gray and red	10	5,610
The red Medina sand, very hard, gray and white	12	5,622
The red Medina sand, soft and red	3	5,625
The red Medina sand, hard and red	11	5,636
The red Medina sand, generally hard, reddish, white, and gray	19	5,655
Sand, very hard, white to light or dark gray	20	5,675
Slate and lime shells, soft, blue and gray	5	5,680
Sandy lime, hard and very dark	2	5,682
Sand, alternating soft and hard, light or dark gray	8	5,690
Sandy lime, very hard, dark gray	2	5,692
Sand, very hard, light to dark gray	8	5,700
Shale, red	5	5,705
Shale and sand, red	55	5,760
Shale, red	10	5,770
Shale and sand, red	15	5,785
Shells, red	15	5,800
Sand and shells, red and slightly harder	20	5,820

VIRGINIA.

POSITION AND EXTENT OF DEPOSITS.

The only economically important deposits of salt in Virginia are in the southwestern part of the State. These, with the gypsum deposits, extend for 20 miles along the valley of the North Fork of Holston River and have been developed extensively in Smyth and Washington counties. Two gypsum plants and one salt or alkali works are now in operation in this area.

STRATIGRAPHY AND STRUCTURE.

The rocks of the region are involved in an overthrust fault which has been called by J. J. Stevenson the Saltville fault.[1] This dislocation brings up Cambrian limestones on the southeast of the fault line and thrusts them over upon Mississippian ("Lower Carboniferous") rocks on the northwest side. The fault plane at the surface has a general direction to the northeast.

In considering the areal and geologic relations of the salt and gypsum deposits the area southeast of the fault line is not important. The deposits are confined to a belt northwest of the fault, and extend from the fault line nearly to the outcropping Mississippian sandstone along the foot of Pine and Little Brushy mountains to the northwest.

According to Eckel[2] they are contained in the lower member of the Greenbrier [Newman] limestone, which ranges in thickness from 600 to 1,000 feet and consists of shaly limestones with one or more beds of gypsum underlain by blue shales or slates, which are in turn underlain by shales or shaly limestones containing thick beds of rock salt. This lower member of the Newman limestone seems to be developed only locally, as it has been recorded only in this region.

Owing to the soft nature of the rocks including the salt and gypsum beds, good natural exposures are rare, but the well records of the region throw some light on the stratigraphic succession. None of the earlier wells drilled on the Robertson property southwest of Saltville show any appreciable amount of salt, owing, according to Eckel, to the possible absence of the salt beds at the places where the drilling was performed or, more probably, to the possible stoppage of drilling before the salt horizon was reached. Though records of the beds penetrated in drilling the salt wells could not be obtained, it is known that salt was reached at a depth of about 800 feet, and it is said that the aggregate thickness of the rock-salt beds passed through is 175 feet.

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[1] Stevenson, J. J., Notes on the geological structure of Tazewell, Russell, Wise, Smyth, and Washington counties of Virginia: Am. Philos. Soc. Proc., vol. 22, pp. 157-160, 1885.

[2] Eckel, E. C., Salt and gypsum deposits of southwestern Virginia: U. S. Geol. Survey Bull. 213, pp. 406-416, 1903.

By combining all the data obtainable Eckel's section of the salt and gypsum bearing or lower member of the Newman limestone is as follows:

Section of lower member of Greenbrier [Newman] limestone.

	Feet.
Top of gypsiferous series to top of Buena Vista wells	100
Gypsum-bearing rocks and shales in deepest well	600
Bottom of deepest Buena Vista well to top of salt beds, probably not over	100
Salt beds and inclosing rocks	175
Bottom of salt beds to Lower Carboniferous [Mississippian] sandstones	(?)

The thickness of the series therefore is considered to be approximately 1,000 feet.

According to Eckel the salt and gypsum deposits are regarded as having originated from deposition through the evaporation of sea water in a partly or entirely inclosed basin, and are of Mississippian age, being overlain by massive beds of Newman limestone and underlain by Mississippian sandstone.

In the descriptions of the area by Stose [1] the local formations are treated more in detail. Stose divides the Mississippian rocks of the area into three formations, as follows: (1) An upper limestone called the Newman limestone, which has a thickness of about 3,325 feet; (2) the Maccrady formation, consisting of shales, sandstones, and limestones, which has a thickness of 1,025 feet more or less, and (3) the Price sandstone, which has a thickness ranging from 327 to 424 feet. The most striking fact in connection with the gypsum and salt deposits of this district is that they have been found in quantity only in the shales of the Maccrady formation along the Saltville fault. From these and from other data Stose's conclusions regarding the origin of the salt and gypsum deposits are quite different from those of Eckel. Stose regards them as largely secondary and not primary and as having been derived from calcareous-argillaceous sediments originally containing disseminated gypsum and salt, which were precipitated in a partially inclosed arm of the sea. This disseminated salt and gypsum was subsequently concentrated in the same formation by ground waters circulating along the fault zone between the Carboniferous and the Cambrian rocks.

RECORDS OF DEEP WELLS NEAR SALTVILLE, VA.

The wells in the open valley near Saltville, Va., are shown in Plate VII. Their records are given below as far as obtainable.

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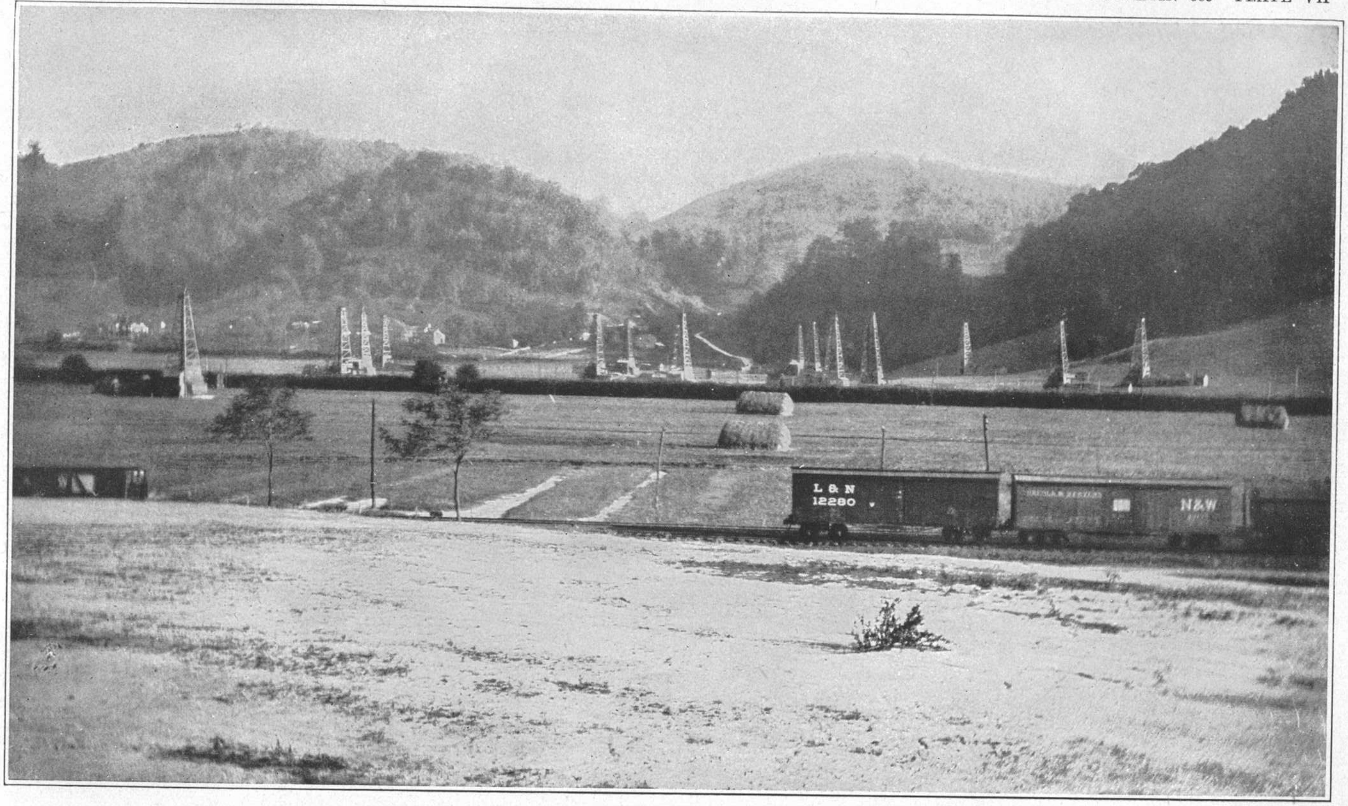
[1] Stose, G. W., Geology of the salt and gypsum deposits of southwestern Virginia: U. S. Geol. Survey Bull. 530, pp. 232-255, 1913.



OPEN VALLEY AT SALTVILLE, VA., SHOWING BRINE WELLS.

Photograph by G. W. Stose.

Log of well A on Robertson property, near Saltville. Smyth County, Va.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay, red	14	14
Clay and plaster	106	120
Plaster, pure [b]	40	160

[a] Eckel, E. C., op. cit., p. 408.

[b] The pure plaster is said to have extended 40 feet deeper—from 160 to 200 feet.

NOTE.—Bored between 1815 and 1820.

Log of well B on Robertson property, near Saltville, Smyth County, Va.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Red clay	10	10
Clay and plaster, burrstones	20	30
Clay and plaster, deep red	20	50
Pure plaster	45	95
Impure blue plaster	68	163
Hard blue slate	257	420

[a] Eckel, E. C., op. cit., p. 408.

NOTE.—Bored in 1847.

Log of well C on Robertson property, near Saltville, Smyth County, Va.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Red clay	10	10
Clay and plaster, with brown rocks	60	70
Pure plaster	30	100
Slate and plaster	100	200
Hard blue slate	160	360
Red slate	120	480
Gray slate	15	495
Red rocks, a little salty	10	505

[a] Eckel, E. C., op. cit., p. 409.

NOTE.—Bored in 1847.

Log of well D on Robertson property, near Saltville, Smyth County, Va.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Red clay	10	10
Clay and plaster	52	62
Plaster, with a little clay	138	200
Red clay, with a little plaster	185	385
Red clay, alkali, and salt	2	387
Pure plaster	203	590

[a] Eckel, E. C., op. cit., p. 409.

NOTE.—Bored in 1847.

Log of well E on Robertson property, near Saltville, Smyth County, Va.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Red clay	10	10
Clay and plaster	6	16
Impure plaster	34	50
Pure plaster	52	102
Slate and plaster	63	165
Nearly all plaster	45	210
Blue slate	110	320
Blue slate and plaster	70	390
Yellow soapstone	55	445
Pure plaster	45	490
Red rock, with a little salt	15	505

[a] Eckel, E. C., op. cit., p. 409.

NOTE.—Bored in 1847.

Log of well F on Robertson property, near Saltville, Smyth County, Va.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	17	17
Clay and plaster	33	50
Pure plaster	33	83
Hard black flint rock	7	90
Pure plaster	6	96
Plaster and sulphur balls	9	105
Strata unrecorded	4	109
Red and yellow soapstone	11	120
Hard blue slate and red, blue, and gray rock	239	359
Yellow and blue slate	31	390
Yellow and blue slate, salty	70	460

[a] Eckel, E. C., op. cit., p. 409.

NOTE.—Bored in 1853.

Log of well G on Robertson property, near Saltville, Smyth County, Va.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Sand and gravel	20	20
Blue clay	10	30
Hard white sandrock	10	40
Clay and plaster	15	55
Burrstone	5	60

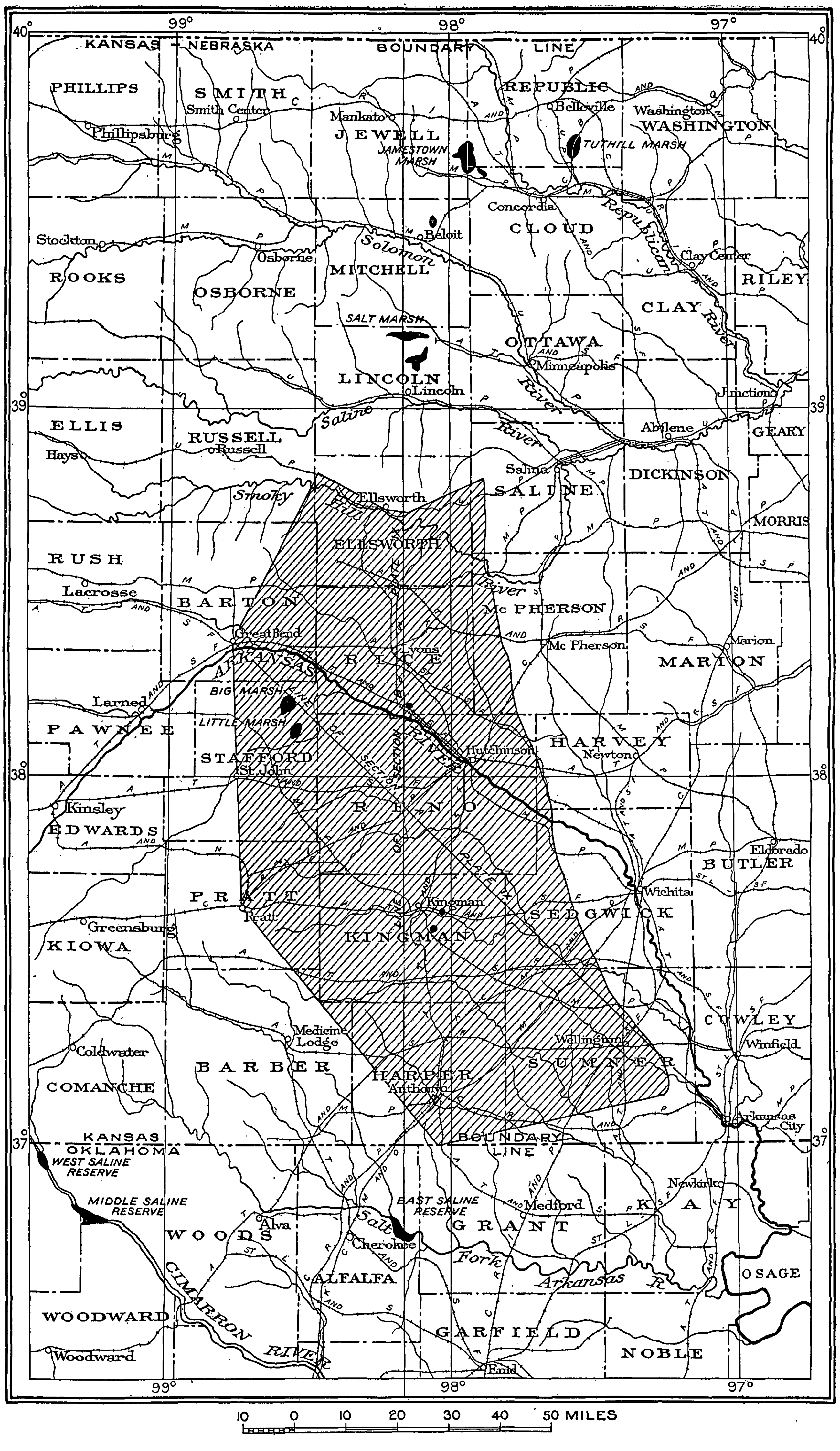
[a] Eckel, E. C., op. cit., p. 409.

NOTE.—Bored in 1854.

Generalized record of typical well on property of the Mathieson Co., at Saltville, Smyth County, Va.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Limestone and shale	26	26
Shale and gypsum	195	221
Mostly shale, with gypsum and some rock salt	359	580
Mostly limestone, with shale, gypsum, and rock salt	215	795
Mostly shale, with gypsum and rock salt	100	895
Mostly rock salt, with little shale	197	1,092

[a] Stose, G. W., Geology of the salt and gypsum deposits of southwestern Virginia: U. S. Geol. Survey Bull. 530, p. 252, 1913.



MAP OF MIDDLE KANSAS, SHOWING LOCATION OF SALT MARSHES AND AREA UNDERLAIN BY ROCK SALT.

From Kansas Univ. Geol. Survey Ann. Bull. Mineral Resources, 1898 (Pl. IV).

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KANSAS.[1]

Kansas ranked fourth among the States in both the quantity and the value of the salt produced in 1915. The State produces much rock salt and also evaporated salt obtained by the open-pan, grainer, and vacuum-pan processes.

POSITION AND EXTENT OF DEPOSITS.

In a small part of Kansas (see map, Pl. VIII) salt occurs in salt marshes as brine, which on evaporation during the dry season leaves a coating of salt and gives the name to the so-called salt plains. Salt from this source is not known to be utilized.

The rock salt which is now worked at Lyons and Kanopolis and from which brines are now obtained at Ellsworth, Hutchinson, Sterling, Lyons, and Anthony and were once obtained at other places lies well below the surface. Salt in the form of brine also occurs in certain beds of the Permian and Pennsylvanian ("Coal Measures") in the eastern part of the State. The part of Kansas below the surface of which rock salt is known to exist is the south-central. By examining the map (Pl. VIII) the extent of the area may be readily determined. It includes Rice and Kingman counties, nearly all of Reno County, and parts of Saline, Ellsworth, Barton, McPherson, Stafford, Harvey, Pratt, Sedgwick, Barber, Harper, and Sumner counties. The heavy line inclosing the shaded area is drawn from point to point where deep wells have proved the presence of rock salt. The eastern limit of the salt in Kansas probably corresponds closely to this line, as the salt approaches the surface eastward and is thinner than it is on the west and north, where it probably extends farther than represented.

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[1] Kirk, M. Z., and Haworth, Erasmus, Salt: Kansas Univ. Geol. Survey Mineral Resources Ann. Bull., 1898, pp. 67-123, 1899. (That part of the bulletin relating to the geology of Kansas salt (pp. 86-97) is by Haworth.)

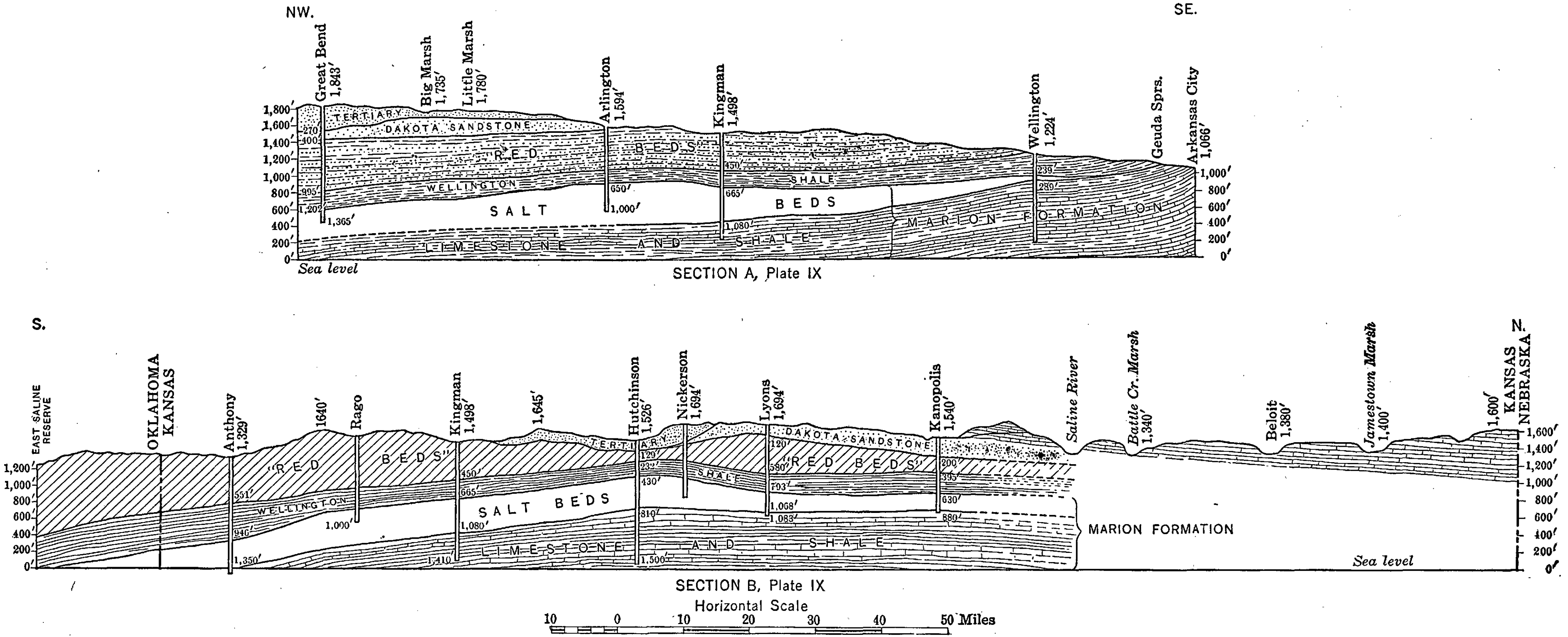
STRATIGRAPHY AND STRUCTURE.

THE SALT-MARSH AREA.

According to Haworth, the salt marshes in northern Kansas and possibly as far south as Stafford County obtain their salt principally from the salt-bearing shales of the Dakota sandstone. These salt-bearing shales have been described as being near the base of the upper Dakota and as ranging in thickness from 15 to 30 feet. On account of their saline content they undergo erosion readily and leave low, level areas which receive the leachings from adjacent salt-bearing shales situated to the west. The origin of the salt in the marshes of Stafford County, whether from the "Red Beds" or the salt-bearing shales of the Dakota, is difficult to determine, owing to the covering of Tertiary and recent sands and gravels. Farther south, however, the salt marshes of the area on Cimarron River and the area on Salt Fork in Oklahoma are thought to come entirely from the rock salt associated with the Permian "Red Beds."

THE ROCK-SALT AREA.

The rock-salt beds of Kansas occur in rocks of Permian age known as the Marion formation. (See Pl. IX, *A*.) They grow thinner eastward to a point beyond Wellington and Little River and die out possibly without coming near the surface. It is thought that the salt springs at Geuda Springs, Sumner County, have their origin in these salt beds. How far the salt and associated beds extend westward is unknown. Northward and southward the beds are fairly well known from drill records, from Kanopolis, Ellsworth County, on the north, to Anthony, Harper County, on the south—that is, very nearly to the Kansas-Oklahoma State line. From the north to south cross section of the State (Pl. IX, *B*) it will be observed that the beds thin northward. At Anthony they are 404 feet thick (depth 946 to 1,350 feet); at Kingman, 415 feet thick (depth, 665 to 1,080 feet); at Hutchinson, 380 feet thick (depth, 430 to 810 feet); at Lyons they are 275 feet thick (depth, 793 to 1,068 feet); and at Kanopolis about 250 feet thick (depth, 630 to 880 feet). If the rate of decrease in thickness from Hutchinson northward were maintained, the salt-bearing beds would disappear before the north boundary of the State was reached. It must be remembered that where more than one record is obtainable at the same place, for example, at Hutchinson, the exact thickness of the salt-bearing beds, as well as the distance of the topmost of them below the surface differs somewhat and at some of these places considerably from the figures given above. The records of the wells at Kanopolis, Lyons, Hutchinson, Kingman, and Anthony contain no reference to appreciable quantities of gypsum below them.



GEOLOGIC SECTIONS ACROSS THE SALT FIELD OF KANSAS.

From Kansas Univ. Geol. Survey Ann. Bull. Mineral Resources, 1898 (Pl. V).

A most interesting question in connection with the geology of the salt beds is their relation to the extensive gypsum deposits in different parts of Kansas and of the Great Plains area. The rock gypsum in the northern part of the State, in Marshall County, lies but a few feet above the Cottonwood limestone, which would place it considerably below the Marion formation. To the south, in the gypsum central field, the rock gypsum occurs in the Wellington shale, which overlies the Marion formation. If, therefore, the correlations made by Grimsley [1] are correct, the salt beds were deposited at a period of time intermediate between the formation of the Marshall County rock gypsum and that in the vicinity of Solomon.

It is difficult to understand how such extensive deposits of salt could be formed without a larger amount of gypsum being formed underneath them. The records of the wells at Kanopolis, Lyons, Hutchinson, Kingman, and Anthony contain no reference to gypsum immediately underlying the salt beds. The question is as to what became of the calcium sulphate held in solution by the ocean water from which the rock salt was obtained. It is barely possible that during the period of the formation of the Marshall County gypsum the inland sea did not reach southward to the salt-beds area, and that after the gypsum was principally precipitated out of the inclosed ocean water and before concentration was carried far enough to precipitate the salt, surface movements resulted in draining this partially purified water southward over new areas from which fresh ocean water was excluded, thus permitting the continued evaporation to deposit the salt now found in the salt beds from the sea water from which the Marshall County gypsum was produced. It is known that the Permian rocks, in general, become quite thin northward, entirely excluding the upper members of the Permian. So far as this has a bearing on the subject, it would tend to favor the view just expressed.[2]

WELL RECORDS.

Log of well at Wilson, Ellsworth County, Kans.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Black soil, sand, and clay	175	175
Sandstone	110	285
Blue shale	50	335
Red shale	390	725
Blue shale	115	840
Rock salt	270	1,110
Black shale	20	1,130
Gypsum	10	1,140
Blue shale and gypsum	125	1,265
Limestone	25	1,290
Slate and gypsum	60	1,350
Sandstone and gas	15	1,365
Limestone	25	1,390

[a] Kirk, M. Z., and Haworth, Erasmus, op. cit., p. 97.

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[1] Grimsley, G. P., and Bailey, E. H. S., Special report on gypsum and gypsum cement plasters: Kansas Univ. Geol. Survey, vol. 5, pls. 2 and 3, 1899.

[2] Haworth, Erasmus, Geology of Kansas salts: Kansas Univ. Geol. Survey Mineral Resources, Ann. Bull., 1898, pp. 88-89, 1899.

Log of well of Crystal Salt Co., Kanopolis, Ellsworth County, Kans.

Material.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
To top of salt	612		612	
Salt with black flakes, quite dark	10		11	
Shale	1			
Fair salt	3		14	
Salt mixed with shale	4		18	
Fair salt, with dirt	6		24	
Parting shale		2	24	2
Fair salt	5		29	2
Shale	1	6	30	8
Salt and dirt mixed	6		36	8
Dirt		3	36	11
Fair salt	3	6	40	5
Shale		2	40	7
Good salt	4		44	7
Shale	1		45	7
Salt and shale mixed	4		49	7
Fair salt	4		53	7
Black flakes and salt	20		73	7
Shale		8	74	3
Dirty salt	7		81	3
Shale	1		82	3
Fair salt	3		85	3
Shale	1	6	86	9
Fair salt	2		88	9
Shale	2		90	9
Dirty salt	11		101	9
Shale	1		102	9
Fair salt	3		105	9
Salt and shale mixed		10	106	7
Clay	7		113	7
Salt and shale mixed	9		122	7
Hard black salt		8	123	3
Good salt with blank streaks running up and down	8		131	3
Fair salt	4		135	3
Salt and shale mixed	1	6	136	9
Fair salt with dark streaks	6		142	9
Shale	1		143	9
Dark salt	7	6	151	3
Parting shale		1	151	4
Dark salt	1	3	152	7
Parting		1	152	8
Dark salt	1	6	154	2
Good salt	3		157	2
Black salt		6	157	8
Fair salt	5	6	163	2
Shale		2	163	4
Good salt	1	8	165	
Fair salt	3		168	
Streaked black salt	2	6	170	6
Salt (bed now being worked)	11		181	6
Total depth	....		793	6

Log of shaft No. 3, of Crystal Salt Co.[a]

Material.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Shale		10	....	
Dark salt	5		5	10
Shale		2	6	
Dark salt	1	10	7	10
Shale		1	7	11
Dark salt	15		22	11
Shale		1	23	
Dark salt	1	4	24	4
Shale	8		32	4
Dark salt	4		36	4
Shale		1	36	5
Light-colored salt	3	6	39	11
Shale		1	40	
Light-colored salt	6	10	46	10

[a] Sunk in a search for potash salt below the bottom of the salt being worked, Kanopolis, Kans.

Log of well at Kanopolis, Ellsworth County, Kans.[a]

Material.	Thick-ness.	Depth.
	Feet.	*Feet.*
Soil, sandy loam	5	5
Brown sand	5	10
Yellow sand	5	15
Sand and fine gravel	5	20
White sand and fine gravel	10	30
Coarse gravel	5	35
Yellow clayey sand	5	40
Gray soapstone	10	50
Light-gray soapstone	5	55
Red shale	5	60
Pink shale	5	65
Gray shale	10	75
Gray sand and gravel	5	80
Gray shale	30	110
Dark-blue shale	35	145
Lead-colored shale	35	180
Red shale	5	185
Silica or light shale	5	190
Silica or light soft shale	10	200
Red Triassic[b] rock	40	240
Brown Triassic rock	5	245
Dark-brown Triassic rock	10	255
Brown and red Triassic rock	10	265
Dark-red Triassic rock	10	275
Brown and red Triassic rock	20	295
Dark-brown Triassic rock	5	300
Red Triassic rock	15	315
Light-red Triassic rock	15	330
Brown and red Triassic rock	5	335
Dark-red Triassic rock	10	345
Brown Triassic rock	15	360
Dark-red Triassic rock	5	365
Dark-brown Triassic rock	5	370
Dark-red Triassic rock	10	380
Traces of gypsum	5	385
Dark-red Triassic rock	5	390
Very dark red Triassic rock	5	395
Dark (gypsum) Triassic rock	5	400
Brown (traces) Triassic rock	5	405
Blue shale	5	410
Blue shale and gypsum	50	460
Blue shale	10	470
Brown shale	15	485
Red Triassic rock, gypsum	5	490
Brown Triassic rock, gypsum	15	505
Brown shale	20	525
Gray shale	5	530
Brown shale	30	560
Blue shale	75	635
Blue shale with few scales of salt	5	640
Blue shale and salt mixed	5	645
Black shale and salt mixed	5	650
Salt	5	655
Salt and shale	5	660
Shale and salt	5	665
Salt	5	670
Salt, bright crystals	185	855
Slightly mixed with shale	5	860
Salt, slightly mixed with slate	10	870
Salt and clay	10	880

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[a] Kirk, M. Z., and Haworth, Erasmus, op. cit., p. 94.
[b] The rocks called Triassic in this record are now classified as Permian.

NOTE.—Record as furnished by the company: "Boring commenced March 1, 1889; well completed March 16. From surface to first specimen of salt intermingled with slate, 640 feet; thickness of pure salt, 230 feet; actual depth of well, 881 feet; 8-inch drive pipe, 105 feet; 5⅜-inch casing, 333 feet; ½-inch tubing in the well, 851 feet and 6 inches. Piping placed in the well and the well completed ready to attach pumps, March 18. The fresh-water well for use of drilling was sunk 35 feet, cased with 5⅝-inch casing properly perforated and driven to the bottom, and furnishes an abundant supply of pure water. The record represents the drillings found in every 5 feet."

Log of shaft of Lyons Rock Salt Co., Lyons, Rice County, Kans.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil and sandy loam	30	30
Sandy loam	15	45
Sandstone	10	55
Variegated clays	12	67
Blue clay	13	80
Black shale	30	110
Gray sandstone	10	120
Red sandstone	78	198
Red sandy shale	56	254
Red clay	18	272
Soft limestone	3	275
Gypsum and limestone	9	284
Blue shale	4	288
Red shale and blue, mixed with gypsum	292	580
Dark-gray shale	60	640
Reddish-gray shale	30	670
Dark-gray shale	123	793
Light-gray salt rock	2	795
Dark-gray salt and rock	½	795½
Light-gray salt rock	2½	798
Dark-gray salt rock	4	802
Light-gray salt rock	3½	805½
Reddish gray salt rock	½	806
Gray shale	8	814
Dark-gray salt rock	10½	824½
Gray shale and salt, mixed	3	827½
Gray shale	4	831½
Light gray salt rocks	9	840½
Rock salt and shale	1½	842
Light-gray salt rock	8½	850½
Gray shale	1½	852
Light-gray salt rock	8½	860½
Shale	1	861½
Light-gray salt rock	6½	868
Shale and salt rock, mixed	2½	870½
Dark salt and shale	8½	879
Crystal salt	4	883
Shale and salt	7	890
Dark salt and shale	18½	908½
Dark-red shale	6	914½
Dark salt and rock	10	924½
Dark salt, with crystals	17	941½
Rock and salt and shale	19	960½
Dark salt and shale	21	981½
Crystal salt	2	983½
Shale	1	984½
Light-gray salt	9½	994
Shale	½	994½
Light-gray salt and a little shale	10	1,004½

[a] Kirk, M. Z., and Haworth, Erasmus, op. cit., p. 93.

Log of Standard Salt Co.'s shaft, Little River, Rice County, Kans.

Material.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Soil	2		2	
Sandy clay	44		46	
Soft red shale	4		50	
Sand and shale	15		65	
Red and blue shale	284		349	
Blue shale	62		411	
Red and blue shale	10		421	
Red shale	13		434	
Blue shale	6		440	
Red and blue shale	22		462	
Red shale	1		463	
Blue shale	73		536	
Gray shale	3		539	
Blue shale	19		558	
Salt and shale	5		563	
Blue shale	2		565	
Salt and shale	10		575	
Salt	10		585	
Shale	1		586	
Salt	6		592	
Shale	3		595	
Salt	6	7	601	7
Shale	8		609	7
Salt	16		625	7
Blue shale	2		627	7
Salt	3		630	7
Blue shale	1		631	7
Red shale		6	632	1
Blue shale	1	6	633	7
Salt	5		638	7
Blue shale	1		639	7
Clear crystal salt	27		666	7
Shale	5		671	7
Salt	2		673	7
Shale	1		674	7
Crystalline salt	22		696	7
Blue shale	4	6	701	1
Crystalline salt	31		732	1
Blue and red shale	1	2	733	3
Salt	6	6	739	9
Shale	3	6	743	3
Salt and shale		6	743	9
Crystallized salt	15		758	9
Salt and shale		6	759	3
Salt	5		764	3
Salt and shale	3		767	3
Crystallized salt (planning to work this bed)	18		785	3
Salt and shale	1	6	786	9
Salt	9		795	9
Shale	4		799	9
Crystallized salt	7	6	807	3
Shale	9	6	816	9
Salt	3	6	820	3
Shale	17		837	3
Crystallized salt	8		845	3
Shale and gypsum	108		953	3
Sand and shale	6	10	960	1
Sandstone	1	6	961	7
Shale and gypsum	16	6	978	1
Blue and red shale	10		988	1
Shale and gypsum	8		996	1

Log of well at Little River, Rice County, Kans.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	16	16
Shale	2	18
Red shale	36	54
Red sandstone	8	62
Red sandstone	9	71
Red shale	258	329
Blue clay and shale	256	585
Salt and shale	10	595
Rock salt	70	665
Shale	4	669
Rock salt	43	712
Salt	39	751
Shale	8	759
Rock salt	35	794
Clear salt	54	848
Shale	4	852
Rock salt	57	909
Clear salt	23	932
Shale	5	937
Rock salt	27	964

[a] Kirk, M. Z., and Haworth, Erasmus, op. cit., p. 95.

NOTE.—Record furnished by the driller, J. P. Brisben, Lyons, Kans.

Log of well of Sterling Salt Co., north of plant, Sterling, Rice County, Kans.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	8	8
Sand	70	78
Clay, lime, and gypsum	34	112
Clay and sand	21	133
Red rock	340	473
Blue shale	221	694
Salt and shale	8	702
Shale	4	706
Salt	5	711
Shale	9	720
Salt and shale	9	729
Shale	18	747
Salt and shale	13	760
Shale	4	764
Salt	40	804
Salt and shale	10	814
Salt	45	859
Shale	10	869
Salt and shale	10	879
Salt	4	883
Salt and shale	10	893
Salt	32	925
Shale	5	930

NOTE.—Drive pipe, 133 feet; casing, 204 feet; tubing, 915 feet. Put down in 1902.

Log of well at Sterling, Rice County, Kans.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil and sand	136	136
Red shale	348	484
Black shale	216	700
Salt	10	710
Shale	25	735
Salt	10	745
Salt and shale	37	782
Salt	28	810
Salt and shale	5	815
Salt	48	863
Salt and shale	6	869
Salt	20	889
Salt and shale	8	897
Salt	68	965
Salt and shale	10	975
Salt	5	980

[a] Kirk, M. Z., and Haworth, Erasmus, op. cit., p. 97.

NOTE.—At old sugar works. Record reported by the drillers, Palmer & Davis.

Log of well No. 2 of Hutchinson Pure Salt Co., Hutchinson, Reno County, Kans.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
First salt struck at depth of		424
Salt	32	456
Shale	9	465
Salt and shale	5	470
Salt	4	474
Shale	9	483
Salt	27	510
Salt and shale	5	515
Salt	45	560
Salt and shale	10	570
Salt	22	592
Shale	5	597
Salt	130	727
Salt and shale	5	732
Salt	19	751
Shale	4	755

NOTE.—Drive pipe, 74 feet; casing, 123 feet; tubing, 741 feet.

Log of well No. 5 of Carey Salt Co., Hutchinson, Reno County, Kans.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil and sand	73	73
Red shale	99	172
Blue shale	271	443
Salt and shale	4	447
Salt	8	455
Shale	8	463
Salt and shale	7	470
Salt	16	486
Salt and shale	5	491
Shale	4	495
Salt and shale	5	500
Salt	65	565
Salt and shale	10	575
Salt	30	605
Salt and shale	9	614
Salt	5	619
Salt and shale	5	624
Salt	20	644
Salt and shale	10	654
Salt (very hard)	50	704
Salt and shale	10	714
Salt	46	760
Gypsum	5	765

NOTE.—Drive pipe, 73 feet; casing, 143 feet; tubing, 750 feet. Total salt deposit, 240 feet; total shale and salt, 65 feet; total shale, 12 feet; gypsum, 5 feet.

Log of well No. 4 of Carey Salt Co., Hutchinson, Reno County, Kans.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil and sand	75	75
Soft lime	5	80
Red shale	75	155
Red and blue shale	145	300
Light-blue shale	40	340
Red and blue shale	40	380
Blue shale	60	440
Salt and shale	8	448
Salt	12	460
Salt and shale	4	454
Shale	12	476
Salt and shale	5	481
Salt	12	493
Shale	4	497
Salt and shale	12	509
Shale	4	513
Salt and shale	5	518
Salt	40	558
Shale	4	562
Salt and shale	8	570
Salt	34	604
Shale	5	609
Salt and shale	4	613
Salt	5	618
Salt and shale	5	623
Salt	15	638
Salt and shale	10	648
Salt	45	693
Salt and shale	5	698
Salt	62	760
Gypsum	5	765

NOTE.—Drive pipe, 75 feet; casing, 140 feet; tubing, 750 feet.

Log of well of Carey Salt Co., Hutchinson, Reno County, Kans.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil and sand	8	....
Quicksand	70	78
Red rock	5	83
Sand, gravel, and water	2	85
Red rock	8	93
Sand	1	94
Red rock	6	100
Sand	1	101
Red rock and small streak of sand, with water	63	164
Gray fire-clay	6	170
Red rock	26	196
Gray fire-clay	9	205
Red rock	25	230
Light shale	55	285
Red rock	41	326
Light shale	140	466
Salt and shale, not differentiated	307	773

NOTE.—8-inch drive pipe, 96 feet; 2½-inch tubing, 756 feet; 5⅝-inch pipe, 164 feet.

Log of Ben. Blanchard prospect well, south of Arkansas River, Hutchinson, Kans.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Sand, drift, and soil	146	146
Red shale	26	172
Shale	2	174
Red shale	76	250
Blue shale	12	262
Gray shale	78	340
Red shale	10	350
Black shale	15	365
Red shale	9	374
Black shale	4	378
Black shale	95	473
Salt	18	491
Shale	8	499
Shale and salt	3½	502½
Salt	13	515½
Shale	7½	523
Shale	5½	528½
Shale	2	530½
Salt	11	541½
Shale	7	548½
Salt	10	558½
Shale	3½	562
Salt	27	589
Flint rock	2	591
Salt	47	638
Shale	3	641
Salt	138	779
Shale	13	792
Salt	8	800
Shale	37	837
Gypsum	28	865
Lime	38	903
Marble	3	906
Clay	1	907
Shale	4	911
Gypsum	8	919
Black shale	5	924
Limestone	6	930
Red shale	2	932
Limestone	19	951
Shale	11	962
Limestone	10	972
Black sandstone	7	979
Limestone	24	1,003
Sandstone	27	1,030
Shale	22	1,052
Limestone	14	1,066
Shale	25	1,091
Red sandstone	45	1,136
Limestone	12	1,148
Shale (small seam coal)	36	1,184
Limestone	26	1,210
Sandstone	35	1,245
Limestone	10	1,255
Shale	30	1,285
Limestone	5	1,290
Shale	7	1,297

[a] Kirk, M. Z., and Haworth, Erasmus, op. cit., p. 92.

NOTE.—Record furnished by the drillers, Palmer & Davis. In the original record the total depth is given as 1,307 feet; there are certain discrepancies between thickness of individual strata and total depth.

Log of well of Kingman Light & Fuel Co., 1½ miles north of Kingman, Kans.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Bed rock	100	100
Blue-white shale	20	120
Red rock	175	295
Blue gypsum	10	305
Mixed red shale and blue gypsum	145	450
Blue shale	135	585
Brown soft shale	5	590
Blue shale	70	660
Hard blue rock	5	665
Salt and shale	165	830
Limestone	5	835
Salt and shale	165	1,000
Limestone	5	1,005
Salt and shale	23	1,028
White limestone	8	1,036
Oily shale	9	1,045
White limestone and shale	16	1,061
Blue shale	4	1,065
Flinty marble	5	1,070
Salt, shale, and shelly rock	10	1,080
Limestone	15	1,095
Limestone and shale	30	1,125
Limestone	35	1,160
Shale	5	1,165
Limestone	5	1,170
Shale	15	1,185
Limestone	12	1,197
Shale	13	1,210
Limestone	10	1,220
Oil sand and shale	5	1,225
Shale and limestone	10	1,235
Shale	5	1,240
Limestone	3	1,243
Sandstone	12	1,255
Shale and sandstone	30	1,285
Blue shale	5	1,290
Shale	5	1,295
Red shale	9	1,304
Sandstone	6	1,310
Sandy shale	10	1,320
Buff sandstone	8	1,328
Shale	6	1,334
Brown sandstone	24	1,358
Sandy shale	5	1,363
Buff shale	30	1,393

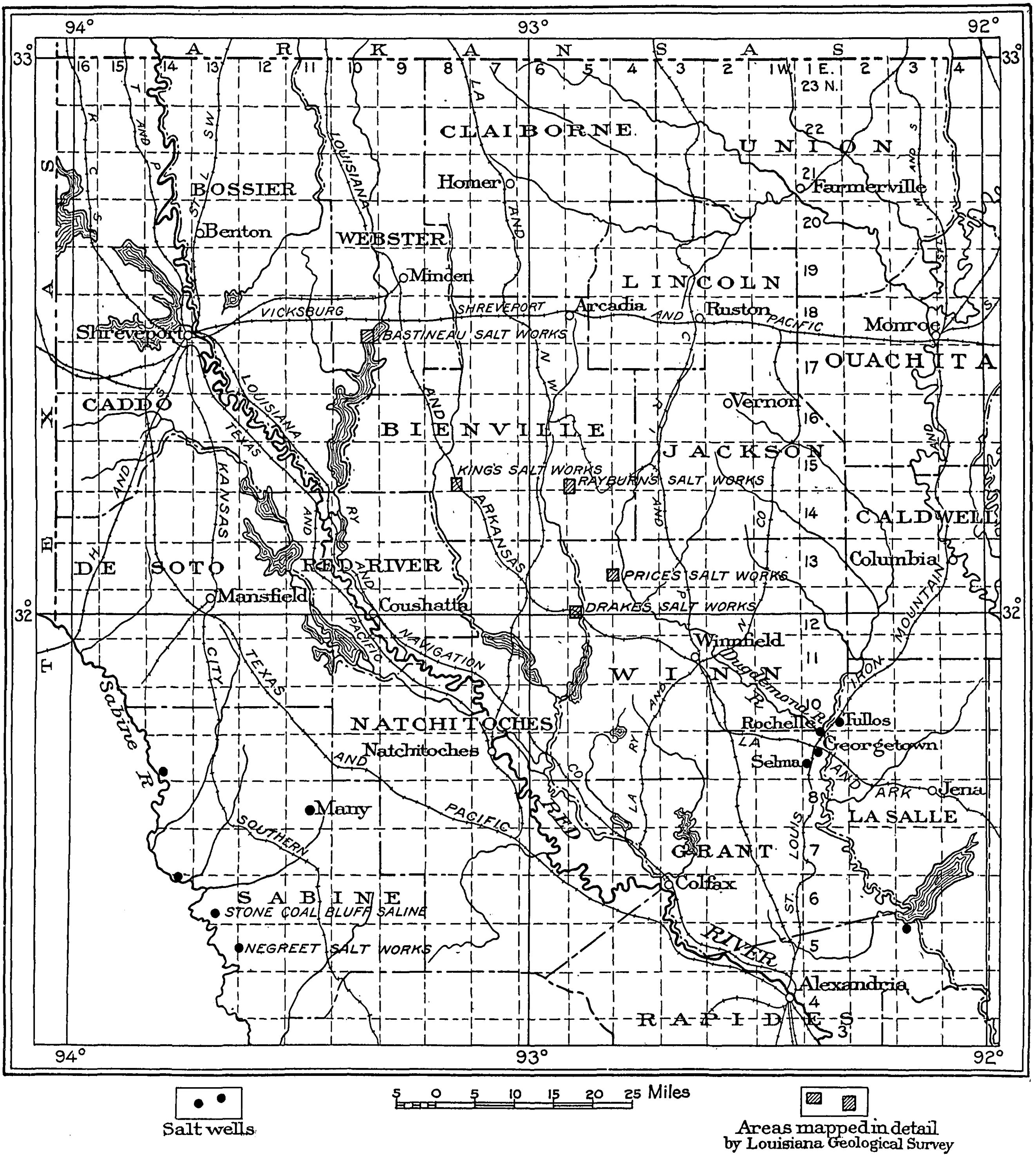
[a] Kirk, M. Z., and Haworth, Erasmus, op. cit., p. 91.

NOTE.—Drilled in 1887. Record reported by county surveyor, W. H. Child. In the original the total depth is given as 1,410 feet. There are certain discrepancies, however, between thickness of individual beds and total depth.

Log of well of Orient Salt Co., Anthony, Harper County, Kans.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	5	5
Light sandy shale	5	10
Red shale	30	40
Sandy shale, with little water	5	45
Red shale	10	55
Light sandy shale	10	65
Red shale	10	75
Sandy shale, water bearing	10	85
Light-red shale	15	100
Red shale	40	140
Pink shale	35	175
Red shale	40	215

[a] For an additional record of strata at Anthony, Kans., see Kirk, M. Z., and Haworth, Erasmus, op. cit., p. 90.



MAP OF NORTHERN LOUISIANA, SHOWING LOCATION OF SALINES.

From map by A. C. Veatch.

Log of well of Orient Salt Co., Anthony, Harper County, Kans.—Continued.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
White shale	20	235
Dark-red shale	55	290
Pink shale	15	305
Red shale	25	330
Red and white shale	125	455
Red shale	80	535
White shale with shells	115	650
White shale	105	755
White and red shale	35	790
Black shale	10	800
Blue shale	20	820
Salt and shale	3	823
Blue shale	7	830
Rock salt	30	860
Gray shale	15	875
Red shale	20	895
Red shale, little salt	5	900
Red and gray shale	10	910
Red shale	5	915
White shale	5	920
Rock salt	40	960
Gray shale	40	1,000

NOTE.—From 1,000 feet to the total depth of the well the strata could not be named on account of excessive caving. At 790 feet a flow of brine was noticeable, and at 797 feet a flow of brine was struck which the drillers were unable to bail out, so the 8-inch casing was put in to stop the flow. The drive pipe was put down to a depth of 75 feet; 4-inch tubing to a depth of 1,025 feet; and 8-inch casing to 1,050 feet. It is peculiar that the caving character of the rock required the tubing to be protected.

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KIRK, M. Z., Salt: Mineral resources of Kansas for 1898, pp. 67–123, 1899. That part relating to the geology of Kansas salt (pp. 86–97) is by Erasmus Haworth.

LOUISIANA.

Louisiana in 1915 ranked fifth in quantity and sixth in value of salt produced, the product being rock salt.

POSITION OF DEPOSITS.

Salt occurs in two distinct sections of the State, in the north-central and northern part and in the southern part, the more important known deposits and those worked at present being in the southern part, in close proximity to the Gulf coast. The locations of the deposits or salines of the State are shown on the accompanying maps (Pl. X and fig. 4).

SALINES OF NORTHERN LOUISIANA.

LOCATION.

In the northern part of Louisiana, in the valley of Sabine River, salt springs occur at Negreet, about 1½ miles above the mouth of Bayou Negreet in Sabine Parish, in the SW. ¼ sec. 24, T. 5 N.,

R. 13 W.; at Stone Coal Bluff, in sec. 33, T. 6 N., R. 13 W.; and near Many, on the road from Marthaville to Many, near Rock Springs Church, in the NE. ¼ sec. 24, T. 8 N., R. 11 W.

In the valley of Red River are the following: Bayou Castor Saline, 5 miles north of Rochelle or about 4 miles above the mouth of Dugdemona River; Catahoula Salt Springs, on Catahoula Lake; Brown's Saline, 6 miles west of Tullos or 18 miles southeast of Winnfield, on Dugdemona River; near Georgetown; at Rochelle, Tullos, and Selma; northwest of Winnfield, Winn Parish; at Cedar Bayou; and at Coochie Dome.

Important salines, from which much evaporated salt was obtained during the Civil War and earlier, were known as Drake's, Price's, Rayburn's, and King's, after the names of their respective owners or managers. A full account of the more important salines of northern Louisiana has been given by Veatch.[1] Bistineau Saline, the largest saline in northern Louisiana, was in Lake Bistineau, secs. 25, 26, 35, and 36, T. 18 N., R. 10 W.

HISTORY.

The works at the old salines in northern Louisiana, now abandoned, were active during the Civil War and for some time before it, but since the war they have not been able to compete with those that produce salt by more improved methods at places that have better transportation facilities. Most of the old salines were areas where brine issued from the ground in the form of springs or where it was pumped in crude fashion and evaporated. These brines indicate that bodies of rock salt lie below.

STRATIGRAPHY.

The salt springs of northern Louisiana are described by Veatch as emerging generally from Upper Cretaceous outcrops and are thus mapped on the geologic map of the State accompanying the report of Harris and Veatch.[2] Harris[3] notes that "the Cretaceous rocks appearing about the peripheries of the northern salines are not the uppermost Cretaceous stages, but rather those at about the horizon of the Nacatoch marls or Anona limestone—that is, below the Arkadelphia clays that cap the Cretaceous in southwest Arkansas." At Rayburn's, Bistineau, and King's salines, fossils characteristic of the upper beds of the Upper Cretaceous have been found. Though proof is lacking of the Cretaceous age of the hard leaf-bearing sandy pyritic limestone that occurs at Coochie Brake and at Price's Saline and that

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[1] Veatch, A. C., The salines of north Louisiana; a report on the geology of Louisiana, pp. 47-100, Louisiana Exper. Sta., 1902.

[2] Harris, G. D., and Veatch, A. C., A preliminary report on the geology of Louisiana, Louisiana Exper. Sta., 1899. The map opposite p. 44 precedes section 2 on general geology. See also The Five Islands, idem, p. 261.

[3] Harris, G. D., The geological occurrence of rock salt in Louisiana and east Texas: Econ. Geology, vol. 4, p. 15, 1909.

seems to be associated with a large bed of soft chalklike limestone at Drake's, the facts thus far collected rather strongly indicate it. In a later report by Veatch[1] some salines are noted as issuing from rocks higher in the geologic column; for example, the brine from the Negreet Salt Works, which issues from the St. Maurice formation, the lower formation of the Claiborne group (Eocene).

SALINES OF SOUTHERN LOUISIANA.

LOCATION.

The most important salt deposits of Louisiana are located near the southern coast on the Five Islands, or Salt Islands as they are sometimes called, namely, Petite Anse, Grande Cote, Belle Isle, Cote Blanche, and Cote Carline. (See fig. 4.) On Avery Island (Petite Anse) and Weeks Island (Grande Cote) rock salt is being mined on an extensive scale.

Other localities in southern Louisiana where the geologic conditions are similar to those on the Five Islands and where rock salt or salt water, indicating the possible presence of rock salt, has been found in deep drillings are Anse-la-Butte, Prairie Mamou, Welsh, Chicot, Vinton, and Hackberry.

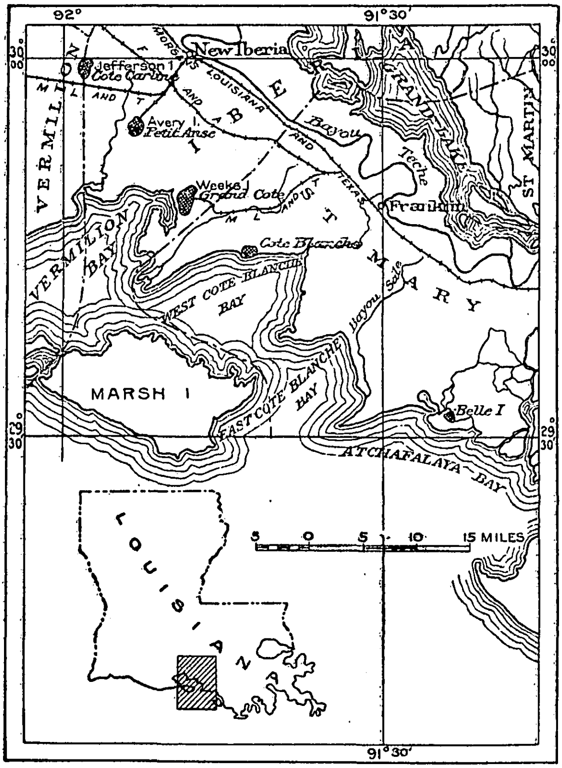

FIGURE 4.—Map of a part of the coast of southern Louisiana, showing location of salt islands.

BELLE ISLE.

Belle Isle, the southeasternmost of the Five or Salt Islands, is 8 miles from the mouth of Atchafalaya River and is reached by boat from Morgan City on the Southern Pacific Railroad. It is surrounded

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[1] Veatch, A. C., The salines of north Louisiana: A report on the geology of Louisiana, p. 90, Louisiana Exper. Sta., 1902.

by a network of bayous and sea marshes. The island is roughly triangular and includes about 360 acres. Along its northwest side is a range of hills, the highest of which reaches an altitude of 80 feet.

After the discovery of rock salt in a well on Cote Carline and because of the increasing difficulty of mining salt at Petite Anse, due to seepage, A. F. Lucas undertook the exploitation of Belle Isle for salt, which he discovered in December, 1896, in well No. 1, at a depth of 373 feet.[1] A short time later a shaft was started on the site of hole No. 11, in which salt was found at a depth of 103 feet.

Fairly complete ideas of the substructure of the island may be gained from the records of the wells drilled on it, of which eight have been plotted by Veatch.[2] These records lead to the belief that the salt on Belle Isle exists in the form of an oblong, dome-shaped mass, longest in a northeast direction, and consequently having the same trend as the hills along the western side of the island, but with the difference that the salt dome is located in its northeastern part. The record of the beds passed through in sinking the shaft, which may be taken as typical of those on the island, is given below. The original figures are quoted in spite of the discrepancies which they show.

Log of shaft, Belle Isle, La.[a]

(Elevation above sea level, 7 feet.)

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	4	4
Sand, hard	9	13
Clay, blue	17	30
Clay, blue, and sand	10	40
Clay, hard, and gravel	23	63
Clay, blue, with barite, galena, sphalerite, pyrite, and chalcopyrite in crystalline masses, from the size of a marble to the size of a man's head	5	68
Clay, blue, and shells	27	95
Rock, impure black limestone and barite	1½	96½
Clay, blue, with masses of barite near the base	6½	103
Clay, dark-colored, with large salt crystals	14	116
Clay, dark-colored, with oil	1	117
Salt, with dark-colored clay	25	142
Salt, discolored	35	162
Limestone, white	$\frac{7}{10}$	163
Salt, dirty, becoming white	12	175

[a] Veatch, A. C., op. cit., p. 225.

NOTE.—This was the depth of the shaft May 19, 1899.

Ten other wells that were sunk on the island subsequent to the investigations of Veatch have furnished most valuable data as to the substructure of the underlying salt mass and have modified in some particulars the ideas previously held regarding its shape. The record of one of these wells is as follows:

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[1] Veatch, A. C., The Five Islands: A preliminary report on the geology of Louisiana, p. 222, Louisiana Exper. Sta., 1899.

[2] Idem, pl. 22.

Log of well No. 1, Belle Isle, La.[a]

[Nature of samples at depths indicated.]

Material.	Depth.
	Fect.
Yellow loamy clay	81
Fine sand	85
Coarse sand	200
Coarse angular gravel	232
Coarse angular gravel with sulphur	256
Sand, with sulphur	285
Sand, sulphurous, with traces of oil	303
Fine gray sand	450
Brown sand	500
Sand (showing gas)	545
Salt and sand	565
Salt, sand, and clay	590
Quicksand, through second belt of salt	608
Sand and hard clay	655
Hard clay (showing gas)	720
Gray sand, with pyrites, hard	756
Fine gray sand	785
Salt and hard clay	840
Hard gray shale	852
Hard gray shale, sulphur	870
Sand and clay, showing oil and gas	940
Hard gray clay	955
Hard brownish-gray clay	960
Brown oil sand mixed with salt	985
Dark clay	1,010
Hard black clay and limestone	1,022
Gray clay and sand	1,039
Hard gray clay and gravel	1,040
Dark hard clay and sand	1,058
Dark hard clay and sand; casing set at 1,066½ feet and baled, bringing up large hard chunks of calcareous gray shale and impure crystalline gypsum	1,068
Brine, oil, sand, salt, etc	1,086
Olive and brownish clay shale, sand, and salt	1,096
Gray hard sandy clay (oil showing)	1,105
Fine brown sandy loam (good oil showing)	1,116
Hard dark flaking clay	1,130
Hard gray sandy clay	1,150
Fine compact sandy shale, salty to taste, hard shell, big pressure of gas, and good showing of oil	1,160
Brown sand and salt	1,170
Dark hard clay and salt	1,180
Salt and fine sand	1,202
Hard clay, salt, and sulphur	1,206
Fine brown sand (oil)	1,212
Dark fine sand (oil)	1,220
Dark fine sand (oil)	1,230
Dark shale (drilled with cable tools)	1,232
Dark hard clay and sand	1,237
Hard clay and oil sand	1,240
Brown sand and hard clay	1,253
Brown sand and hard clay	1,318
Light-drab sandy clay	1,355
Light-gray sandy clay (fine showing of oil on the return)	1,365
Dark hard clay and sand (best oil showing yet)	1,370
Hard light-drab to dark clay sandstone	1,430
Hard dark-gray shale	1,445
Fine drab loamy sand	1,475
Salt	1,545-2,450

[a] Harris, G. D., Rock salt: Louisiana Geol. Survey Bull. 7, pp. 22-23, 1908.

The great depth to the salt mass in this well should be noted. The domelike shape of the salt mass explains the great differences in the depths at which the salt was encountered.

In 1907 the salt mass at Belle Isle was pierced by I. N. Knapp, who found that the salt had a thickness of 2,740 feet at the point where the drilling was done.[1]

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[1] Lucas, A. F., Rock salt in Louisiana: Science, new ser., vol. 35, p. 962, 1912; The origin of petroleum: Am. Inst. Min. Eng. Bull. 90, p. 1383, 1914.

COTE BLANCHE.

Cote Blanche occupies the geographic center between the two extremes of the Five Islands, Cote Carline on the northwest and Belle Isle on the southeast. It lies near the center of the north shore of Cote Blanche Bay, in T. 15 S., R. 5 E. It is approximately circular and it ranks third in size among the islands, having an area of 1,400 acres.

After the discovery of salt at Petite Anse in 1862, numerous shallow pits were sunk on Cote Blanche in the search for salt. Though these threw some light on the surface geology, the main sources of information with reference to the underground geology are the eroded sea cliffs on the south side of the island and the eight well sections plotted by Harris.[1] None of these borings reached a depth of 500 feet and none reached the salt mass, but possibly they were not located where the salt mass lies nearest the surface. It is possible, as Harris states, that the apex of the salt dome may now lie out at sea, for the waves are rapidly undermining the sea cliffs along the south shore of the island, which consequently has been rapidly receding for some time. Harris concludes his description of this island with the remark: "That the uplift or form of the island is due to salt and its attendant materials and phenomena, as in the other salt islands, we do not for a moment doubt." No salt has yet been discovered on Cote Blanche.

COTE CARLINE.

Cote Carline is known by various names, but perhaps best as Jefferson Island, from the fact that for several years it was the winter home of the famous actor, Joseph Jefferson. It is the northwesternmost of the Five Islands and is near the line between Vermilion and Iberia parishes, in the southwestern part of T. 12 S., R. 5 E. It is about 9 miles west of New Iberia and but a short distance from the Abbeville branch of the Southern Pacific Railroad. Its area is approximately 300 acres. Cote Carline rises out of a prairie, except on its northwestern side, where there is a body of water known as Lake Peigneur. The prairie lands surrounding the rest of the island are given up to the cultivation of rice.

Salt was discovered on the island early in the summer of 1895 at a depth of 334 feet. The same hole was drilled by A. F. Lucas to a depth of 2,090 feet and the drill was in salt when the work ceased.[2] The section of the well is as follows:

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[1] Harris, G. D., op. cit., pl. 28.

[2] Veatch, A. C., The Five Islands; A preliminary report on the geology of Louisiana, p. 255, Louisiana Exper. Sta., 1899. Lucas, A. F., Rock salt in Louisiana: Am. Inst. Min. Eng. Trans., vol. 29, p. 465, 1900. Lucas's statement differs slightly from the one in the text. Lucas states that he took charge of the boring which resulted, in 1896, in the discovery at a depth of 290 feet of a magnificent bed of rock salt. This discovery was followed by systematic explorations determining a zone within which rock salt was encountered at 90 to 350 feet from the surface.

Section of well No. 1, Cote Carline, La.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Unknown	265	265
Gravel, coarse, and sand	69	334
Rock salt, white, without noticeable impurities	1,756	2,090

[a] Veatch, A. C., op. cit., p. 255.

Eight holes in all were drilled to determine the contours of the underlying salt mass, four of which succeeded in reaching it. The records indicate that there is a surface layer of clay from 33 to 110 feet thick, below which are irregular layers of sand and gravel and locally layers of blue clay. In one well a layer of lignite was encountered. The salt comes nearest the surface in hole No. 8, in which the following section was measured:

Section of well No. 8, Cote Carline, La.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	33	33
Sand and clay	58	91
Rock salt, not passed through	21	112

[a] Veatch, A. C., op. cit., p. 256.

The arrangement of the beds of the island are shown in well No. 7, where drilling was carried to a depth of 442 feet without finding salt. The section of this well is as follows:

Section of well No. 7, Cote Carline, La.[a]

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Clay	80	80
Sand	107	187
Sand and clay, blue	8	195
Sand	65	260
Sand and gravel	18	278
Gravel, coarse	25	303
Sand and gravel	60	363
Clay, blue, and zinc sand	33	396
Sand	32	428
Sand, cemented, and clay, blue[b]	16	444

[a] Veatch, A. C., op. cit., p. 256.

[b] To this Lucas adds: "Salt is probably not very far from this point."

ANSE-LA-BUTTE.

Anse-la-Butte is about 5 or 6 miles northeast of Lafayette and 1 mile east of Bayou Vermilion in St. Martin Parish. Several wells drilled in this locality struck salt. On the southern border of the swamp a drill hole entered salt at a depth of 225 feet and continued in it until drilling was discontinued at a depth of 1,530 feet. In a well on the northwest side of the swamp, Fenneman[1] gives the known salt mass as extending from 220 feet to the bottom of the well at a depth of 1,803 feet. In one of the first wells sunk on top of the high mound north of the swamp salt is reported as extending from depths of 391 to 570 feet and from 578 to 790 feet, an approximate total of 400 feet of salt. Salt was encountered in still another well north of the swamp.

Harris's interpretation of the facts observed at Anse-la-Butte and those obtained from the deep drillings is that the salt forms a central core and the beds of sand, gravel, and clay are bent upward around it at angles of 45° or more. All the dips have been interpreted by the drillers as being away from the center of the field or swamp. In his descriptions of this occurrence Harris also gives an account of the origin of the small outlying masses of salt near many of the main salt domes of southern Louisiana and Texas.

PRAIRIE MAMOU.

Prairie Mamou (Jennings oil field) is about a mile west of the center of T. 9 S., R. 2 W., in Acadia Parish, about 6 miles northeast of Jennings. Though a rock salt core has not been found at this place, according to Harris,[2] this locality is similar to Anse-la-Butte, except that the salt mass has not been laterally concentrated and therefore occupies a broader area, in consequence of which the dome lies much deeper than it would under other conditions. The abundance of salt water obtained at this place points to the presence of a near-by mass of rock salt.

WELSH.

The occurrence at Welsh is about 4 miles west and a little north of Welsh station, on the Southern Pacific Railroad, in secs. 21 and 22, T. 9 S., R. 5 W., in Calcasieu Parish. No rock salt has thus far been found in this locality, but the abundance of salt water is evidence that it exists in the region.

CHICOT.

Chicot is between Oakdale and Ville Platte, 8 miles southwest of Bayou Chicot post office, in sec. 35, T. 3 S., R. 1 W., in St. Landry Parish. Thus far no salt has been discovered, but the anticlinal or dome structure and the occurrence of limestone here are points of strong resemblance to other localities where salt has been found.

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[1] Fenneman, N. M., Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 282, p. 109, 1906.

[2] Harris, G. D., op. cit., p. 34.

VINTON.

The Vinton dome is located in secs. 33 and 34, T. 10 S., R. 12 W., and in secs. 4 and 5, T. 11 S., R. 12 W., approximately 3 miles southwest of Vinton station on the Southern Pacific Railroad, in Calcasieu Parish. No salt is known to occur here, but brine is found in small quantity.

HACKBERRY.

Published descriptions [1] indicate that a feature which may possibly be a low, broad dome, with less definite domal characteristics than the one at Vinton, lies about 33 miles southwest of Lake Charles, on the south bank of Black Bayou, between Black Lake and Calcasieu Lake. The so-called island is known as Hackberry Island. Salt water has been reported here.

STRATIGRAPHY.

The appellation "island" has been applied in southern Louisiana to small domes that rise out of marshes which are sometimes dry and sometimes flooded with water. The geology of these islands has been described in detail by Lucas, Harris, Veatch,[2] and others. According to Lucas,[3] "The geological formation of this series of islands is undoubtedly Quaternary, while the salt deposits belong to the Tertiary and are supposed to rest on the Cretaceous." Harris,[4] in his discussion of the geology of Petite Anse (Avery Island), states that all the exposed beds are of Quaternary age. That the true nature of the structural features of these salt domes was understood by Lucas seems apparent from his descriptions and his illustrations. The explanation of the mode of formation of these domes is another matter, about which there are many conflicting opinions. The correctness of Lucas's ideas with reference not only to the occurrence of salt but also to the occurrence of oil was demonstrated in a signal manner after his opinion had been published.

STRUCTURE AND ORIGIN OF SALT DOMES.

The general dip of the rocks of Louisiana is southeast, or at right angles to the general strike of the Tertiary and Cretaceous formations of Texas, Arkansas, and Louisiana. Up Sabine and Red rivers the ascent is made over the beveled edges of increasingly older geologic strata. Near the surface of these formations, at the localities just

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[1] Fenneman, N. M., Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 282, pp. 111-112, 1906. Hayes, C. W., and Kennedy, W., Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 212, pp. 131-133, 1903.

[2] Lucas, A. F., Rock salt in Louisiana: Am. Inst. Min. Eng. Trans., vol. 29, pp. 462-474, 1900. Harris G. D., Rock salt: Louisiana Geol. Survey Bull. 7, 1908. Veatch, A. C., The Five Islands: A preliminary report on the geology of Louisiana, pp. 209-262, Louisiana Exper. Sta., 1899.

[3] Lucas, A. F., op. cit. p. 465.

[4] Harris, G. D., op. cit., p. 15.

given and at others in Texas, there are large masses of gypsum, salt, and sulphur, either alone or associated with one another and in places with salt water, oil, and gas. These chemical sediments, gypsum, salt, and sulphur, were early recognized as being foreign to the regularly bedded sedimentary clays, sands, and gravels which they accompanied. They are associated with what has been called dome structures or domes, and interest in their study has been quickened and drilling on them been pushed with vigor since the discovery of oil associated with them, by A. F. Lucas, at Spindle Top, Tex., in January, 1901. They have been studied by Fenneman, Harris, Hayes, Kennedy, Lucas, Veatch, and other geologists, and their relations to one another and to the Balcones fault zone of Texas have been pointed out. The dome structure is entirely different from that of the ordinary Appalachian anticlines. The domes are believed by some to have been formed by gas pressure from below; by others they are attributed to hydrostatic pressure; and by others to isostatic movements. Still others regard them as of volcanic origin. one such hypothesis being the volcanic-plug hypothesis of Hager.[1]

In discussing the dome structure of the Winnfield area of Louisiana,[2] in which there are three well-defined areas that suggest the presence of dome structure, Harris has mentioned an interesting theory of their origin, which, with other theories that preceded it, is amplified in his report for 1907.[3] Instead of attributing the pressure necessary for the uplifting of these remarkable circular domes with their quaquaversal dips to gas, oil, water, or any combination of them under a heavy head, or to an igneous plug, Harris regards the power of growing crystals as the agent responsible for their formation. All geologists who have studied the phenomena in Louisiana and Texas have independently concluded that the salt masses are secondary, and all perhaps will admit that water has been the dissolving and transporting agent. Accepting those fundamental facts, Harris regards precipitation of the salt from the rising brines as being due to decrease in temperature and believes that the "unlifting force is amply accounted for by the power of growing crystals." He adduces the following points in support of this hypothesis: (1) The concentric figures and streaks, very faint in places, that may be due to infiltrating waters carrying impurities; (2) the planes of cleavage explicable as having been formed by great pressure normal to their surfaces; (3) the poorly formed and crushed salt crystals at considerable depth and conversely the perfect crystals found near the surface, as at Avery Island and Belle Isle; and (4) the extreme purity of the salt in

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[1] Hager, Lee, The mounds of the southern oil fields: Eng. and Min. Jour., vol. 78, pp. 137-180, 1904.

[2] Harris, G. D., Notes on the geology of the Winnfield sheet: Louisiana Geol. Survey Bull. 5, pp. 8-9, 1907.

[3] Harris, G. D., Rock salt: Louisiana Geol. Survey Bull. 7, pp. 59-82, 1908; also, The geological occurrence of rock salt in Louisiana: Econ. Geology, vol. 4, pp. 12-34, 1909.

the mines where it is now being worked at considerable depths. During the slow growth of the domes by this process surface erosion would probably prevent the formation of any sharp and elevated hill that would largely increase the pressure at the base of the salt column; indeed, some of the older domes to the north are topographically plane or even concave. For further details regarding the relations of temperature and pressure to the deposition of the salt in these dome-shaped masses the reader is referred to Harris's report.[1]

In order to understand the arrangement of the domes and the detailed structure connected with them some of the broader geologic facts concerning the region as a whole must be comprehended. The region in which they occur is known as the Mississippi embayment, which is structurally a great pitching trough. East of Mississippi River the dips are to the southwest and west of that river the dips are to the southeast and on both sides they are much sharper than the slope of the land toward the Gulf. Thus, Tertiary and Cretaceous beds which are exposed in the northern part of Louisiana are deeply buried in the southern part of the State. It is believed that strata impregnated with salt lie beneath this pitching trough. As deposits accumulated in this oil trough slips or faulting occurred because of differential loading, and most of them probably are related to the V-shaped area called the Mississippi embayment. There would be expected to result from this faulting a twofold system of faults or anticlinal ridges. The domes of the Gulf Coast States are believed to be located along these lines of weakness. Where such faults or structural lines of weakness intersect hot saline waters from great depths could move upward to higher and cooler horizons more easily and more quickly than at other points along such structural lines. At such places the older beds and the newer ones immediately overlying them would tend to buckle upward in fourfold or quaquaversal arrangement and to form the most pronounced dome structure. Finally, it is thought that the Mesozoic and Paleozoic beds may not be buried very deeply in places in Louisiana and Texas; that the salt now found in Tertiary and Quaternary beds may have originated in these older beds, probably of early Mesozoic or later Paleozoic age; and that the local salt masses may now be increasing in size and causing the doming of superficial layers.[2]

In an effort to harmonize the field evidence presented by the salines of Louisiana and eastern Texas, E. G. Norton [3] has formulated a hypothesis that is probably the latest attempt at an explanation of the origin of these salt deposits.

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[1] Rock salt: Louisiana Geol. Survey Bull. 7, pp. 75-79, 1908; also Cowles, A. H., Min. and Metall. Soc. America Bull. 57, vol. 6, p. 44, 1913; also Econ. Geology, vol. 4, pp. 12-34, 1909.

[2] Harris, G. D., op. cit., pp. 75-79.

[3] Am. Inst. Min. Eng. Bull. 97, pp. 93-102, 1915.

Briefly, he considers that the Tertiary salt deposits of the Gulf coast and the Cretaceous salines of eastern Texas and northern Louisiana were initiated by the intrusion of molten rocks into the underlying Paleozoic sediments along lines of structural weakness. These great faults were the sites of frequent upward displacements during the subsidence and deposition of the sands, clays, and littoral marine sediments of the Mississippi Embayment.

Hot ascending solutions, containing calcium and magnesium carbonates, sodium chloride, carbon dioxide, and varying amounts of hydrogen sulphide, mingled with the artesian saline waters of the Cretaceous beds. These waters were forced upward to the surface by the hydrostatic head of the region through channels that were opened by the faulting and movement which took place above the intrusions of igneous rock. Great deposits of travertine or calcareous sinter were formed near the thermal springs which issued from these openings, and the sinter continued to form as long as the hydrostatic head was sufficient to maintain the flow.

The salt was deposited by ascending solutions, which became supersaturated by the release of pressure as well as by evaporation sustained at the surface as the rapid accumulation of sinter checked the flow from springs. In this way the salt deposits were built up contemporaneously with the sedimentation of the region and formed under covers of sinter as they are found to-day. These covers protected them from erosion, so that they have been preserved in their entirety.

SALT-PRODUCING LOCALITIES.

Only rock salt is now produced in Louisiana. It is mined on Grande Cote (Weeks Island) and Petite Anse (Avery Island). (See fig. 4, p. 103.)

GRANDE COTE.

LOCATION.

Grande Cote, or Weeks Island, is located on the eastern shore of Weeks Bay, an eastern lobe of Vermilion Bay, in Iberia Parish. It can be reached over the Cypremort branch of the Southern Pacific Railroad, which runs west from Baldwin. Its position in the State is shown on the map (fig. 4, p. 103). It is called Grande Cote on account of its size, though it is barely 2 miles in diameter. It is the largest of the five islands described by Veatch.[1] The topography and culture are shown in figure 5.

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[1] Veatch, A. C., op. cit., pp. 209 et seq.

GEOLOGY.

The most striking feature of the geology of Weeks Island is the great mass of rock salt which has formed or is forming beneath the thin superficial beds of unconsolidated sands, clays, and gravels. The topography is not rugged, and there are few good outcrops of the overlying materials. Those that are made where the streams cut down the soft, yielding materials are soon covered by rank, rapidly growing vegetation. The uppermost bed on the island is yellow loamy clay, which is visible in a few of the natural exposures.

FIGURE 5.—Topographic sketch map of Grande Cote (Weeks Island), La. (After A. C. Veatch.)

The records of 44 wells driven in different parts of the island also begin in clay ranging in thickness from 40 to 60 feet. Below the clays are sands, ferruginous in places, sand containing chert pebbles, and gray sandy clays—all tilted at different angles and striking in different directions. Sections of wells driven on the island show layers of gravel and sand several hundred feet thick in places. The salt is generally, though not everywhere, overlain by a few feet of clay, but layers of lignite have been found just above the salt in some of the wells.

The salt mass of the island comes nearest the surface at the mine, slopes abruptly to the south and west, less abruptly to the east, and but slightly to the north. Its form is that of an elongated dome with its northern diameter longer than the other. It occupies the west side of the island and appears to be a little west of the main ridge. The upper surface of the salt mass is known to be quite irregular, and the borings already made indicate little relation between it and the surface irregularities of the island. The present general shape of the salt mass is regarded by Harris[1] as nearly its original shape, and he thus thinks that its main configuration is not due to erosion or subterranean solution. The character of the strata

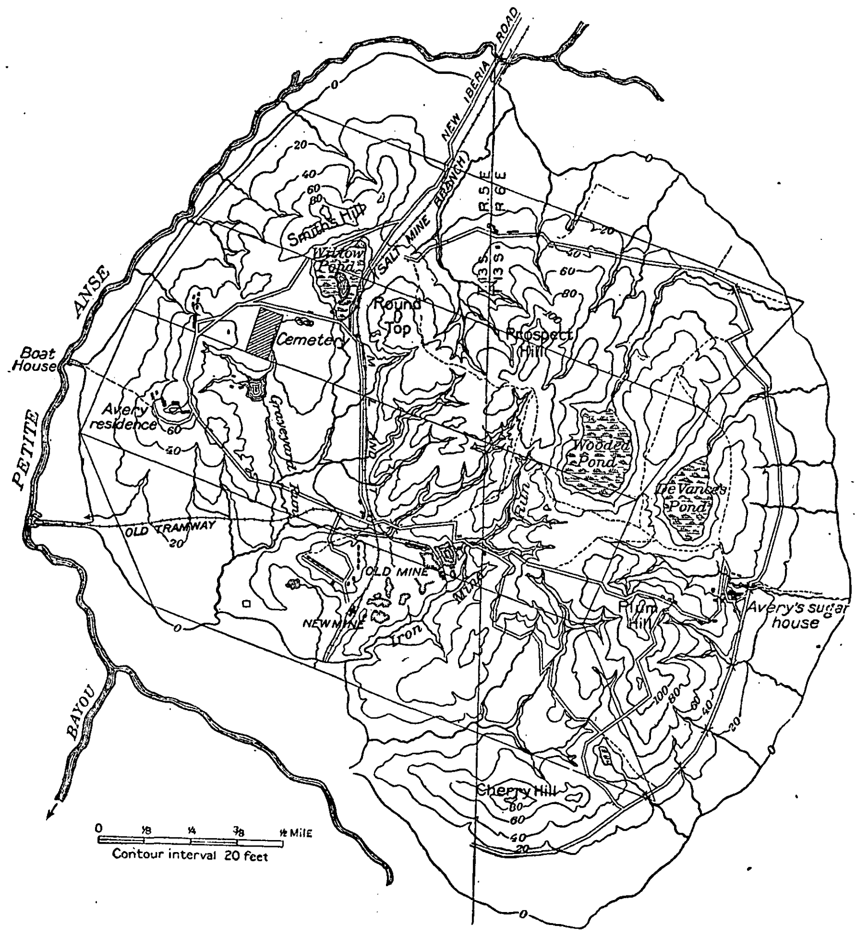

FIGURE 6.—Topographic sketch map of Avery Island (Petite Anse), La. (After A. C. Veatch.)

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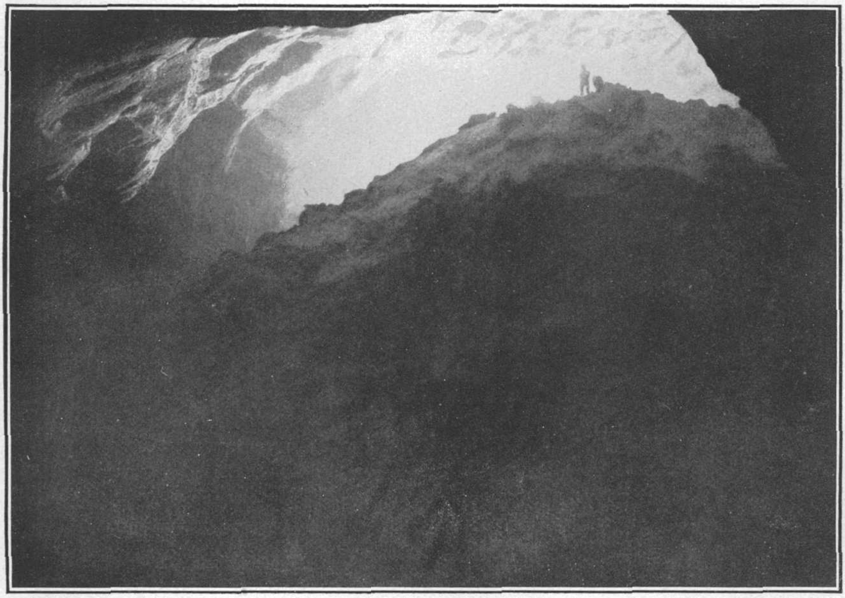
[1] Harris, G. D., Rock salt: Louisiana Geol. Survey Bull. 7, pp. 8-9, 1908.

A.



B.

MYLES SALT MINE, WEEKS ISLAND, LA.

A. Almost perpendicular strata or bands of salt lying in closely compressed folds. *B*. View in interior of mine, showing process of working. Photographs by A. C. Veatch.

in the Myles salt mine on Weeks Island and the method of working the mine are shown in Plate XI.

PETITE ANSE.

LOCATION.

Petite Anse or Avery Island is in Iberia Parish, about 10 miles south-southwest of New Iberia, in T. 13 S., Rs. 5 and 6 E., of the Louisiana prime meridian. (See fig. 6.)

GEOLOGY.

Veatch and others have described the geology of Petite Anse in considerable detail.[1] According to Harris,[2] the details given in the earlier descriptions "are of no serious moment in the interpretation of the geology of this and the other salt islands. All beds here seen are admittedly of Quaternary age, none containing anything that can not be referred to inter or post glacial times."

A brownish-yellow loamy soil forms the greater part of the surface, but exposures of gravel are commoner than on the other islands. The exposures of gravel and sand seem to be confined chiefly to the southern extremity of the island. In its northern part there are numerous outcrops of a variegated chocolate-yellow or green jointed clay. A bed of lignite was found at the head of Iron Mine Run Hollow, and remains of Pleistocene mammals (according to Veatch) have been found.

The records of two wells which throw some light on the underground conditions of the island are given below:

Section of well near sugar house, Petite Anse, La.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Superficial detritus	330	330
Rock salt	2,263	2,593
Blue gas sand	70	2,663
Salt	66	2,729

Section of well at pumping station, Petite Anse, La.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Yellowish clay	500	500
Gravel	200	700
Grayish sand	2,112	2,612

NOTE.—A gravel bed at about 1,500 feet. No salt or water struck in the well.

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[1] Veatch, A. C., op. cit., pp. 243-248.

[2] Harris, G. D., op. cit., pp. 14-17.

The upper surface of the salt mass is irregular, as on Weeks Island, and in a few places it rises slightly above sea level. It is therefore higher than at any place on Grande Cote or at any other point in the State. The rise of the salt mass toward the surface is confirmed by the existence here of brine springs, well known long before rock salt was actually discovered. Streaks of transparent anhydrite crystals occur here, as on Grand Cote, and the apparent darkness of the layers containing them is considered by Harris to be due to the difference in the way it and the purer salt admit, absorb, and refract light rays.

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TEXAS.

LOCATION OF SALT-PRODUCING AREAS.

Salt in Texas in recent years has come chiefly from Palestine, Anderson County, and Grand Saline, Van Zandt County, in the eastern part of the State. Colorado, Mitchell County, in the western part of the State, formerly produced salt, but only solar salt now comes from this place. Some solar salt comes from Crane County also. The industry is of large commercial importance and consists chiefly in the manufacture of evaporated salt; but the salt formed naturally by solar evaporation in the playas of the western and the lagoons of the southwestern parts of the State is used locally.

SALT DOMES OF EASTERN TEXAS.

LOCATION.

Rock salt has been encountered at the following localities in southeastern Texas, all within the area mapped as Pleistocene and Recent by Deussen:[1] Spindletop, Jefferson County; Sour Lake, Hardin County; High Island, Galveston County; Damon Mound, Brazoria County; and Dayton Hill, Liberty County, and there has been a single mention of salt in drilling at Batson, Hardin County,[2] where, according to an observation of the drillers, 12 feet of salt was encountered in a well northeast of the center of the Batson field at a depth of 1,007 feet or 130 feet above the oil rock. In the absence of other mention of salt in this field the observation can not be finally accepted. According to Harris [3] streaks of salt have been found at Kisers Hill, Brazoria County. Though no rock salt has been found, salt water in abundance has been encountered in drilling for oil and gas at Saratoga, Hardin County; Big Hill, Jefferson County; and Humble, Harris County. Saratoga, Big Hill, and Humble are all mapped by Deussen as in the Pleistocene area.

GEOLOGY.

Along or near the Gulf coast of Texas and at other places in the eastern part of the State occur domes or dome structures like those in Louisiana. (See pp. 109–112.) The general geologic conditions described under Louisiana extend westward into Texas, and the correct theory of the origin of the domes or mounds in Louisiana will probably be found to hold good in Texas, not only for the mounds themselves, but also for the economic mineral products occurring in them, namely, salt, oil, gas, gypsum, and sulphur.

INDUSTRIAL DEVELOPMENT.

At none of the localities mentioned has salt ever been mined, and so far as known no serious attempts have been made to obtain it by evaporation of the natural brines. Efforts have been confined solely to exploitation for gas and oil, and some of them have been richly rewarded. The work done has, however, added a fund of informa-

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[1] Deussen, Alexander, U. S. Geol. Survey Water-Supply Paper 335, pl. 1, 1914. See also Fenneman, N. M., Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 282, pl. 1,, 1906.

[2] Fenneman, N. M., op. cit, p. 53.

[3] Harris, G. D., Rock salt: Louisiana Geol. Survey Bull. 7, p. 47, 1908.

tion to our knowledge of the underground formations and structure of the Gulf coast domes without which it would have been difficult if at all possible to construct any well-substantiated theory as to their origin.

The time may come when the salt deposits may be of value. Already the sulphur deposits at Bryan Heights, Brazoria County, Tex., are being worked in the same manner as those at Sulphur City, Calcasieu Parish, La.

SALINES OF EASTERN TEXAS.

LOCATION.

The principal salines so far described in eastern Texas are Grand Saline, Van Zandt County; Palestine, Anderson County; Steen Saline and Brooks Saline, Smith County; and a saline 2 miles east of Butler, Freestone County.

GEOLOGY.

Nearly all the salines are low, flat areas that occupy depressions where brine has been obtained by sinking shallow wells and where an industry in evaporated salt has grown up. They are surrounded by wooded hills in which white or gray limestone is found. The depressions are usually marshy and may hold water during the winter. As summer approaches, the water evaporates, leaving an incrustation of salt. The limestones are in some places siliceous and in others glauconitic. They appear from their fossils to be the equivalent of the Ripley formation (late upper Cretaceous) of Alabama and Mississippi. The underlying clays belong to the Taylor marl, also upper Cretaceous. Surrounding these salines on every side are strata of Tertiary age, and the salines themselves are therefore in the nature of Cretaceous inliers in the rocks of that system.

These salines, like those in northern Louisiana, do not form topographic features like mounds or islands, but their origin is regarded as being the same as that of the domes in Louisiana and also farther south in Texas.

GRAND SALINE.

Grand Saline is in northeastern Texas, in Van Zandt County, on the main line of the Texas & Pacific Railway running east from Dallas. The Texas Short Line Railway also enters the town.

The saline itself is a small prairie-like sandy plain, in which the sand is strongly impregnated with salt. It is about a mile long from east to west and about half a mile wide from north to south. From the borings made the conclusion is reached that the beds underlying it are comparatively level, though in this general region the strata have been somewhat disturbed.

The surficial rocks at this place belong to the Tertiary, and in the wells from which data are available the Cretaceous beds containing the rock salt are overlain by approximately 160 to 180 feet of Tertiary beds. Toward the southwestern part of the saline, beds of Quaternary age cover the surface. According to Kennedy[1] "the Cretaceous rocks found at Grand Saline nowhere, so far as known, approach the surface, but are covered with over 180 feet of Tertiary sands, clays, and shaly clays, and are only found in borings of the several wells put down for the purpose of obtaining salt. The upper series of the Cretaceous formation found in these wells appears to be a blue limestone mixed with streaks of sand and gray limestone, having a thickness of 42 feet in the Lone Star well and 28 feet in the Richardson well, a few feet below which the salt deposit of 300 feet occurs."

The sections of the two wells just referred to are given below:

Log of Lone Star well, Grand Saline, Van Zandt County, Tex.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Brownish-gray sandy clay	26	26
Brown sand	8	34
Sand and gravel	3	37
Black shaly clay	20	57
Lignite	3	60
Sandy shaly clay	20	80
Sand and water	5	85
Sandy clay shale	65	150
Sand and water	14	164
Hard sandrock	6	170
Shale containing pyrites	4	174
Blue limestone mixed with streaks of sand and gray limestone, but blue forming chief deposit	42	216
Hard white sand, with a vein of salt water, 5 per cent salt	14	230
Gypsum	5	235
Rock salt, stopped in salt	120+	355+

Log of Richardson well, Grand Saline, Van Zandt County, Tex.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Soil, brownish-black sand	3	3
Sandy clay	12	15
Gravel and clay	5	20
Yellow sand and water	6	26
Fine blue clay and gravel	2	28
Quicksand, with water	2	30
Coarse white sand	5	35
Blue-gray merging into bluish-black dirt, with pyrite and broken limestone	48	83
Hard gray limestone	3	86
Sandy shaly clay (slate?)	17	103
Blue clay with pyrite	20	123
Shale?	9	132
Shale with iron pyrite	5	137
Sandy shale with pyrite	12	149
Sandstone with pyrite	14	163
Hard blue limestone	25	188
Hard gray limestone	3½	191½
Quicksand	2½	194
Alternate strata of salt and limestone	18	212
Rock salt	300	512
Bluish-gray sand	2	514
Black sand, with water; not penetrated	6	520

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[1] Kennedy, William, Texas Geol. Survey Third Ann. Rept. 1891, pp. 46, 76–81, 1892.

Six wells have been drilled at Grand Saline, 4 at the plants of B. W. Carrington & Co. and 2 at the plant of the Grand Saline Salt Co. At the present time one well is being used at each of the two plants of the Carrington Co. and one well at the plant of the Grand Saline Salt Co. The exact thickness of the rock salt is not known in all the wells, but it is known that its development is only local. It pinches out eastwardly a few hundred feet east of the plant of the Grand Saline Salt Co. Not even brackish water is obtained here at as great a depth as 322 feet, whereas in most of the other parts of this region brackish water is obtained comparatively near the surface. West of the town of Grand Saline, where a well was sunk about 1,000 feet, salt is not encountered in depth, and from this direction the town drinking water is obtained at rather shallow depths—about 40 feet. No salt has been encountered at any considerable distance north or south of the town. The salt bed has been developed only for a mile, and it is reported that only half a mile appears favorable for exploitation.

PALESTINE.

Palestine, the county seat of Anderson County, is in the south-central part of the county on the International & Great Northern Railway and on the Texas State Railroad. It is in the eastern part of the State and about midway between Red River, the northern boundary of the State, and the Gulf coast.

Palestine is located on a series of glauconitic sandy and clayey beds, the sandy beds containing Tertiary (Claiborne) fossils. West of the town the land slopes toward Trinity River, and 6 miles southwest of the town the saline itself is situated. It is a flat plain, 1 mile wide from east to west, and half a mile from north to south.[1] Incrustations of salt may be observed around its edge. Its surface is a dark or lead-colored clay, as at Grand Saline.

The saline is surrounded by a ring of hills rising 60 feet or more above the lowland. In places on the tops and slopes of the hills there are outcrops of white chalklike fossiliferous limestone containing specks of glauconite. The limestone is not seen continuously all around the saline, but outcrops in many places, particularly on the northwestern and eastern sides. It is also seen in outcrops on the southern side, but to the southeast the hills are 20 to 30 feet higher than elsewhere and it is quite likely that the limestone is here concealed under the overlying clay. The fossils from the limestone have been determined by R. T. Hill as belonging to the glauconitic beds of the Upper Cretaceous epoch, possibly representing the time during which the Ripley formation was laid down in Alabama. The lime-

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[1] Dumble reverses this statement. Dumble, E. T., Texas Geol. Survey Rept. 1890, vol. 2, p. 305, 1891.

stone contains seams of yellow crystalline calcite. It is surrounded and in many places covered by lower Tertiary clay and by river alluvium.

STEEN SALINE.

Steen saline is in the northern part of Smith County, 5 miles east of Linsdale and 14 miles north of Tyler, on Saline Creek, a short distance north of where it forks. The saline proper is a small prairie 1 or 2 miles in length and from half a mile to three-quarters of a mile in width. The surface of the saline is covered with incrustations of salt and is composed of black or grayish-black clays. Limestone outcrops in the hills surrounding it, and this limestone is overlain and surrounded by lead-colored and laminated Tertiary clays.

Large quantities of salt were made at this saline during the Civil War by digging shallow wells and evaporating the brine thus obtained in huge iron kettles and boilers. It has been reported that as many as twenty furnaces were run at times, turning out 12,000 sacks of salt daily. It took 190 gallons of water to make 1 bushel of salt.[1]

BROOKS SALINE.

Brooks saline is in the southwestern part of Smith County, about 17 miles southwest of Tyler. It is about 2½ miles long and from a half to three-quarters of a mile wide. Its surface consists of blue and black clays, and around its edges is seen a yellow laminated clay. Like Steen Saline it is in a depression surrounded by hills in which a yellow fossiliferous limestone occurs, which, as already indicated, probably is of Ripley age (late Upper Cretaceous). During the Civil War seven furnaces, making 100 sacks of salt daily, were in operation at this saline. It has been estimated that 300 gallons of water were required to make 1 bushel of salt.[2]

OTHER OCCURRENCES OF SALT.

NORTHWESTERN TEXAS.

In the search for a source of drinking water at Spur, Dickens County, Tex., a well has been recently drilled by S. M. Swenson & Sons, of New York, to a total depth of 4,489 feet.

The presence of much anhydrite and salt in the section led to the suggestion by J. A. Udden, of the University of Texas, that the deposits might contain potash salts. The well had in the meantime been cased below 1,300 feet. A sample was taken after the water had been bailed to a depth of 2,200 feet and was examined by S. H. Worrell, with the following result:

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[1] Buckley, S. B., Texas Geol. and Agr. Survey First Ann. Rept., p. 126, 1874.

[2] Idem, p. 126.

Analysis of water from well at Spur, Tex.

	Grains per gallon.
Calcium sulphate	1,406.19
Calcium chloride	679.02
Magnesium chloride	219.20
Sodium chloride	3,410.55
Potassium chloride	324.14
	6,039.10

The potassium chloride, therefore, amounts to 5 grams per liter and constitutes more than 5.4 per cent of the total solids. As this quantity of potash salts is somewhat high for a natural water, arrangements were later made for obtaining samples from different depths below the foot of the casing (1,350 feet). Fourteen samples were obtained about two months later and were tested for potash salts, but only one of them contained any considerable quantity of potash salts, and this was a sample taken at the same depth as that which by the earlier tests showed a marked content of potassium chloride, and the quantity found was only about one-third of that shown by the earlier sample. The results, therefore, seem to indicate the presence in the well of a potash-bearing layer, bed, or stratum approximately 2,200 feet below the surface.

Udden writes:[1]

> In either direction north or south from Spur the formations lie practically horizontal for at least a hundred miles, and the potash-bearing horizon, whether it be such or not in other places, must be at about the same depth as here, in these directions. It seems to the writer that the general conditions indicated in [the Spur] boring, the existence of great salt beds and beds of anhydrite, together with the proved potash-bearing stratum, warrant an examination for potash in water from the same horizon in any boring made in this territory.

The strata in the region dip to the west; hence the depth to this horizon will be greater westward and less eastward.

> The elevation of the railroad depot at Spur is 2,274 feet above sea level. This is 666 feet higher than the elevation at Cisco, about 120 miles to the east-southeast. A line connecting these two points may be taken to follow the direction of the general dip of the formations to the west. The bottom of the well may be taken to represent the beds outcropping at Cisco. On this assumption the general dip between Cisco and Spur, a distance of 120 miles, will be equal to the depth of the Spur well, less the difference in elevation of the two places. This gives us a dip to the west of nearly 32 feet per mile. Our inability to fix the precise level in the Cisco formation reached in the boring may make this figure either a little too high or too low, but it can not be far from right. Taking into consideration the general east slope of the land surface which averages 6 feet per mile, any stratum should come nearer the surface at the rate of 38 feet per mile eastward from Spur.
>
> *Outcrop of potash-bearing horizon.*—Assuming now that this general dip is constant [between Spur and Cisco] and that the formations are continuous, the horizon which yielded potash in the Spur well should outcrop in a belt where the land surface inter-

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[1] Udden, J. A., The deep boring at Spur: Texas Univ. Bull. 28, Sci. ser., pp. 82-89, 1914.

seeks the dipping plane lying 2,200 feet below the surface at Spur. This belt would extend through Haskell and Jones counties. It is not to be expected that potash should be found in any outcropping rock in this belt, owing to the surface leaching, but well waters there should show its former existence.

A number of samples of water from wells near Haskell have been analyzed and found to contain an unusually large quantity of nitrate, which is not believed to be derived from the surface.

It is suspected that this nitrate exists in the form of a potassium compound, as saltpeter. Along the line of the Kansas City, Mexico & Orient Railroad in these counties the potash-bearing horizon may be looked for at depths of from 100 to 400 feet.

In a later publication Udden [1] gives the logs of several wells drilled in the Panhandle of Texas and in the region to the south in western Texas. In nearly all the wells drilled salt in important beds was discovered, and in some of the beds significant quantities of potash salts were found. The names and locations of the wells are as follows:

Glenario well, Glenario, Deaf Smith County.
Adrian Oil & Gas Co. well, near Adrian, Oldham County.
Adrian Townsite Co. well, near Adrian, Oldham County.
Boden well, Potter County.
Miller ranch well, Randall County.
McLean well, Gray County.
Four wells in or near Childress, Childress County.
Spur well, Dickens County.
Post city well, Garza County.
Justiceburg well, Garza County.
Snyder well, Scurry County.
Scoggin well, near west boundary of Kent County.
Upland well, Upton County.
Buena Vista well, Pecos County.
Deep well northwest of Toyah, Reeves County.

In the region of the Permian beds and to a certain extent in those of later beds in northwestern Texas, the constant recurrence of such geographic names as Salt Fork, Salt Creek, and Salt Basin indicates the widespread distribution of superficial or underground salines. In addition to salt lakes and springs, from which salt is obtainable by solar evaporation, extensive beds of rock salt occur. Many wells in the Permian areas of Texas yield salt water, some so salty as to render them unfit for household or drinking purposes, but they have never been utilized, so far as is known, for salt. Small areas in central Texas contain brine wells.

The conditions for the deposition of salt seem to have been peculiarly favorable during the Permian. An inclosed sea which existed in the epoch that followed the Pennsylvanian is supposed to have been very shallow for a long time. Red saline clays several feet thick and extending over broad areas in places were deposited in it. All the streams that have their origin in these clays and sandy shales are impregnated with salt, many of them to complete

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[1] Udden, J. A., Potash in the Texas Permian: Texas Univ. Bull. 1915, No. 17.

saturation. The Salt and Double Mountain forks of Brazos, Big Wichita, and Pease rivers, and Prairie Dog and Salt forks of Red River originate in or pass through the "Red Beds" of the Triassic and Permian and are more or less impregnated with salt, the Salt forks of Brazos and Red rivers being conspicuous examples.

WESTERN TEXAS.

SALT BASIN OF TRANS-PECOS REGION.

Location.—One of the salt basins of western Texas, known as Salt Basin, which has been described by Richardson,[1] is in the trans-Pecos region, and the portion studied lies north of the Texas & Pacific Railway, near Culberson in El Paso County, west of the Guadalupe and Delaware mountains and east of the Sierra Diablo. The basin, which is one of the prominent débris-filled intermontane valleys of this region, trends to the northwest, and its total length is about 150 miles, the area described by Richardson including 70 miles of this linear extent. The area studied ranges from 8 to 20 miles in width and averages 15 miles, and is a typical closed basin. It is covered with unconsolidated Pleistocene "wash" derived from the adjacent mountains, and this loose material conceals the relations between the Pennsylvanian rocks of the Sierra Diablo on the west and the Permian rocks of the Guadalupe and Delaware mountains on the east.

Salt deposit.—The deposit of salt is on the west side of the basin, about 15 miles southwest of El Capitan Peak and a little more than 50 miles north of Van Horn. It occupies a slight depression, being one of several "salt lakes" in this part of the basin. The layer of salt that covers the surface is said to attain occasionally a thickness of 4 to 6 inches, but the measurements made by Richardson showed only 1 inch of commercially valuable deposit. The salt is grayish-white, coarsely crystalline to granular, and deliquescent. Wind-blown impurities occasionally cover its surface. During the dusty dry season the salt becomes impure, but after a rain, and especially in localities where the surface salt has been recently removed, beautiful hopper-shaped crystals are formed. Analyses of these salt crystals and of a typical specimen of salt from the basin are given in the following table:

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[1] Richardson, G. B., Salt, gypsum, and petroleum in trans-Pecos Texas: U. S. Geol. Survey Bull. 260, pp. 573-585, 1905.

Analyses of salt from Salt Basin, El Paso County, Tex.[a]

[S. H. Worrell, analyst.]

	Hopper-shaped crystals.	Typical specimen of salt deposit.
Chlorine (Cl)	59.5	59.0
Sodium (Na)	38.6	38.3
Calcium (Ca)	.1	Trace.
Magnesium (Mg)	.2	Trace.
Sulphate radicle (SO_4)	1.2	1.0
Potassium (K)		.0
Silica (SiO_2)		.6
Alumina (Al_2O_3)		.6
Iron (Fe)		Trace.
Water	1.0	
	100.6	99.5

[a] Richardson, G. B., op. cit., pp. 579-580.

The ground-water level lies very near the surface in the region, and test holes rapidly fill with water. When the surface layer of salt is removed it is replaced by brine, which, on evaporation, forms a new deposit of salt within a few weeks. This phenomenon indicates an underground source of supply, either disseminated salt or a concentrated deposit with which the ground waters come into contact. Immense quantities of the salt have been hauled away for feeding stock and for use in metallurgic operations at Shafter, 150 miles distant. Gypsum forms the floors of these "lakes" and surrounds and unites many of them. Borax and potash salts have also been found in some of them. Strontium minerals are associated with the gypsum that surrounds Salt Lake, and traces of lithium minerals have also been noted.

COLORADO.

Salt is obtained by evaporation at Colorado, Mitchell County, in the western part of the State. Where the Pennsylvanian and Permian beds are developed in this region numerous salt springs and wells are found. At Colorado a bed of rock salt was found at a depth of 850 feet in drilling for water, and 140 feet of rock salt was passed through in the next 250 feet. The water in several wells rose within about 150 feet of the surface and could not be exhausted by pumping. There has been little or no change in the character of the water since the salt company began operations. The wells are cased to the first bed of rock salt at 850 feet. Fresh water was found above and below the beds of salt.

OTHER LOCALITIES.

In the northwest and west-central parts of Texas, at Graham, Young County, for example, salt has been obtained from shallow wells. The wells at Gordon and other places in Palo Pinto County, the flowing well near Waldrip, McCulloch County, and those near San Angelo, Tom Green County, yield salty water.

Along the coast lagoons or salt lakes have yielded and can still yield a large yearly production of salt.

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OKLAHOMA.

The salt industry in Oklahoma is unimportant and mainly local. During the last few years salt has been produced on a small scale near Ferguson, Blaine County, in the western part of the State, and near Salton and Vinson, Harmon County, in the southwestern part.

SALT PLAINS.

LOCATION.

Salt-water wells and springs are found in both eastern and western Oklahoma. In the eastern part of the State the water generally is only slightly salty; in the western part the water is so saline in places that the terms "salt springs" or "salt plains" are in common usage.

The regions where the springs are located are known generally as "salt plains," and according to a recent report of the Geological Survey of Oklahoma ten of these are well known, as follows: Two along Cimarron River in Woods, Woodward, and Harper counties; two in northwestern Harmon County; one each in Alfalfa, Blaine, and Beckham counties; and three on Sandy Creek, south of El Dorado, Jackson County. (See fig. 7.) A recent progress geologic map of Oklahoma issued by the State Geological Survey[1] shows surficial rocks in these regions as belonging in the Permian. All the salt springs of western Oklahoma issue from the "Red Beds," and probably originate in them, but they do not all issue from the same geologic horizon.

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[1] Oklahoma Geol. Survey Bull. 5, 1911.

CIMMARRON RIVER PLAINS.

Two salt plains, known locally as Big Salt Plain and Little Salt Plain, stretch along Cimarron River in Woods, Woodward, and Harper counties, in northwestern Oklahoma. Both plains are fed by streams that issue from the Permian "Red Beds" and lie 100 feet or less below a heavy bed of gypsum. Little Salt Plain is just south of the point on the Kansas line where Cimarron River first breaks through the gypsum hills. It is 2 or 3 miles long and a mile or more wide. Big Salt Plain is 15 or 20 miles farther down the river. Its length is 8 miles and its width ranges from half a mile to 2 miles. It lies in a broad canyon of Cimarron River, inclosed on both sides by gypsum-capped hills. During the dry season (summer) nearly all the water either evaporates or sinks into the sand. Where a small stream is left the water running in it is so impregnated with salt that a crust forms on its surface. The entire area, except just after a rain, is covered with a thin incrustation of salt crystals. According to Gould[1] the combined flow of the springs which feed the plain approximates several thousand gallons an hour.

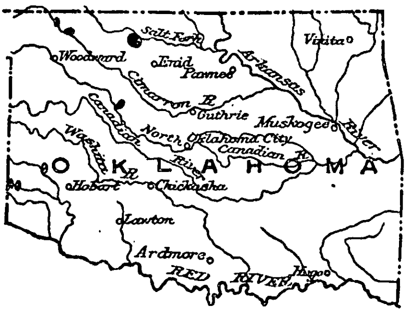

FIGURE 7.—Sketch map showing location of salt plains in Oklahoma.

In former years there were a number of primitive salt plants in this region. The water was dipped or pumped from the springs or shallow wells and evaporated either by the sun or over fires. No salt is now made in this region.

HARMON COUNTY PLAINS.

There are salt plains in Harmon County, in small canyons in the gypsum hills south of Elm Fork of Red River, about 5 miles east of the Texas border and 1½ miles south of the north county line, in secs. 4 and 11, T. 6 N., R. 26 W. The plains are known locally as the Chaney or Salton Salt Plain and the Kiser Salt Plain. They are both small, neither covering an area of more than a few acres, and they are not more than a mile apart. The salt is contained in spring water that issues from shallow beds overlain by gypsum. Springs also boil up from the level floor of the plain.

A local industry has been carried on for many years in this region at the old Kiser salt works and also farther west. The springs 1½ miles west of these works have been worked in recent years and are now known as the Salton salt beds. The old Kiser salt beds also have recently been worked.

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[1] Gould, C. N., Oklahoma Geol. Survey Bull. 6, p. 70, 1910.

ALFALFA COUNTY PLAIN.

The Alfalfa County plain is 30 miles or more from the gypsum hills, among which lie the other salt plains here described. It is about 4 miles east of Cherokee, just south of the Salt Fork of Arkansas River. It is 10 miles from north to south and 6 to 8 miles from east to west, its area being from 60 to 80 square miles.

Though it is the largest of the Oklahoma salt plains, it has no large salt springs at its surface. The plain is composed of loose reddish-brown sand and clay, apparently saturated with salt water, for a hole a few feet deep dug in any part of the plain soon fills within a few inches of the top with salt water. The surface evaporation of this water produces the white incrustation observed over the field. The supposition that the plain is underlain by rock salt is probably incorrect, a more plausible hypothesis being that the underlying shale is permeated with salt, which dissolves in the ground water and is thus brought to the surface. No salt from this area is being used.

BLAINE COUNTY PLAIN.

The Blaine County salt plain, 4 miles west of Ferguson, is fed by streams which come from the main Salt Creek canyon, among the gypsum hills. The flow from springs forms a small creek. Along the bottom of the canyon the salt incrustations formed by evaporation cover a strip about 100 yards wide. Where the canyon widens on entering the flat country, about a mile below the springs, the salt plain expands and becomes as much as a quarter of a mile wide. Its total length is 3 miles.

This plain is nearer to both the coal fields and the market than any other in the State. A number of small salt plants have been operated at different times along its edge. The methods employed in obtaining salt were very simple. A hole or well was dug in the sand, and the brine collected in it was poured into vats and evaporated over wood fires. The trade was local, but the demand is said to have exceeded the supply for several years. It is stated that a grainer plant having a capacity of 450 barrels a day was set up at Ferguson a few years ago. The brine was piped from the plain. After operating a short time the plant was shut down and dismantled. A small output of solar salt has lately been reported from the region.

BECKHAM COUNTY PLAIN.

The Beckham County plain is in the southeast corner of the county, in secs. 10, 11, 14, and 15, T. 8 N., R. 22 W. It is about half a mile from North Fork of Red River, near the base of the gypsum hills. Its area is about 40 acres. Springs issue from the strata beneath the gypsum beds in places and also from the level surface of the plain. The combined flow of the springs would form a stream of considerable volume were not much of the water lost in the sand. Salt has been manufactured in the locality from time to time.

JACKSON COUNTY PLAINS.

There are three salt plains in Jackson County, situated close to each other on the west side of Sandy Creek and on small tributaries flowing northeast into it. They are about 3 miles from the mouth of the creek and about the same distance south of El Dorado. The north plain is in the E. ½ sec. 31, T. 2 S., R. 23 W.; the middle plain in the NE. ¼ sec. 5, T. 3 S., R. 23 W.; and the southern plain in the NW. ¼ sec. 5, same township and range. The north and south plains are each about a quarter of a mile long by one-sixteenth of a mile wide, and the middle plain, though approximately the same length as the others, is very much narrower. The salt water comes from numerous springs, and a thin saline incrustation covers the sandy floor of the plains. Analysis of the soluble salts in the saline incrustation showed the presence of more sulphate than chloride, and also of considerable potassium. In the incrustation from the middle plain the proportion of salt is greater than the proportion of sodium sulphate, but there is so much sodium sulphate and potassium that it is doubtful whether the common salt could be profitably extracted. The occurrence of potassium is interesting and may be important.

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OREGON.

No salt has been made in Oregon in recent years, but J. Ross Browne [1] says in a report on the mineral resources of the State that it was made from brine from springs in the Willamette and Umpqua valleys and at other places. According to Browne, the salt works in Douglas County in the Umpqua Valley for several years prior to 1869 produced 700 to 1,000 pounds of salt daily during the summer season. The distance from Portland, the chief market, prevented

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[1] Resources of the Pacific slope, pp. 255-256, San Francisco, 1869.

the development of the industry, as a cheaper supply could be obtained from works erected in the lower Willamette Valley.

The Willamette salt works were approximately 13 miles from Portland, halfway between that city and St. Helens, and half a mile from the banks of the Willamette slough. The salt was obtained from one of several salt springs, which issued from the base of a low eastward-trending range of hills. When Browne's report was written 4,000 pounds of salt were being produced daily. Samples of the salt were analyzed by W. P. Blake and were found to be free from lime and magnesia, making it of value for dairying and preserving.

Springs in Jackson County are reported by Browne[1] to have produced annually 10,000 pounds of a similar quality of salt.

Beds of rock salt are reported near the base of Mount Jefferson, in the Cascade Range.

ALKALI LAKE.

There is a shallow and variable lake of strong brine in Alkali Valley, southern Oregon, which occupies the bottom of one of the typical desert basins of this part of the Great Basin. A notable deposit of soda is found in and around the lake. The alkali occurs as a crust on the surface of mud in and around shallow saline ponds, and there are "pot holes" near the margin of the deposit in which almost pure soda crystallizes. These "pot holes" have been worked for soda in a small way, and the deposit as a whole has been taken up by a company which plans to work it for soda and perhaps for other products. Attention has been directed to this deposit as a possible source of potash.

Hoyt S. Gale, of the United States Geological Survey, examined this deposit in August, 1915, and took samples of the brine and salts. The results do not seem to indicate that the materials are of promise as a source of potash salts, though these may be recovered in conjunction with other salines. For example, the brine from a pool known as Little Alkali, which is probably the largest body of open water, carries 10.63 per cent dissolved matter (ignited residue), in which potash ran 3.25 per cent as potassium, or 6.19 per cent calculated as potassium chloride. This content of potash is somewhat higher than that commonly obtained in such brines, but it is not comparable, for example, with that in the brine from Searles Lake, in southern California, and the brine from Alkali Lake was less than half saturated.

ABERT AND SUMMER LAKES.

Reports have been published from time to time relating to a project for extracting salt, soda, potash, and other mineral salts from the waters of Abert and Summer lakes, southern Oregon. These lakes,

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[1] Browne, J. R., op. cit., pp. 255, 256.

which are of considerable size, carry alkali salts in rather dilute solution, ranging, according to analyses available, from 3 to 8 per cent in Abert Lake, and from 2 to 4 per cent in Summer Lake. Although the aggregate quantity of salts in these waters is undoubtedly large, the waters are only about as concentrated as sea water, and the potash content, as shown by authoritative determinations, is only slightly greater than that of sea water. Soda might be recovered from these waters by solar evaporation, in the same manner as salt is now recovered from sea water. It is also conceivable that potash might be recovered as a by-product.

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IDAHO AND WYOMING.

DEVELOPMENT.

Salt has been produced in Bannock and Bear Lake counties, Idaho, in recent years. Though the production has been usually reported from Idaho, the headquarters of most of the operators have been at Auburn, Wyo.

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.

Interest in these salt deposits has recently been revived by the discovery of rock salt beneath the brine springs in lower Crow Creek. In deepening these springs in 1902, a formation of rock salt was encountered 6 feet below the surface which 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 future railroad connections lend interest to the deposits of the entire district. (See fig. 8, p. 133.)

LOCATION.

The only rock salt thus far found in the region is 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 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, which has not been worked in recent years.

The principal operating brine springs are 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 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 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, are the old Stump and White springs. These have not been operated in recent years. To the south, up Tygee Creek, the next spring operated 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.

GEOLOGY AND ORIGIN.[1]

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.

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.

According to Breger, the salt was originally disseminated in small quantity in the red sandstones, conglomerates, and shales of the Beckwith formation (Jurassic and Cretaceous) at the time these rocks were laid down in the shallowing and disappearing Jurassic and early 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;

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[1] Breger, C. L., The salt resources of the Idaho-Wyoming border, with notes on the geology: U. S. Geol. Survey Bull. 430, pp. 566-567, 1910.

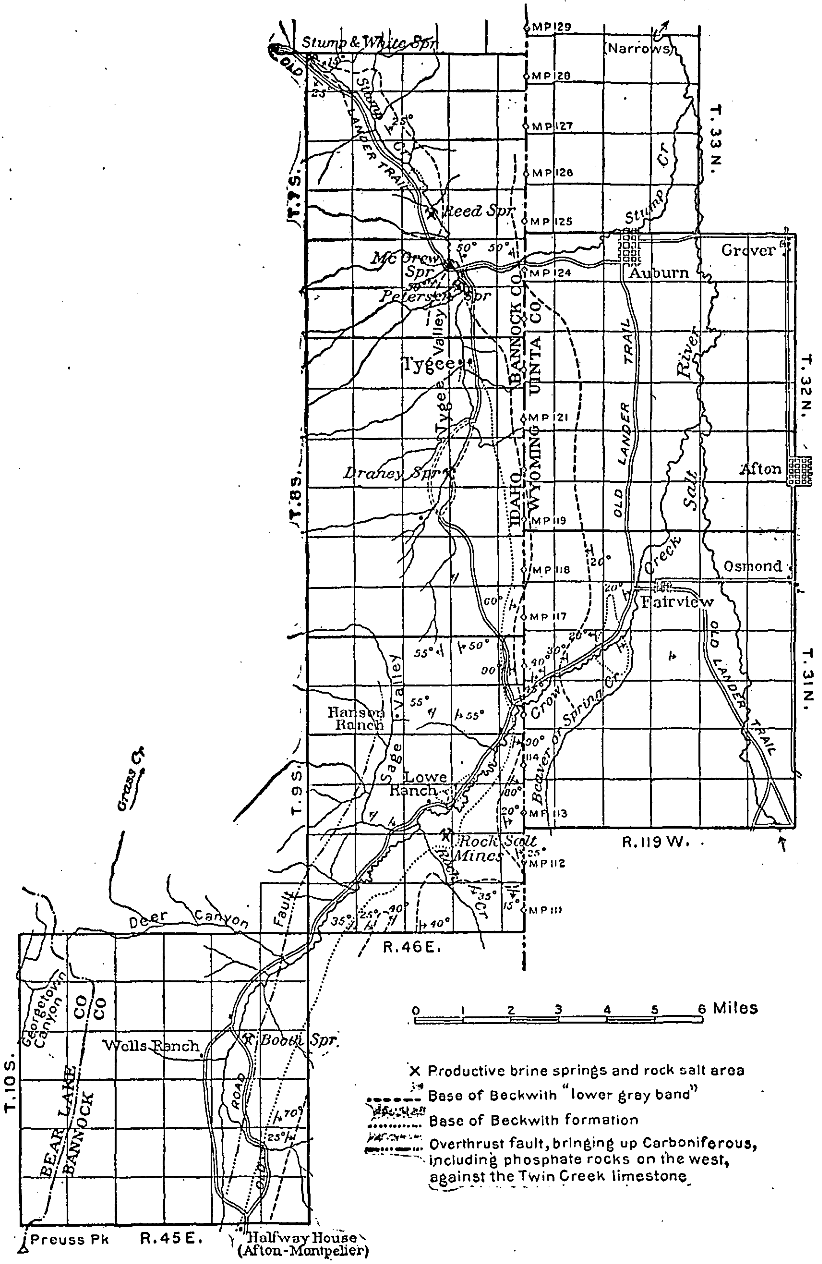

FIGURE 8.—Sketch geologic map of part of Idaho-Wyoming border country. (After C. L. Breger, U. S. Geol. Survey Bull. 430, 1910.)

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. When the salt-bearing waters reached the main valleys they 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.

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 climate, 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.

On the recurrence of a humid climate in the Pleistocene epoch 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.

Solid salt deposits of some kind apparently underlie all the productive brine-spring areas, as is borne out by (1) the saturated character of the brines, (2) the similarity of geologic conditions in the single 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.

Definite estimates of the amount of salt underlying the brine areas are, with the present data, impossible. Although the existence of rock salt underneath them 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 Stump and Tygee creeks 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 bedrock on both sides suggest a very small salt body. 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.

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 is 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 to be destitute of salt. Conservative estimates of the portion of the terrace 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).

The existence of anticlines in the sandstones of the Beckwith formation in the hills on the west side of Star Valley and the presence of the Pleistocene stony red clays in places 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 Valley proper.

SUMMARY.

The workable areas along the Idaho-Wyoming border consist of isolated salt bodies. These were formed during a long period of pre-Pleistocene aridity by salt waters from the lateral streams (either surficial or underground drainage), which reached the valley bottoms and evaporated 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 aided in the accumulation of salines, which intensified the salinity of some of the streams. 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 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. 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.

COMPOSITION OF THE SALT.

Analyses of the rock salt of the district made in the laboratory of the United States Geological Survey gave the following results:

Composition of rock salt of Idaho-Wyoming district.

[Chase Palmer, analyst.]

Soluble matter ("salt")	91.79
Insoluble matter	6.42
Moisture and undetermined	.85
	99.06

The salt has 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 insoluble matter was determined as follows:

Analysis of insoluble matter in rock salt of Idaho-Wyoming district.

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

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NEVADA.

The salt industry in Nevada is unimportant. Scattered deposits are worked from time to time to supply local demand, but most of the enterprises started have been small and have been operated spasmodically.

SALT MARSHES.

LOCATION.

During recent years salt has come from Sand Springs, Leete, and Parran, Churchill County; from the Silver Peak playa, Esmeralda County; and from the Buffalo Salt Works, Sheepshead, Washoe County. The salt is usually obtained by solar evaporation, and the finer grades, such as table, dairy, and common fine salt, are prepared from the solar product by different refining processes. Other known deposits are at White Plains and Dixie Salt Marsh, Churchill County; Rhodes and Columbus marshes, Esmeralda County; Railroad Valley, Nye County; and west of Diamond Range, in Eureka and Elko counties. Other deposits of present or prospective importance lie along Virgin River in the southeastern part of the State. In fact numerous saline valleys are widely distributed in the part of Nevada included in the Great Basin.

CHURCHILL COUNTY.

SAND SPRINGS.[1]

Sand Springs is about 25 miles southeast of Fallon, Churchill County, which is the nearest railroad point. It is in Sand Springs Valley, known also as Alkali Valley and now generally as Fourmile and Eightmile flats. Solar rock salt was produced at Sand Springs in 1915.

The surface of the lake beds in the valley when deposited was of course horizontal. The present inclination of the beds is due to a

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[1] Browne, J. R., Resources of the Pacific slope, pp. 309-311, San Francisco, 1869. This book contains an interesting account of the early workings at Sand Springs.

fault which crosses the valley and strikes to the north. The tilting of the valley floor resulting from this fault caused the surface waters to drain eastward and to form a small lake at the eastern end of the valley near Sand Springs.

During the winter water collects in this lake and forms a sheet of brine 10 to 15 square miles in extent but only a few inches in depth. In the dry summer season the water evaporates and adds a layer of salt to that previously deposited. The salt deposit thus accumulated is 3 to 5 inches thick near the margins and is said to have a depth of not less than 3 feet in the center of the basin. Associated with the salt here, as well as at the Buffalo Salt Works and the Eagle Salt Works, are greater or less quantities of sodium and calcium borate. Borax has been produced at the borax works of Alkali Valley.

The occurrence of salt at Sand Springs is typical of a large class of salt deposits in Nevada and the Great Basin region in general. The amount of salt formed as indicated must be very great. In collecting the salt, the crust is broken up and scraped into heaps, formerly with broad wooden hoes, the ground being divided into long strips and gone over in regular order. The heaps thus formed are allowed to drain for a few days and are then carried in wheelbarrows or cars to platforms, where, after further drying, the salt is pulverized, if necessary, and sacked, after which it is ready for shipment. After one crust of salt is removed, another begins to form, the process repeating itself so rapidly that several crops can be gathered in a year. As the ground below is heavily charged with salt, the replacement of the layer removed would go on almost indefinitely. A large part of the alkali flat outside of the depressed area is covered with a thin coating of salt during the dry season, but generally it is too impure for gathering.

A test well sunk in the region under the direction of H. S. Gale, of the United States Geological Survey, showed a surface layer of 7 feet of hard crystalline salt underlain by soft black mud. A flow of water was encountered at a depth of 26 feet. The water was tested for potash salts, but the richest sample showed only 2.37 per cent expressed as K_2O. The great distance of this place from a market is one of the drawbacks to the salt industry, which is purely local.[1]

LEETE.

Leete, the location of the Eagle Salt Works, is in northwestern Churchill County, and is reached from Fernley, opposite the old Wadsworth station on the Southern Pacific Railroad. The region about the works is a desert mud plain covered during the summer by a white saline efflorescence. The locality is within the drainage

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[1] Hance, J. H., U. S. Geol. Survey Bull. 540, pp. 457-463, 1914. Young, G. J., U. S. Dept. Agr. Bull. 61, p. 59, 1914.

boundary of the Great Basin, and the deposits associated with the salt are of Quaternary age.

The salt is procured by solar evaporation from a natural brine that stands not far below the surface. The surface material is sandy and is about 5 feet thick. It is underlain by a more or less impervious clay. At an approximate depth of 20 feet a natural flow of brine is encountered. This brine is collected in shallow excavations called vats, which are 50 or 60 feet wide and a few hundred feet long and are arranged parallel to one another. The salt water is allowed to run into them to a depth of an inch and evaporates to dryness, making a hard foundation for the salt subsequently formed. Additions of brine are made and evaporated, and the salt layer is thus thickened. The salt formed is hoed up into piles. The Eagle Salt Works has reported a substantial production in recent years.

The method described differs somewhat from the procedure formerly employed at the Eagle Salt Works, which has been described by I. C. Russell[1] as follows:

> Water from springs on the eastern edge of the plain is conducted over the surface of the lake beds, and is made to flood small areas inclosed by low dams or ridges of clay. The brine soaks from the flooded areas through the ridges of clay, and enters shallow vats dug in the lake beds on either side. Here, on evaporation, the salt deposits. The areas flooded by the fresh water are called reservoirs, the troughs between them are called "vats." They are arranged alternately and may be multiplied to any extent. A profile through a reservoir and vats is shown in the figure.

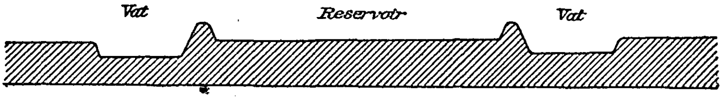

FIGURE 9.—Section of reservoir and vats, Eagle Salt Works, Leete, Nev. (After I. C. Russell.)

The accompanying table gives an analysis of brine from a vat in which the salt had begun to crystallize. The figures, originally stated in conventional combinations in percentage, have been calculated to ionic form in grams per kilogram. The content of potassium of this concentrated solution is very small.

Analysis of brine, Eagle Salt Works, Leete, Nev.

(Specific gravity, 1.2115; results in grams per kilogram. F. W. Taylor, analyst.)

Radicles.		Conventional combinations.	
Silica (SiO_2)	0.028	Silica (SiO_2)	0.028
Oxides of iron and aluminum (Fe_2O_3 and Al_2O_3)	.004	Oxides of iron and aluminum (Fe_2O_3 and Al_2O_3)	.004
Calcium (Ca)	2.14	Calcium sulphate ($CaSO_4$)	2.90
Magnesium (Mg)	.97	Calcium chloride ($CaCl_2$)	3.58
Sodium (Na)	100.00	Magnesium chloride ($MgCl_2$)	3.79
Potassium (K)	.012	Potassium chloride (KCl)	.023
Sulphate (SO_4)	3.05	Sodium chloride (NaCl)	253.79
Chloride (Cl)	158.91		
			264.095
	265.122		

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[1] Russell, I. C., Geological history of Lake Lahontán, a Quaternary lake of northwestern Nevada: U. S. Geol. Survey Mon. 11, pp. 233-234, 1885.

PARRAN.

Parran is on the main line of the Southern Pacific Railroad between Ogden and San Francisco, in the northwestern part of Churchill County, about 10 miles south of the south end of Humboldt Lake. A small quantity of salt obtained by solar evaporation and used chiefly for stock was collected there in 1911.

WHITE PLAINS.

White Plains (Huxley station) is on the main line of the Southern Pacific Railroad, about 4 miles north of Parran and 5 or 6 miles from the south end of Humboldt Lake. It is one of the notable salines in this part of Nevada. No report reached the Survey of the production of salt at this place in 1915, but formerly it was an important salt-producing locality, and the Desert Crystal Salt Co. operating there had an extensive acreage of vats for making salt by solar evaporation. These vats were simply shallow excavations inclosed by low embankments, into which the brine was run.

DIXIE SALT MARSH.

The saline deposit in Dixie Valley (Osobb Valley of the older reports[1]) lies east of Carson Desert and nearly 500 feet lower, being separated from it by the Stillwater Mountains. The valley was formerly occupied by a shallow lake, the final stages of the evaporation of which probably occurred on the site of the present marsh, which covers an area of about 40 square miles. An area of 9 square miles near the center of the marsh is covered with a crust of salt 1 to 5 feet thick, below which is a saline mud, underlain by layers of salt and mud. During wet seasons portions of the flat are flooded to a depth of a few inches.

During the sixties much salt was hauled from the marsh to Virginia City, where it was used to chloridize silver ores. Borax also was obtained just north of the marsh. Salt is not produced here at the present time.

The brines in the marsh have been tested by the United States Geological Survey[2] and by private corporations to obtain data on the occurrence of potash salts. The tests show that the potash content of the brines and salines is commercially negligible. The following analysis by R. W. Woodward[3] shows that the salts are nearly pure sodium chloride.

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[1] Hague, Arnold, and Emmons, S. F., Descriptive geology: U. S. Geol. Expl. 40th Par. Final Rept., vol. 2, pp. 707-708, 1877.

[2] Hance, J. H., Potash in western saline deposits: U. S. Geol. Survey Bull. 540, pp. 463-464, 1914. Young, G. J., Potash salts and other salines in the Great Basin region: U. S. Dept. Agr. Bull. 61, pp. 54-56, 1914.

[3] Hague, Arnold, and Emmons, S. F., op. cit., p. 708.

Analysis of salt from Dixie Salt Marsh, Nev.

Sodium chloride (NaCl)	96.49
Sodium sulphate (Na_2SO_4)	1.91
Sodium carbonate (Na_2CO_3)	.96
Water	.52
Insoluble residue	.12
	100.00

ESMERALDA AND MINERAL COUNTIES.

LOCATION OF DEPOSITS.

In a district comprising the central and northwestern parts of Esmeralda County and the southeastern part of Mineral County there is a series of extensive alkali flats containing salt deposits similar to that at Sand Springs, Churchill County. Rhodes Marsh, in Mineral County, is in the northern part of this district; Columbus Marsh is farther south, Blair Junction being a railroad station in its border; and Silver Peak Marsh, from which production of salt has been reported in recent years, lies still farther south, near the settlement of Blair.

RHODES MARSH.

Rhodes Marsh is circular in form and 2½ to 3 miles in diameter; its area is 5 to 6 square miles. In its center is a layer of pure salt, which occupies an area of a square mile or so. Surrounding this central crust of salt occur borax, in pure form and in the form of tincal, ulexite, a hydrous borate of sodium and calcium, and sodium sulphate and carbonate. Common salt is found almost everywhere, but in pure form only in the central part of the marsh.

The localization of the salts of different kinds contradicts the idea that the marsh is a simple dried-up lake. The most logical explanation is that the former lake must have been supplied by springs which brought to the surface various kinds of salts. These springs continued to act after the lake dried up, thus localizing the material deposited from them. Common salt, the most abundant ingredient of the lake water, left everywhere as a crust when the lake dried up, was subsequently leached out and accumulated in very pure form in the central or lowest part of the playa.

This marsh, as well as Columbus Marsh, was better known as a borax marsh, as it contained large deposits of the borates of lime and soda. It is of interest to know, however, that Columbus Marsh was located as a salt bed in 1864.

The United States Geological Survey has done some drilling at Rhodes Marsh in connection with its potash investigations, and information has been obtained on the potash content of a flowing well out on the salt flat. The spring issues among blocks of basalt, possibly along or near a basalt dike. The salt is not worked, but there was formerly an extensive equipment on the railroad.[1]

COLUMBUS MARSH.[2]

Columbus Marsh is situated on or near the line between Esmeralda and Mineral counties. The marsh is approximately 30 square miles in area, about 8 miles in longest dimension from north to south, and about 6 miles in greatest width. It is a typical playa, and little salt shows on its surface except in the marginal areas, where several borax plants were located during the early days of the borax industry. Under the direction of the United States Geological Survey six shallow wells were sunk in the marsh during 1912 and three others during 1913. The muds encountered in these wells differed somewhat in character, consisting of sand, clay, and hard consolidated material, but no distinct saline horizons were observed. The analytical data as originally published showed that some of the muds from one of the wells contained unusual amounts of potash in the soluble salts, but a more extended investigation[3] has shown that these apparent high values resulted from the method of clarifying the water extracts with ammonium chloride, that a large part of the potash present in the muds is held either mechanically or in a loosely combined form, and that only small quantities of soluble matter including potash are extracted by water alone. The average results for one of the wells, excluding surface material, gave 2.84 per cent of total dissolved salts, 5.17 per cent of which is potassium. With few exceptions the waters from the wells bored in Columbus Marsh were very dilute and contained only small amounts of potash. Consequently, it is not believed that potash salts in commercial quantity can be derived from the brines or muds of Columbus Marsh.

SILVER PEAK MARSH.[4]

Silver Peak Marsh is 30 miles southeast of Columbus and occupies the lowest part of the Clayton Valley. It is included in Tps. 1 and 2 S., Rs. 39, 40, and 41 E. It is about 10 miles long from northeast to southwest, about 4 miles wide, and has an area of approximately 32 square miles. (See Pl. XII.) It is reached on the Silver Peak Railroad, a short line running southward from Blair Junction on the Tonopah & Goldfield Railroad to Blair.

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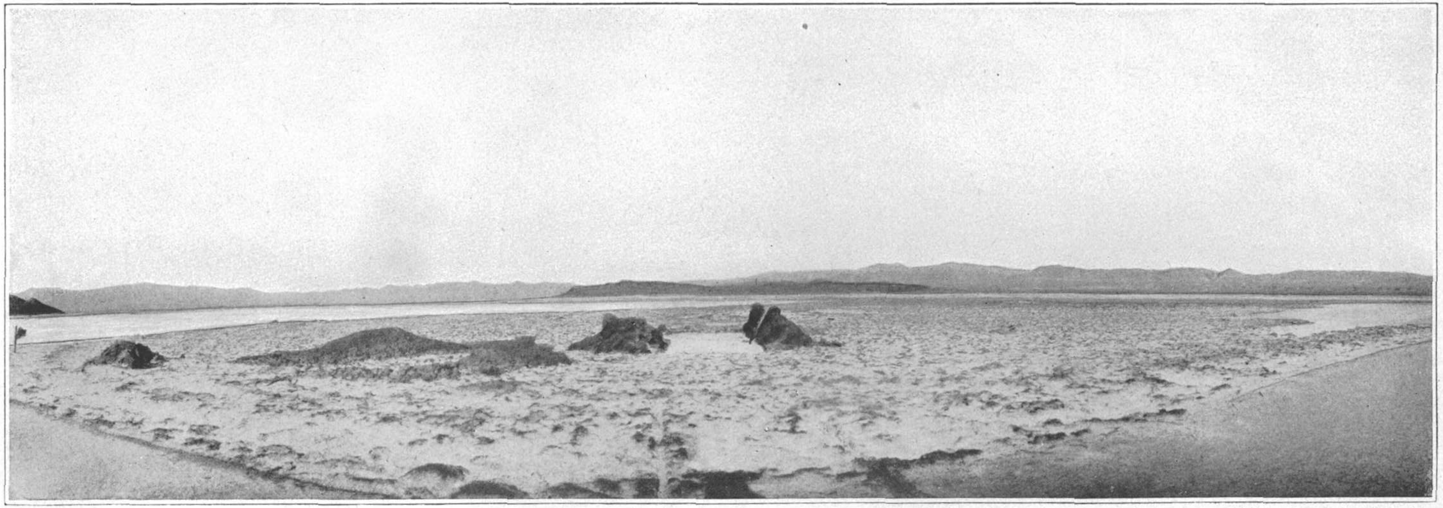
[1] LeConte, Joseph, California State Mineralogist Third Ann. Rept., 1883. Young, G. J., op. cit., pp. 42-43.

[2] Gale, H. S., Potash tests at Columbus Marsh, Nev.: U. S. Geol. Survey Bull. 540, pp. 422-427, 1914. Young, G. J., op. cit., pp. 53-54.

[3] Hicks, W. B., Composition of muds from Columbus Marsh, Nev.: U. S. Geol. Survey Prof. Paper 95, pp. 1-11, 1915.

[4] Dole, R. B., Exploration of salines in Silver Peak Marsh, Nev.: U. S. Geol. Survey Bull. 530, pp. 330-345, 1911. Young, G. J., op. cit., pp. 39-43.



VIEW OF SILVER PEAK MARSH, NEV., A TYPICAL PLAYA.

Photograph by F. R. Porter.

The surface of the marsh is generally dry but after a heavy rainfall may be covered a foot deep with water. Ground-water level is near the surface, and shallow holes find mud and concentrated brines. The water has been derived in part at least from the drainage of the surrounding mountains. According to Dole, leachings from the stratified Tertiary rocks, extensive areas of which occur in the basin, account in part for the saline residue, and it is possible that a far greater area than the present basin was formerly tributary to Silver Peak Marsh and furnished part of the saline material now found in it.

The drainage area of each of the playas in this region includes large districts of upturned early Tertiary sediments, so that the playa deposits would naturally be expected to show the same characteristics. However, they do not, and the difference in chemical composition between the salts in Silver Peak Marsh and those farther north, which contain borax predominantly, has led Spurr[1] to suggest that special agencies have been at work in Silver Peak Marsh. The special agency which has given rise to the salt (sodium chloride) at Silver Peak he regards as the deep-seated hot springs, which furnish water whose solid contents differ in composition from the surface leachings from the Tertiary borate deposits in the surrounding hills. This explanation was also offered for the localization of salts in the Rhodes Marsh, by Le Conte.[2] Dole further suggests, however, that the brine springs may get their salt from the muds of the flat instead of adding salt to them.

The following quotation on the commercial possibilities of salt production at Silver Peak Marsh is taken from Dole:[3]

> Practically the entire surface of the playa, 32 square miles, is covered with salt that averages in depth about one-quarter of an inch. The upper muds, averaging probably 10 feet thick, contain not less than 2 per cent of salt. It is estimated that not less than 15 square miles of the northeastern part contains a 10-foot saline bed, of which at least 60 per cent is salt. It is calculated from these moderate estimates that 15,000,000 tons of salt lies within 40 feet of the surface. The high rate of evaporation, which would permit solar concentration of brines, the absence of long-continued rainfall to interfere with operations, the nearness of a railroad, and more especially the high degree of purity of the product as indicated by analyses of the brines, are extremely favorable in considering the possibility of utilizing these deposits.
>
> Salt is now being produced on a small scale by Frank Porter, of Silver Peak, whose works are situated in sec. 24, T. 2 S., R. 39 E. Brines from pits in the upper muds or from furrows filled with rainwater that has become saturated are concentrated and crystallized by solar evaporation in shallow vats dug in the playa, and the salt thus obtained is bagged for sale. Mr. Porter states that about 150 tons has been produced in three years.

A composite sample of the salt that crystallizes in surface pits in Silver Peak Marsh was collected by Dole, May 25, 1912. It was com-

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[1] Spurr, J. E., Ore deposits of the Silver Peak quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 55, pp. 158–165, 1906.

[2] Le Conte, Joseph, California State Mineralogist Third Ann. Rept., p. 51, 1883.

[3] Op. cit., pp. 340–341.

posed of 35 portions taken from sumps at the foot of every second pole along the power line crossing the marsh. The composite, having a total weight of 5 pounds, was dried, mixed, quartered, and analyzed. The results are shown in the following table:

Analysis of salt from Silver Peak Marsh, Nev.

[W. B. Hicks, analyst.]

Constituents.	Percentage of sample as collected.	Percentage of soluble matter.	Conventional combinations.	Percentage of total weight.
Moisture at 120° C	1.22		Moisture	1.22
Insoluble matter	1.12		Insoluble matter	1.12
Calcium (Ca)	.51	0.52	Calcium sulphate ($CaSO_4$)	1.16
Magnesium (Mg)	Trace.	Trace.	Calcium chloride ($CaCl_2$)	.46
Sodium (Na) by difference	37.15	38.00	Potassium chloride (KCl)	1.26
Potassium (K)	.66	.67	Sodium chloride (NaCl)	94.71
Sulphate radicle (SO_4)	.82	.84	Borax ($Na_2B_4O_7$)	.07
Chlorine (Cl)	58.46	59.92		
Borate radicle (B_4O_7)	.06	.06		100.00

NYE COUNTY.

RAILROAD VALLEY.

Railroad Valley is about 100 miles northeast of Tonopah and a somewhat shorter distance southwest of Ely, the two nearest railroad stations. The valley proper is a typical desert basin, extending 85 miles in a northerly direction and having a maximum width of 15 miles. A saline mud playa occupies the lowest part of the valley. It is lowest in the north-central part and has an area of approximately 40 square miles. The surface of the mud bears a thin crust of salt, especially after flooding and evaporation. The margins of the mud flats also show salt deposits. At the north end of the marsh is a series of so-called "salt pans." These are irregularly shaped areas more heavily incrusted with salt than the rest of the marsh. They range in size from a fraction of an acre to several acres. Saline efflorescences several inches thick occur on them. After periods of high water, following floods, they drain to the lower parts of the marsh. Salt from the pans at the north end of the marsh has for many years been collected for local use. In the early days it was scraped into piles and hauled to Tybo, a mining camp 45 miles southwest, for chlorinating lead-silver ores.

These saline efflorescences were long reported to contain considerable potash salts, and samples of them tested by the United States Geological Survey were found to contain as high as 12 per cent

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[1] Hance, J. H., Potash in western saline deposits: U. S. Geol. Survey Bull. 540, pp. 457-462, 1914. Young, G. J., Potash salts and other salines in the Great Basin region, U. S. Dept. Agr. Bull. 61, pp. 56-59, 83-85, 1914. Railroad Valley Saline Co., Potash, Sept. 7, 1911. Free, E. E., Potash, Aug. 22, 1912; rev. ed., Nov. 25, 1912. Chandler, A. E., Railroad Valley water supply, Aug. 12, 1912. Marcan, H. W., Railroad Valley soils, Aug. 10, 1912. Several minor circulars also were issued by the Railroad Valley Co.

potash (K_2O) in the soluble portion. The valley has also been drilled by the Railroad Valley Co. for potash salts, but only negative results have thus far been obtained. Analyses of saline residues and natural spring and well waters from the drainage basin of Railroad Valley, together with analyses of brines from shallow pits in salt pans north and northwest of Butterfield Marsh, have been published by the Geological Survey.[1] These analyses, numbering 164 in all, were undertaken primarily to determine the potash content. The results of the analyses of 85 samples of saline residues, including efflorescences and crusts from the drainage basin of Railroad Valley, show an average content of 5.23 per cent potash in the soluble portion, which was 45.57 per cent of the sample. Eleven samples of brine from shallow pits dug in the salt pans north and northwest of Butterfield Marsh were also analyzed. The average content of dissolved salts, dried at 105° C., expressed in grams per 100 cubic centimeters of original sample, is 12.33. The content of potash expressed as percentage of dissolved salts is 7.23.

ELKO AND EUREKA COUNTIES.

WEST OF DIAMOND RANGE.

Arnold Hague[2] mentions the occurrence of salt in the lower Quaternary plains which occupy the valley west of the Diamond Range, Nev. These plains are strongly impregnated with salt, and on evaporation of the water in the upper end of the valley exhibit broad fields of salt crust, which was used years ago for extracting silver from its ores.

WASHOE COUNTY.

BUFFALO SPRINGS SALT WORKS.[3]

Salt was formerly obtained at the Buffalo Springs Salt Works, on the west side of Smoky Creek Desert, Washoe County. The desert is a vast expanse of barren yellowish mud, impassable except during the dry season. Water that flows over the surface of the lake beds in the vicinity of the salt works soon becomes strongly impregnated and on evaporating in low places leaves a crust of salt several inches thick. The less pure grades formerly used in chloridizing silver ores were obtained from this source. Sodium sulphate and other saline minerals are also found at places in the lake beds. The sodium sulphate is known to be several feet thick in places, but it has never been completely explored. At the salt works the brine

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[1] Hance, J. H., op. cit., pp. 457–462.

[2] Hague, Arnold, and Emmons, S. F., Descriptive geology: U. S. Geol. Expl. 40th Par. Final Rept., vol. 2, pp. 549-550, 1877.

[3] Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U. S. Geol. Survey Mon. 11, pp. 232-233, 1885.

which impregnates the lake beds was collected in wells and was then pumped into surface vats, where it evaporated, and the resulting crust was gathered. The brine from the wells has been analyzed, with the following results:

Analysis of brine, Buffalo Springs Salt Works, Washoe County, Nev.

[Specific gravity, 1.133. F. W. Taylor, analyst.]

Silica (SiO_2)	Trace.
Calcium sulphate ($CaSO_4$)	0.1467
Magnesium sulphate ($MgSO_4$)	.8833
Potassium sulphate (K_2SO_4)	.3111
Sodium sulphate (Na_2SO_4)	.5306
Sodium chloride (NaCl)	14.8383
Water (H_2O)	83.2900
	100.0000

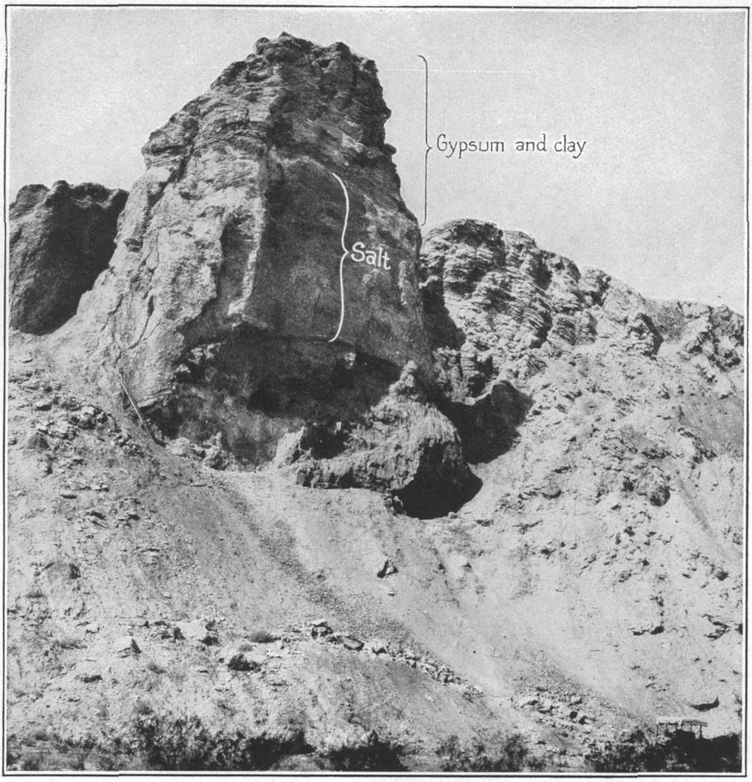
CLARK COUNTY.

VIRGIN RIVER SALT DEPOSITS.

Virgin River valley is mostly in Nevada. Rock salt occurs in this valley a few miles north of the Colorado in beds that lie below beds of gypsum. The presence of the gypsum and salt indicates that the formation containing them is not a part of the overlying Temple Bar conglomerate (Quaternary), which does not contain gypsum or salt in the typical exposures so far observed. The stratigraphic position of the saline beds indicates that the formation containing them may be the time equivalent of the Greggs breccia (Tertiary).

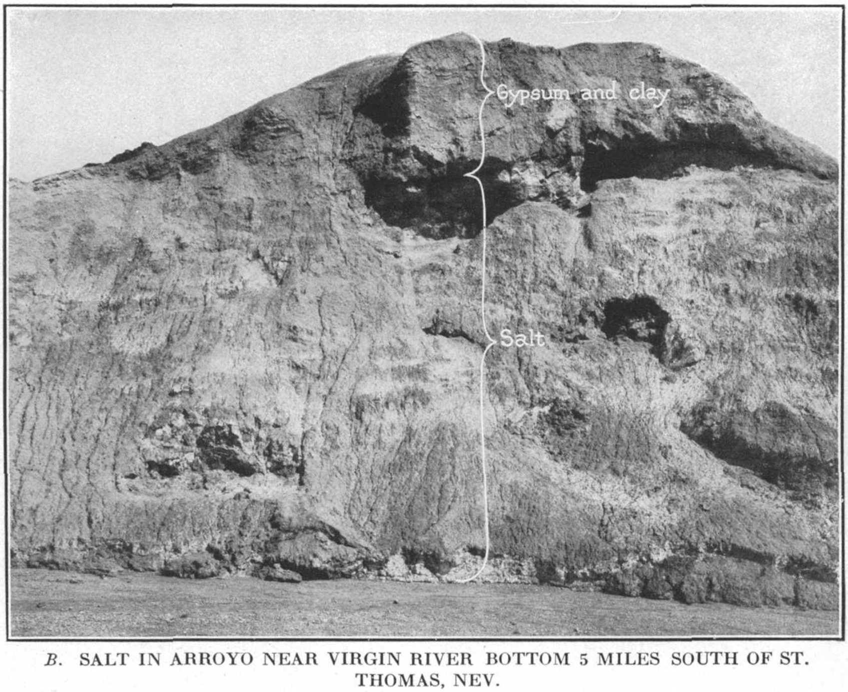
The cliffs of salt, which are remarkable, are exposed in natural outcrop along the valley of Virgin River. (See Pl. XIII.) Although these have attracted attention from the days of earliest exploration in the West, they lie in a region that is not readily accessible, and the salt has not been utilized except locally in a very small way. Hoyt S. Gale contributes the following notes regarding the deposits:

The salt ledges are exposed at several places along both sides of the Virgin River valley between St. Thomas and the mouth of the Virgin at Colorado River, the outcrops extending over a distance of at least 12 miles. Similar outcrops are also reported 30 miles east of St. Thomas, so it appears evident that the salt was originally a continuous and widely distributed stratum laid down during the formation of a certain part of the sedimentary rocks of this part of the country. The salt is associated with a great thickness of gypsum and gypsiferous shales and is included in a series of characteristically red shales and sandstones, usually referred to as "Red Beds," of Triassic or Permian age. The beds including the salt have been very much faulted and folded, and the present outcrops represent disconnected parts of them. Only in exceptional positions has the salt itself been preserved in open exposures or under shallow cover above ground-water level.



A. SALT EXPOSED ON WEST SIDE OF VIRGIN RIVER 5 MILES SOUTH OF ST. THOMAS, NEV.

Photograph by N. H. Darton.



B. SALT IN ARROYO NEAR VIRGIN RIVER BOTTOM 5 MILES SOUTH OF ST. THOMAS, NEV.

Photograph by N. H. Darton.

It is natural to look to such a region as this for the possible occurrence of potash-rich portions of these saline deposits. The largest salt ledge exposes an almost vertical face of solid crystalline salt, representing a bed at least 100 feet in height, in nearly horizontally bedded position. The base is concealed, so the bed may be actually much thicker. The top of the salt is very sharply defined, and the bed is overlain by reddish clay and higher in the section by gypsum, shale, and red sandstone, the beds including also an interbedded flow of dark lava. Samples of the salt dug from the face of this cliff have been analyzed with the following results:

Tests of samples from Salt Cliff, 3½ miles south of St. Thomas, on Virgin River, Nev.

No.	Distance below top of cliff.	Soluble portion.	KCl in soluble portion.
	Feet.	*Per cent.*	*Per cent.*
1	60	94.98	0.29
2	50	98.52	0.08
5	40	97.12	0.09
6	35	98.88	0.08

The great mass of crystalline translucent salts appears to be rather uniform in composition, though it contains an interbedded layer of gypsiferous clay a few inches thick. So far as present evidence goes, it appears to carry no potash-rich layers.

The other salt cliffs or exposures down the Virgin River valley, including the last one just below the "Narrows," about 6 miles above the mouth of the Virgin, were examined and some samples taken, with results similar to those already given. A salt well near Colorado River below the mouth of the Virgin was also visited and sampled, and the results of the tests are as follows:

Potassium chloride in soluble portion of samples from salt well on Colorado River.

	Per cent.
Brine containing 30.77 per cent of dissolved salts	2.39
Efflorescence about rim of well containing 33.31 per cent of matter soluble in water	1.68

Samples of river water above and below this salt field were taken to obtain information concerning salt beds that were being leached.

Tests of samples of water from lower Virgin River valley, Nev.

	Total soluble salts.	KCl in total salts.
	Per cent.	*Per cent.*
Surface stream in gypsum beds on "Diehl potash claims"	0.97	3.07
Seep in Bitter Spring draw	.38	7.82
Water from shaft on "Diehl potash claims"	4.19	.28
Virgin River water, below the salt cliffs, 5 miles above mouth	.365	Not det.
Virgin River water, below the salt cliffs, near mouth	.38	4.93
Colorado River, water just above mouth of Virgin River	[a] .102	Not det.

[a] This result may be too high, as sample was difficult to filter.

Probably the object of these last tests was not accomplished because the test was not complete enough. One result, that from the seep in Bitter Spring Draw, which gave 7.82 per cent of potassium chloride in the salts dissolved in a rather dilute water, may be of some significance. Of itself, of course, so dilute a water could be of no value, and the quantity of the flow is insignificant.

Potash may be present in this area, in association with salt and gypsum, but no very definite indication of its existence, certainly not in commercial quantity, has been brought to light.

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NEW MEXICO.

PRODUCTION OF SALT.

That the actual commercial output of salt in New Mexico is and has been small is not due to a scarcity of salt. The salt-bearing lakes or salines of this State are to be considered among its important future resources. Little of the product is exported, but a considerable quantity of crude salt is used for salting stock. The salt thus used is gathered by scraping up the deposit formed about salt springs or as a thin layer on the surface of the salines or playas during the dry season. The principal lake-basin deposits are those in Estancia Valley, from which a small production of salt has been reported during recent years.

SALT DEPOSITS.

GENERAL GEOLOGIC OCCURRENCE.

Salt in New Mexico occurs chiefly in the upper Carboniferous "Red Beds." It is noteworthy that salt accumulated in this region mainly in upper Carboniferous time and that conditions favoring its deposition prevailed over a wide extent of territory. "Red Beds" underlie the greater part of New Mexico, they outcrop in nearly half the State, and there is more or less salt and gypsum associated with them throughout their extent. It does not follow from these facts, however, that salt in commercial quantities may be found everywhere in the "Red Beds," but the association is so general as to be a helpful guide in the search for both salt and gypsum. The salt worked so far has all been in more recent deposits, probably derived in part directly from the "Red Beds" and in part from springs flowing from them.

ESTANCIA SALT BASIN.

LOCATION.

The salt basin of Estancia Valley is in the central part of Torrance County, near the geographic center of New Mexico. It lies in a depression having no outlet. This depression has a maximum extent of about 65 miles from north to south and 40 miles from east to west and has an area of about 2,000 square miles. The valley is traversed by two railroads, the Panhandle division of the Santa Fe system and the New Mexico Central Railroad, both of which pass near the salt basin.

GEOLOGY.

West of the valley are the Manzano Mountains, a high range composed largely of metamorphic rocks, including schists and quartzites, with associated masses of granite and other igneous rocks. This range forms a sharp divide between the Estancia and the Rio Grande basins. On the east are the Hills of Pedernal, made up principally of quartzite. Mesas and isolated mountains form the north rim of the valley, and the Mesa Jumanes bounds it on the south.

EXTENT OF THE ANCIENT LAKE.

At the period of its greatest extension the lake that occupied the central portion of the valley was about 35 miles long and 23 miles wide; its area was approximately 450 square miles. Its maximum depth at this period was about 150 feet, and its shore line, which nearly coincides with the 6,200-foot contour, was about 150 miles long. If the ancient lake were now in existence several of the villages in this region would be under water. The evidence of the existence of the ancient lake in this valley consists of shore features and lake sediments.

CHARACTER AND EXTENT OF THE DEPOSITS.

The salt basins in the Estancia Valley are not remnants of the ancient lake but are rather distinct basins sunk below the level of the plain by which they are surrounded, and most of them are bordered by definite and nearly vertical walls. Their flat bottoms coincide practically with the ground-water level and consist of mud covered with crusts of salt, but after rains they may be covered with water. The floor of one basin—Salt Lake (Laguna Salina)—is covered with salt sufficiently thick and pure to be commercially valuable. Thin layers of bloedite crystals ($MgSO_4.Na_2SO_4.4H_2O$) occur here, this being one of the two recorded occurrences of this mineral in the United States.

The largest basin, Dog Lake (Laguna del Perro), is about 12 miles long and covers an area nearly equal to the combined areas of all the other basins. Altogether there are scores of salt basins, and their total area is estimated at 13,500 acres.

According to Meinzer,[1] the most reasonable hypothesis to account for the salinity of the water is that at several horizons in the valley of the central area there are beds which were impregnated at the time of their formation with salt deposited by evaporating waters and that afterward these beds were buried under later accumulations. It is likely that the shallow sheet of brine coincides approximately with a buried deposit of salt, laid down at the bottom of the ancient lake at a certain stage of its existence. This hypothesis would also explain the sharp boundary of the saline area. The geologic horizon of the zone from which the salt is supposed to have been derived originally is that of the Carboniferous "Red Beds."

SALT LAKES OF THE WHITE SAND PLAINS.

The White Sand Plains of New Mexico are in the Tularosa Basin, which includes parts of Dona Ana, Socorro, and Otero counties. The extent of these plains from north to south is about 35 miles; their greatest breadth, at their southern margin, is 18 miles. The lines connecting the extreme points are irregular, inclosing a roughly triangular area of about 350 square miles. To this area may be added a tract nearly as large, comprising saline land on the west and that in isolated localities on the south. The whole plain is Quaternary, but inasmuch as it is either higher than the rest of the basin or is more completely drained to the south, the saline materials are not brought to the surface.[2]

The salt flats occur among the gypsum ridges. This occurrence of the salines accounts for the most curious and notable of the many peculiarities of these plains, namely, the dunes of white sand from which the plains take their name. These drifting sands are almost pure gypsum and are derived from the gypsum sand formed in the lakes. The common salt and the alkaline salts are also driven with

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[1] Meinzer, O. E., Geology and water resources of Estancia Valley, N. Mex.: U. S. Geol. Survey Water-Supply Paper 275, p. 51, 1911.

[2] Herrick, C. L., The geology of the white sands of New Mexico: New Mexico Univ. Bull., vol. 2, fascicle 3, p. 12, 1900.

the gypsum, but on account of their solubility they do not remain in the dunes. These dunes lie to the south and east of the flats whither they are driven by the prevailing winds, and they not only cover a large part of the salines themselves but form a growing fringe to the east and south. The soil underneath them is impregnated with salt and soda, and salt lakes are scattered over the area. Near the southeastern limit of the sands is a salt lake which for many years has been a source of salt for the surrounding ranches. Near the south end of the basalt flow, about a mile from the Malpais Spring, there is still another small salt lake, which likewise has furnished salt to ranches within a large radius for many years, and which is usually covered with a thin crust of pure salt. Farther west, along the course of a drainage arroyo, are numerous salines and alkali flats, which gradually broaden and form what may be described as one vast alkali and salt plain, in which brine stands for part of the year. Where these arroyos end in the salt lake and along the shores of the lake are erosion bluffs, some over 20 feet high, in which are exposed the various deposits of the valley filling, some of reddish tint, with their contained saline and gypsum deposits.

Herrick[1] has given a detailed description of the general geology of this region and of Lake Otero, as he has called the basin. The saline beds comprised in the lake basin are called the Otero marls by Herrick, who says in his later descriptions of the salines:

> The salts upon the playas differ in different cases. In some cases, when dry, there is a layer of nearly pure salt (chloride of sodium) several inches thick. More frequently other salts occur in considerable abundance. When carbonate of soda preponderates it will often form a dense crust in which little common salt is a prominent ingredient. Borax and carbonate of potassium also occur under somewhat different conditions. There seems to be considerable uniformity in the amount of salt in the several divisions. Thus in the series of playas north of the barrier above described as separating the great western salt lakes into two portions an average of two samples gave over 6 per cent of salt, while to the south the Soda Lake, which is the southern part of this chain, gave an average of 14.6 per cent, besides large quantities of other salts. This might seem to indicate a tendency to concentrate toward the southern part of the area. Nevertheless the area near "Malpais Spring," which issues from the southern end of the lava sheet, and the flats of the northern end of the old Lake Otero are heavily charged with salt. An average of over 15 per cent was found here without including several lakes whence commercial supplies of salt have been taken and which afford a continuing supply of the pure mineral.
>
> All the arroyos in the east side of the basin are saline. The water flowing in Lost River, for example, carries 7 per cent salt, while soil in Tularosa Arroyo runs 7.8 per cent. The salt lake into which Lost River flows is saturated brine and furnishes commercial supplies. Analyses of the "white sands" show that this gypsum sand contains very little salt.

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[1] Herrick, C. L., Lake Otero, an ancient salt lake basin in southeastern New Mexico: Am. Geologist, vol. 34, pp. 186-187, 1904.

Meinzer and Hare[1] state that the deposits of sodium chloride, or common salt, and sodium sulphate, locally and incorrectly called "soda," are found in certain low places. Thin crusts of salt occur on the small northern alkali flats, in places along Salt Creek, and in some of the arroyos and small flats east of the white sands. The salines were formed in part when the ancient lake dried up. They were also formed in part and are still being formed by the evaporation of mineralized ground waters that reach the surface through springs and by capillary action. Of the sodium salts common salt is the most abundant, but in certain localities the sulphate predominates.

Free,[2] who examined the basin of Lake Otero, concluded that potash salts do not occur in commercial quantity as surface deposits, as the mountains bordering the basin are made up of rocks almost entirely of sedimentary origin, and hence can not be expected to carry or to yield any significant quantity of potash salts. He estimates that less than 5 per cent of the exposed rocks in the drainage area are potash bearing and therefore concludes that potash salts are not entering the present drainage basin and that the supply in the past was probably no greater than at present. Though saline beds probably underlie the present surface of the basin, the chance that potash salts may be found associated with them is considered negligible. Free expresses the opinion that the chances for finding buried beds of potash salts in this basin are less than in many other undrained basins of the region.

ZUNI SALT DEPOSITS.

The Zuni salt deposits of New Mexico are in the northwestern part of Socorro County, about 80 miles south of Gallup, which is on the main line of the Atchison, Topeka & Santa Fe Railway, and about the same distance west of Magdalena, which is on a branch line of the same system.

The salt deposits occur in a lake and in part of a deep depression in a plain of Cretaceous sandstone. The depression is about a mile in diameter and is inclosed by walls of sandstone, capped in part by lava, and averaging 150 feet in height. The lake is about 4,000 feet long east and west and about 3,000 feet wide and is apparently shallow. The water is practically saturated with salt, which crystallizes out, especially where the water is most shallow. In the southern part of the lake extensive bodies of salt rise a few inches above the surface of the water.

The lake is fed by a spring or springs below the water level near the southern margin. The springs are believed to emerge from "Red Beds," which occur at no great distance below the bottom of the

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[1] Meinzer, O. E., and Hare, R. F., Geology and water resources of Tularosa Basin, N. Mex.: U. S. Geol. Survey Water-Supply Paper 343, pp. 72, 130, 1915.

[2] Free, E. E., U. S. Dept. Agr. Bur. Soils Circ. 61, 1912.

depression and are usually slightly saline. In the southern part of the lake are two cinder cones, one of which contains a crater that has a salt pool in its bottom, in which the water stands at lake level. The water in this pool is salty though somewhat less so than that in the lake.

It is probable that at one time the lake filled the entire depression, but owing to evaporation and the deposition of wash from the adjacent slopes it has shrunk to its present size. Extensive bodies of salt will probably be found below the bottom of the lake and along its shores.

The deposit has been a source of supply for Indians and Mexicans for centuries, and the salt is still collected by a small colony of Mexicans in a very crude manner and is hauled to the surrounding ranches. A large output could be obtained by solar evaporation of the lake water, if the demand justified the effort.

The soluble matter in samples of the brine and of the mud from the bottom of the lake analyzed in the laboratory of the United States Geological Survey is nearly pure sodium chloride.

OTHER LOCALITIES.

The water of a small lake 15 miles southeast of Carlsbad, sampled by Hance[1] and analyzed in the Survey laboratory, contained 11.15 per cent of dissolved salts, 0.85 per cent of which was potash. The dissolved material probably came from the adjacent rocks, which belong to the "Red Beds." A lake at Playas reported as alkaline was also visited by Hance,[2] but the water in it was found to be comparatively fresh. At certain seasons of the year the lake bed is entirely dry, but even then very little alkali is present.

There are many salt springs in New Mexico, but salt is not obtained from them except for local use. One large spring is on the Rio Salada, 30 miles northwest of Albuquerque; another is 20 miles west of Belen, and a third is at the south end of the Malpais in Tularosa Valley, 48 miles northwest of Alamogordo. There are scores of small salt springs in this State.

The "Red Beds" which underlie the Pecos Valley and Staked Plains in Eddy, Chaves, and Roosevelt counties contain many thick beds of salt of wide extent, but they lie far beneath the surface. Information regarding them is derived from records of scattered borings for water or oil. These salt deposits are 300 to 500 feet thick and occur in heavy beds separated by layers of clay or sand; in part of the area they lie only a few hundred feet below the surface. The 2,600-foot boring at Carlsbad penetrated many thick salt beds in this area; they have been reached also by borings east of Artesia and Roswell, as well as by numerous deep holes in the Staked

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[1] Hance, J. H., Potash in western saline deposits: U. S. Geol. Survey Bull. 540, pp. 467–468, 1913.

[2] Idem.

Plains region in western Texas, some of them not far east of the New Mexico line.

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ARIZONA.

Though no salt is produced at present on a commercial scale in Arizona, the mineral exists in appreciable quantities in places.

OCCURRENCES.

SALT RIVER VALLEY.

Common salt and other chemically precipitated salts have been deposited along with clastic sediments from the river water in the valley of Salt River. These salts do not form important deposits in the geologic sense, being irregularly diffused through the sediments comprising the valley fill, but they are of great economic importance because of their effect on the river water. The salt (sodium chloride) in Salt River is thought to be derived from large salt springs in the upper reaches of the river. The water issuing from these springs has been described as a weak brine.

VIRGIN RIVER VALLEY.[1]

Virgin River valley is mostly in Nevada, but its geology has been studied chiefly from the Arizona side of Colorado River. Between Temple Bar and Boulder Canyon along the northwestern boundary

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[1] Browne, J. R., Resources of the Pacific slope, p. 311, San Francisco, 1869.

of Arizona Colorado River crosses an old débris-filled valley. The old valley fill is composed of two distinct formations, the older consisting of sand and clay beds with important gypsum deposits. Rock salt occurs in the Virgin River valley a few miles north of the Colorado in beds similar to those containing the gypsum.

The salt deposits are described under Nevada. (See pp. 146–148.)

OTHER LOCALITIES.

Blake[1] refers to the occurrence of rock salt disseminated in the beds in the valley of Verde River, Yavapai County, in the south-central part of the State.

Though a prehistoric lake covered Cochise Flat, which is about 50 square miles in area and borders the Southern Pacific Railroad in southeastern Arizona, no notable concentration of salts seems to have taken place there. A sample of the efflorescence contained 11.74 per cent of soluble material, 1.29 per cent of which was potash.[2]

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UTAH.

The nonmetallic mineral resources of Utah, like those of other Western States, are still so little known that descriptions of almost any class of them are incomplete, particularly of deposits of rock salt and underground brine.

The salt industry of Utah, which is important and flourishing, is located mainly on the east shore of Great Salt Lake, at Saltair, 15 miles west of Salt Lake City. Some salt is produced also at Garfield. All the salt now and heretofore obtained along the lake shore is produced by solar evaporation of the water of the lake.

PRODUCING LOCALITIES.

The most important occurrences of salt in the State are as brine in the water of Great Salt Lake; as rock salt in Sevier Valley, near Salina, Redmond, and Gunnison, in Sevier and Sanpete counties; as

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[1] Blake, W. P., Am. Jour. Sci., 3d ser., vol. 39, p. 44, 1890.

[2] Hance, J. H., Potash in western saline deposits: U. S. Geol. Survey Bull. 540, p. 469, 1913.

rock salt east of Nephi, Juab County, where brine also is found; as salt lake crusts near Clear Lake, in the eastern part of Millard County; and as brine at Salduro Salt Marsh, Tooele County. (See Pl. XIV, *A*.) Salt is or has been produced at all these localities.

GREAT SALT LAKE.

Production has been reported from time to time along the shores of Great Salt Lake in Box Elder, Weber, Davis, and Salt Lake counties, but with the exception of the works of the Inland Crystal Salt Co., at Saltair, the operations are small and are carried on somewhat sporadically. Small quantities of salt are reported to have been gathered recently at Promontory Point, Box Elder County, at Withee, Weber County, 15 miles west of Ogden, at Syracuse, Davis County, and at Garfield, Salt Lake County. The processes of evaporation employed along the lake shore are generally similar, and the methods of the Inland Crystal Salt Co. are typical.[1] The chemical composition of the lake water is discussed on pages 220–221.

SEVIER VALLEY.

Salina, Redmond, and Gunnison are in the valley of Sevier River, the first two places in Sevier County and the last in Sanpete County. The rock salt mined near these places is obtained entirely in open cuts, and the views given show the method of procuring it (see Pl. XIV). Several small mines are in operation on each side of the valley, most of them being on the west side. Some are as much as 50 feet deep. Though the deposits on the west side are close to the wall of the valley, they nevertheless lie definitely within the valley proper. The deposits of the Gunnison Valley Salt Co., however, lie well up on the eastern valley wall.

The salt occurs in places in thin beds apparently separated by layers of clay. At the mine of the Inland Crystal Salt Co. the beds appear to have been disturbed and to stand on edge. On the east side of the valley the structure is more complex and the beds are involved in folds or faults, possibly in both. The salt occurs also massive in places. It is found impregnated with red clay, and the deposits are covered by a thin mantle of residual clay left by the leaching of the accompanying salt.

As to the age of the deposits, on maps of the Wheeler Survey,[2] the general area occupied by the salt beds is mapped as Quaternary, with small areas of Jurassic. In another place Howell[3] says:

> Salt is found in apparently inexhaustible quantities in a red clay of Jurassic age near Mount Nebo, on Salt Creek; on the west side of the Sevier Valley between Gun-

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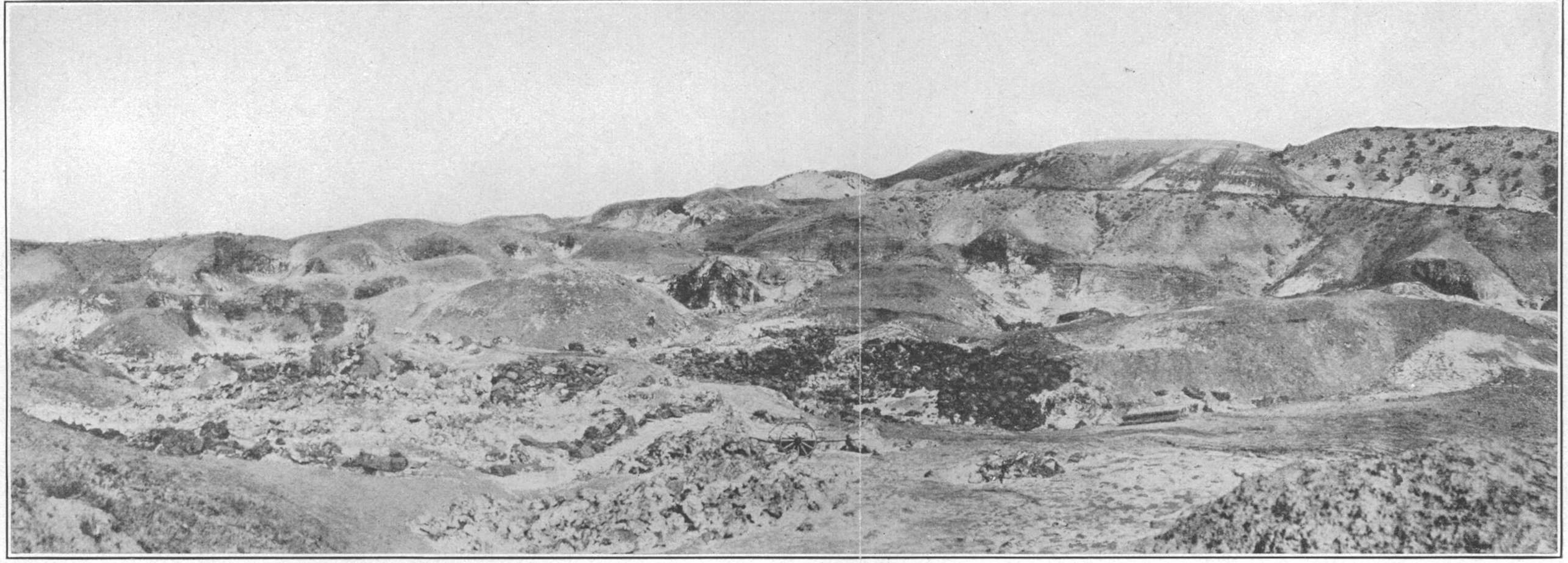
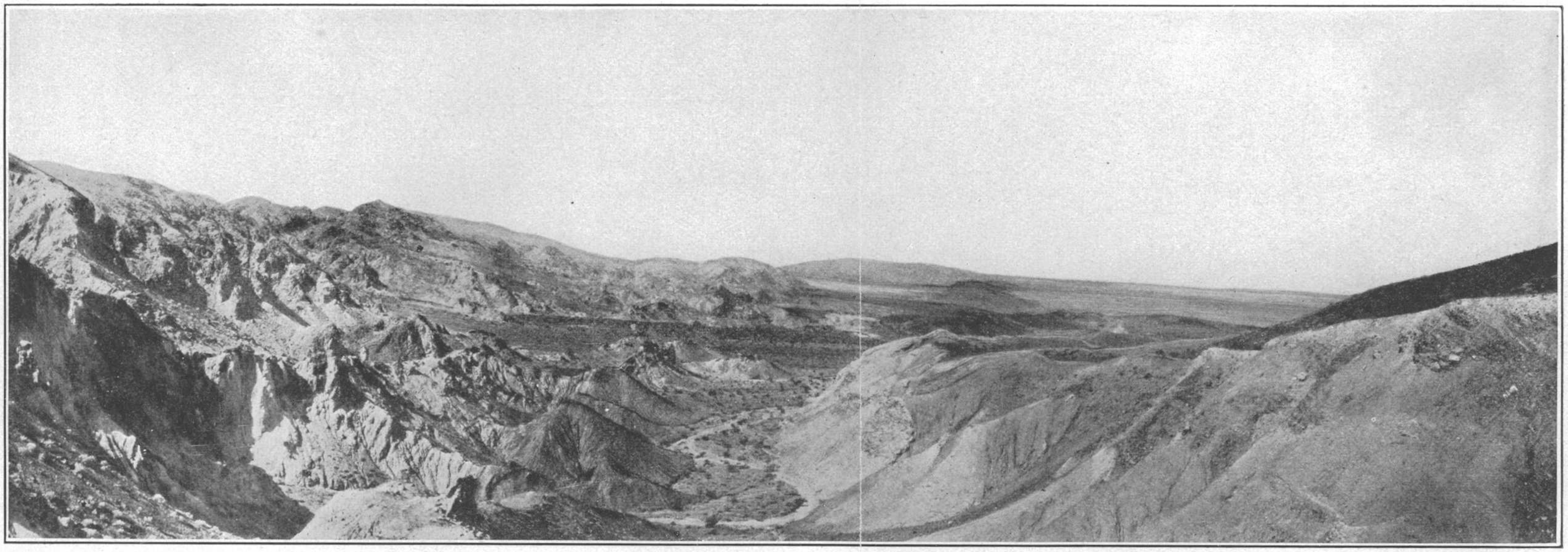
[1] Phalen, W. C., Technology of salt making in the United States: Bur. Mines Bull. 146, pp. 49-52, 1917.

[2] U. S. Geog. Surveys W. 100th Mer., atlas sheets 50 and 59, 1875.

[3] Howell, E. E., U. S. Geog. Surveys W. 100th Mer. Final Rept., vol. 3, pp. 263-264, 1875.



A. PANORAMIC VIEW OF SURFACE MINE IN ROCK SALT, GUNNISON VALLEY SALT CO., NEAR REDMOND, UTAH.



B. PANORAMIC VIEW SHOWING GYPSUM AND SALT BEDS, AVAWATZ SALT & GYPSUM CO., AVAWATZ MOUNTAINS, SAN BERNARDINO COUNTY, CAL.

nison and Salina, a few miles south of Salina; and in Salina Canyon. These salt deposits are all of excellent quality, being remarkably free from sulphates and from the other chlorides.

Thus the age of the deposits under discussion is given as Jurassic by the geologists of the Wheeler Survey.

In the geologic reconnaissance map accompanying Richardson's report on underground water in Sanpete and central Sevier valleys, Utah,[1] the areas containing the salt are mapped provisionally as Jurassic. They are regarded by Richardson as certainly older than Cretaceous. The salt deposits west of Sevier River are associated with two Jurassic inliers in Quaternary beds and extend for a total length of about 6 miles; the deposits east of the river are in Jurassic beds and extend intermittently in a northeast direction for approximately 35 miles.

Regarding the rocks of the Jurassic and the associated beds of salt, Richardson states:[2]

> So far as known, the oldest rocks of Sanpete and Sevier valleys are of Jurassic age. They consist of a considerable but undetermined thickness of fissile clay shales, generally drab in color but locally red, with some intercalated layers of drab sandstone ranging in thickness from a few inches to a few feet. Lenses of gypsum and rock salt are irregularly interbedded throughout the formation. These rocks outcrop in a range of low hills, about 30 miles long and 2 miles wide, that extend along the eastern margin of Sevier Valley from Glenwood to the vicinity of Mayfield. A less extensive outcrop occurs in the center of the valley, mostly west of Sevier River, between Redmond and Gunnison. On the east a fault causes these Jurassic strata to abut against Tertiary beds, as mentioned later, but relations are generally concealed by Quaternary deposits. The hills are practically bare of vegetation, and the soft beds have been eroded into badland topography. These rocks are of no value in the recovery of underground water. They exert, however, an important deleterious influence upon the character of streams with which they come in contact because of the ready solubility of their interbedded salt and gypsum.

Dutton[3] does not indicate the presence of Jurassic beds in the Sevier Valley west of Sevier River in the vicinity of Salina, Redmond, and Gunnison. The Jurassic is indicated, however, east of the river. Dutton explains in the preface to his report that the greater portion of his time was devoted to acquiring a general and connected view of the broader features of the geology of this region, and that details could not receive the attention which their importance really demanded. For this reason it is possible that a small area in the valley proper may have been overlooked. In describing the Jurassic system, however, no mention is made of salt occurring in it, but the presence of gypsum is noted.

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[1] Richardson, G. B., Underground water in Sanpete and central Sevier valleys, Utah: U. S. Geol. Survey Water-Supply Paper 199, pl. 2, 1907.

[2] Op. cit., pp. 8-9.

[3] Dutton, C. E., Report on the geology of the high plateaus of Utah, atlas sheet 2: U. S. Geog. and Geol. Survey Rocky Mtn. region, 1880.

NEPHI, JUAB COUNTY.

The salt deposits east of Nephi, Juab County, are in Salt Creek canyon. They have been worked on a small scale, but no rock salt is now being taken out. Salt springs occur in the district, and from the brine of one of these springs salt is made at a small evaporating plant belonging to Jackson Bros., of Nephi.

The deposits of salt in this locality are among those mentioned in the quotation above by E. E. Howell, of the Wheeler Survey, as occurring on Salt Creek near Mount Nebo. On the atlas sheets of that Survey the rocks of the locality are mapped as Jurassic sediments and the mass of Mount Nebo to the north as composed of Carboniferous rocks. The salt occurs in the area mapped as Jurassic, and the springs probably originate along the fault plane and encounter salt beds before they emerge at the surface.

CLEAR LAKE, MILLARD COUNTY.

The salt deposits of Clear Lake, Millard County, are derived most probably from beds of Quaternary age. The salt occurs in the waters of a salt lake found in the Quaternary basin of ancient Lake Bonneville. During the dry season the water of the lake dries up and leaves a crust of salt, which has been gathered and used. No salt is now produced.

SALDURO SALT MARSH, TOOELE COUNTY.

In the northwestern part of Utah, west and southwest of Great Salt Lake, is a desert of enormous extent, over a great portion of which a crust of salt was deposited from the waters of Lake Bonneville. The waters of this ancient lake have receded greatly and have left only remnants, the most important of which are Great Salt and Sevier lakes. The waters, on evaporating, left bodies of salt, of which that covering the floor of Great Salt Lake Desert, in Tooele County, is an example. Other deposits of salt are probably buried and will be revealed only by drilling or by seepages from springs. Only a little of the salt from this desert has been utilized, and this in recent years, but plans are now under way to obtain salt commercially from the Salduro salt marsh.

Salduro salt marsh, in Great Salt Lake basin, is west of Great Salt Lake and on the main line of the Western Pacific Railroad. It was examined with special reference to the possibility of obtaining potash, in October, 1914, by H. S. Gale, of the United States Geological Survey, who contributes the following notes:

Several shallow holes were bored through the hard surface salt crust that forms the floor of this basin and into the underlying mud. Analyses of samples taken from these borings show that the surface salt is comparatively pure sodium chloride, containing an exceedingly small quantity of potassium. The water-soluble potassium contained in the underlying mud ranges from about 1.8 to 3.5 per cent (expressed as K) of the dissolved salts included in the mud, which salts formed about 12 to 15 per cent of the entire samples taken, about 5 to 7 per cent of the samples being water. Brines were found both in the salt crust and in the underlying mud and on analysis proved to be saturated solutions carrying 25.68 to 26.85 per cent dissolved salts, of which 2.8 to 4 per cent was potassium (expressed as K). This is equivalent to 0.75 to 1.03 per cent of potassium in the entire solution, or only about half the potassium content of the brine in Searles Lake, Cal. It is, however, about double the potash content of the water of Great Salt Lake (0.34 per cent potassium in the sample taken in October, 1913), which, however, is not usually a saturated solution. The brine at Salduro appears to flow freely into holes cut into the salt or mud. It is possible that potash might be produced there in some form, perhaps as a by-product of some other industry, or perhaps only under the stimulus of present abnormal conditions.

OTHER OCCURRENCES.

Other occurrences of salt in Utah are in Little Salt Lake, Iron County; south of Beaver, in Beaver County; and in the salt marshes in Snake Valley, in the western part of Millard County.

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CALIFORNIA.

California ranked sixth among the States in the quantity of salt produced in 1915; in value of output the State ranked fifth.

OCCURRENCE OF SALT.

Salt occurs in California in practically every known form. In solution it is found in the Pacific Ocean, which borders the entire length of the State; in salt springs; in salt lakes or marshes; and in saline streams, of which certain tributaries of Salinas River, in San Luis Obispo County, are examples. In Inyo, San Bernardino, and other counties in the Great Basin, many springs and streams are slightly brackish or salty. Many of the so-called alkaline or salt lakes contain water only during certain seasons of the year; during the dry seasons they are covered with a crust of salt, locally several inches thick. The Great Basin region (see fig. 10) contains many of these marshes, playas, or lakes, from which the salt may be collected by scraping the crust. In addition to the deposits of salt resulting from the evaporation of these saline solutions, rock salt undoubtedly will be found, either disseminated or segregated in beds or masses, in the sediments of Quaternary lakes. These salt deposits have originated

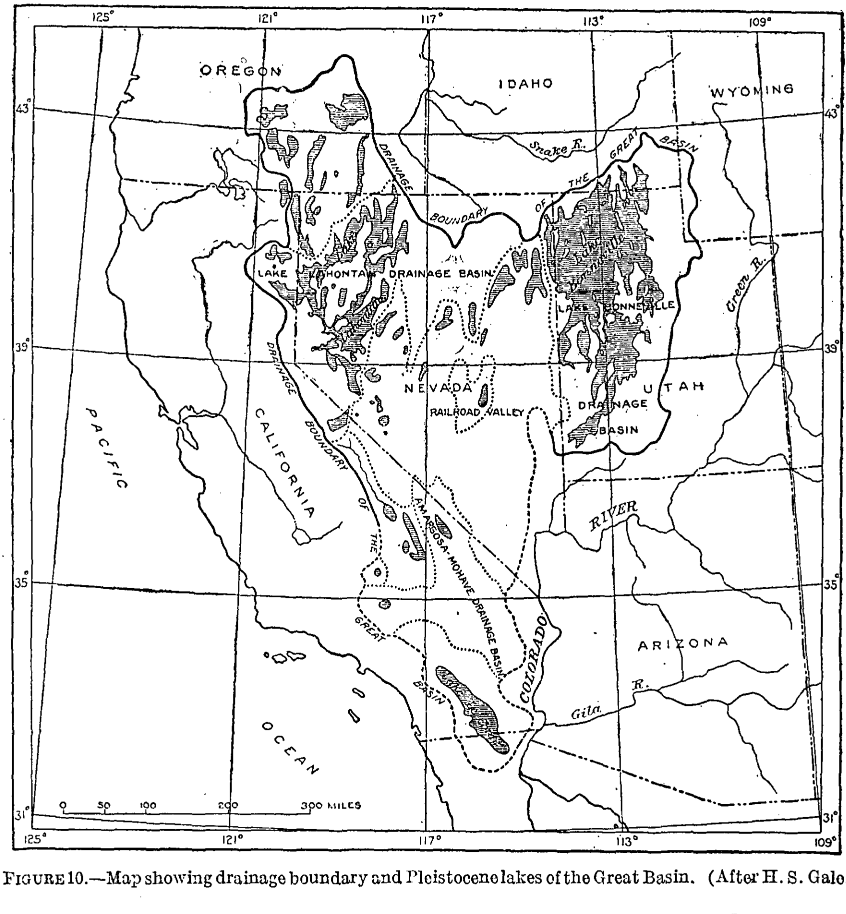

FIGURE 10.—Map showing drainage boundary and Pleistocene lakes of the Great Basin. (After H. S. Gale.)

in the periods of desiccation that were followed by periods of deposition of clastic materials at certain stages of the lakes. Rock salt occurs in a few deposits in the earlier lake beds, of which the deposit on the north side of the Avawatz Mountains is a fine example. (See Pl. XIV, *B*, p. 156.)

PRODUCING LOCALITIES.

More than 97 per cent of the salt produced in California is obtained by the solar evaporation of sea water along the coast, where the main centers of population afford an immediate market for the product, and the cost of transportation is reduced to a minimum. Most of the solar salt, including the finer grades, comes from the shores of San Francisco Bay, in Alameda and San Mateo counties. The headquarters of the salt industry are at Alvarado, Newark, Mount Eden, Russell, and Baumberg, formerly Arffs, in Alameda County, on the east shore of San Francisco Bay, and at Redwood City and San Mateo, in San Mateo County, on the west shore. In the southern part of the State solar salt is made at Ostend station, near Long Beach, Los Angeles County, and on San Diego Bay, San Diego County. General methods of procuring this salt and preparing it for market are described in the bulletin on the technology of the manufacture of salt.[1]

In addition to the output along the coast, salt has also been produced in small quantity in recent years at inland points as follows: Tramway (Keeler post office), Inyo County; Ward, San Bernardino County; Saltus (Amboy post office), San Bernardino County; Cedarville, Modoc County; Ceneda, a few miles southwest of Randsburg; and Saltdale, Kern County.

COLUSA COUNTY.

About 25 years ago the manufacture of salt was begun at certain brine springs near Sites, Colusa County, and has continued more or less intermittently at that locality ever since, though the latest reports are that no more salt is being gathered. A number of other salt springs are known in different parts of Colusa County.

INYO COUNTY.

Inyo County is in eastern California and is wholly within the boundaries of the Great Basin. In this county are included Owens Lake, Death Valley, the Saline Valley salt marsh, and the dried valleys of numerous other salt lakes.

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[1] Phalen, W. C., Technology of salt making in the United States: Bur. Mines Bull. 146, pp. 40-48, 1917.

OWENS LAKE.

By H. S. Gale.

GENERAL FEATURES.

The salts found in solution in the water of Owens Lake have been brought in by the rivers that enter it. The salts dissolved in the water of Owens River have been carefully studied in connection with the diversion of the river for the Los Angeles municipal water supply. An estimate has been published giving the content and total weight of dissolved salts in the water of Owens River at Charlies Butte from November, 1906, to November, 1907, a period of 13 months.[1] This estimate is based on determinations made on 40 or more samples collected at different times throughout the year, and according to it the average dissolved salt content of the river water for that year was 278 parts per million. The mean of thirty-six 10-day composite samples collected from December 31, 1907, to December 31, 1908, showed the mean salinity of the river water for that period to be 339 parts per million.[2] The latter figures indicate a greater concentration, but the discharge in 1908 was only little more than half that of the preceding year. Thus the saline material may prove to be very constant from year to year when all the compensating factors are considered.

The salts that accumulate in the water of the lake do not at all represent the constituents brought in by the drainage, for it is well known that these constituents undergo many changes, which result in their precipitation after they reach the lake as well as earlier, during their stay in the tributary waters. Two radicles, however, that are stable under most conditions are the sodium and chlorine radicles, and from the data accumulated for the year 1908, it is estimated that 17,000 tons of sodium and 9,500 tons of chlorine were contributed by Owens River to Owens Lake during that year. The figures of course represent the sodium and chlorine content of water passing Charlies Butte and not the content of the river as it enters the lake.

COMPOSITION OF THE WATER.

Owens Lake is a large, shallow body of water in the extreme southern part of Owens Valley. (See Pl. XV.) Its water is a dense brine, containing common salt, soda, borax, and other salts in solution. The lake lies in a depression which has no outlet, so that its volume depends on its water supply, or on the relation of inflow to evaporation.

The composition of the water of Owens Lake is recorded in a series of analyses that have been made from time to time, beginning with one by J. Arthur Phillips from a sample collected in January, 1866. These analyses agree fairly well, as appears from the following table:

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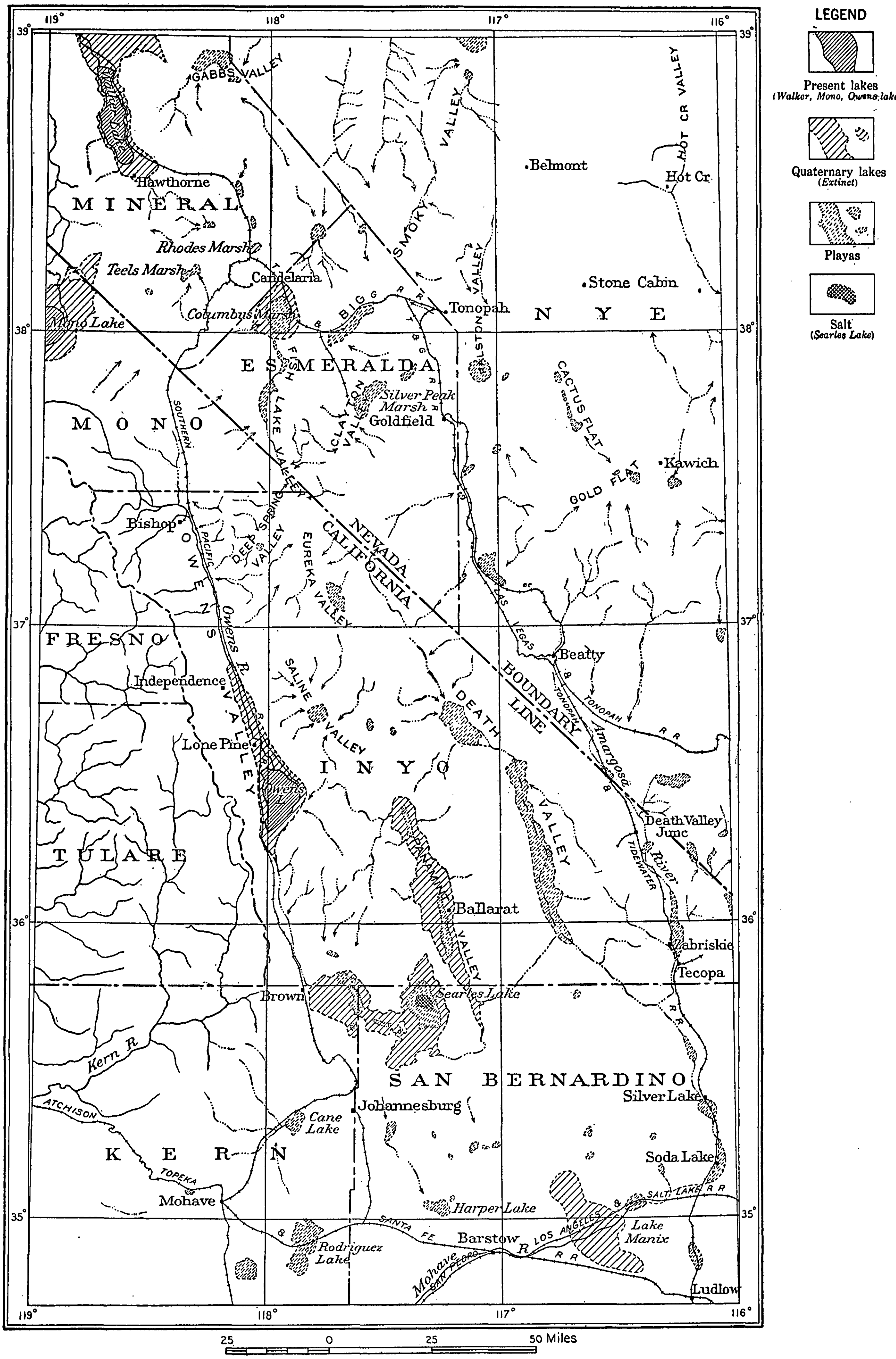
[1] Los Angeles Aqueduct Third Ann. Rept., pp. 113-114, 1907.

[2] Van Winkle, Walton, and Eaton, F. M., The quality of the surface waters of California: U. S. Geol. Survey Water-Supply Paper 237, p. 121, 1910.



MAP SHOWING THE GENERAL LOCATION OF THE OWENS-SEARLES-PANAMINT LAKE SYSTEM, CAL.

From map by H. S. Gale.

Composition of salts dissolved in water of Owens Lake, Cal.

[Calculated to percentage of anhydrous residue.]

	1	2	3	4	5	6	7	8	9	10
Date of collection	Jan., 1866	Oct., 1876	Mar., 1882	Sept., 1886	Quoted in 1902	July, 1904	Aug., 1905	May, 1912	Oct., 1912	Feb., 1914
Analyst	Phillips.	Loew.	Lunge.	Chatard.	Unknown.	Wrinkle.	Stone and Eaton.	Bailey.	Hicks.	Hicks.
Specific gravity	1.076	1.051	1.063	1.062 at 25° C.		1.186	1.195	1.0845	1.0977 at $\frac{21^\circ}{20^\circ}$ C.[a]	1.0972 at $\frac{23^\circ}{20^\circ}$ C.
Cl	25.12	22.20	25.80	25.67	25.75		24.82		25.56	
SO_4	10.06	15.47	9.97	9.95	10.00		9.93		9.96	
CO_3	23.22	21.73	23.60	23.51	18.34		24.55		22.18	
PO_4	.23						.11			
B_4O_7				.48	.50		.14		1.92	1.92
NO_3							.45			
Na	38.55	35.78	40.63	37.83	42.79		38.09		38.07	
K	2.05	4.55		2.18	2.20		1.62		2.10	2.07
Li							.03			
Ca				.02			.02			
Mg				.01			.01			
SiO_2	.77	.28		.29	.29		.14		.21	
Al_2O_3				.04	.13		.04			
Fe_2O_3				.02						
As_2O_3							.05			
Total anhydrous salts in percentage of entire sample	8.74	6.05	6.88	7.27			21.37	9.59	10.95	10.95

[a] The specific gravity given is that of the solution at the temperature of 21° referred to water at 20° C.

1. Analysis by J. A. Phillips. The alkaline and boracic lakes of California: Pop. Sci. Rev., vol. 16 (2d ser. vol. 1), pp. 153-164, London, 1877. The original analysis is stated in grains per imperial gallon and includes 16.94 grains of organic matter, which has been eliminated in the recalculation given in the above table.
2. Analysis by Oscar Loew. The Owens Lake, Inyo County, Cal.: U. S. Geog. Surveys W. 100th Mer. Ann. Rept., 1876, p. 190.
3. Analysis by George Lunge (one of two analyses quoted). Sulphuric acid and alkali, vol. 2, pt. 1, 1890.
4. Analysis by T. M. Chatard. Natural soda, its occurrence and utilization: U. S. Geol. Survey Bull. 60, p. 58, 1890.
5. Bailey, G. E., Saline deposits of California: California State Min. Bur. Bull. 24, p. 95, 1902. No name of analyst or date given.
6. Analysis by Noah Wrinkle, cited by Lee, W. T., Geology and water resources of Owens Valley, Cal.: U. S. Geol. Survey Water-Supply Paper 181, pp. 21-22, 1906. The lake is reported to have been 16 feet lower at this time than in 1894.
7. Analysis by C. H. Stone, cited by Lee, W. T., idem, p. 22. (Recalculation of analysis by F. W. Clarke in U. S. Geol. Survey Bull. 616, p. 160, 1916.)
8. Partial analysis by R. K. Bailey, U. S. Geol. Survey. Sample collected by F. L. Young, supt. Inyo Development Co., Keeler, Cal., from sump at the end of the company's pipe line, where water is said to have been 9 feet deep.
9. Analysis by W. B. Hicks, U. S. Geol. Survey. Sample collected by H. S. Gale at same place as sample 8, below water surface.
10. Partial analysis by W. B. Hicks, U. S. Geol. Survey. Sample collected by F. L. Young at same place as sample 8.

In all these analyses bicarbonate in the original solution is reduced to carbonate in the anhydrous residue and is so expressed. In the sample of October 23, 1912, analyzed by W. B. Hicks, the bicarbonate radicle (HCO_3) amounted to 4,790 parts per million by weight.

On the assumption that the lake level in October, 1912, when the last recorded sample for fairly complete analysis was taken, was about 3,577 feet, a volume of approximately 1,000,000 acre-feet of water is indicated. A calculation from the analysis quoted shows that the lake waters contain in round numbers as follows:

Approximate total content of chlorine, sodium, and other substances, in the waters of Owens Lake.

	Short tons.
Chlorine	40,000,000
Sodium	60,000,000
Potassium	3,360,000
Anhydrous boric acid (B_2O_3)	3,070,000
Total anhydrous salts	160,000,000

TOTAL SALINES.

These figures are considerably in excess of the estimates made by Loew,[1] who calculated 5,000,000 tons of sulphate of potash; but Loew's figures for volume were very moderate, even for the data which he then had, and the present estimates have the advantage of much more exact computations of volume.

The estimate that over 3,000,000 tons of potassium is dissolved in the Owens Lake water is doubtless not far from correct, but this figure is not intended for direct comparison with the estimates of available potash given for the deposits of Searles Lake. The percentage of potash in the water of Owens Lake is so much lower than that in the brine of Searles Lake that there is much doubt if the water of Owens Lake may ever be used for the extraction of that substance, unless it is obtained as a by-product of some other process, or unless the water shall reach a greater natural concentration. There is, of course, a vastly greater quantity of potassium in the water-soluble salts in the Searles Basin than that included in the 4,000,000-ton estimate made by the United States Geological Survey and the Bureau of Soils in 1912.

SEARLES LAKE.[2]

By H. S. Gale.

GENERAL FEATURES.

Searles Lake or Searles Marsh, also known as Slate Range Marsh and Borax Flat, is a dry lake basin, superficially much like many other desert basins of the western arid region of the United States.

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[1] U. S. Geog. Surveys W. 100th Mer. Ann. Rept., p. 190, 1876.

[2] Described here for convenience, though it lies chiefly in San Bernardino County.

These names, as generally applied, refer to the broad, flat salt-incrusted surface in the center of the desert basin, although, except when it is flooded by shallow waters, the region does not contain a lake at all. The basin in which Searles Lake is situated seems to have no generally accepted name, but will here be designated the Searles Basin. It is a broad, oval valley or depression, extending 8 to 10 miles from east to west and 20 to 25 miles from north to south, and bordered by the abruptly rising slopes of the surrounding mountain ranges. This basin lies between the Argus Range on the west or northwest and the Slate Range on the east, which is a narrow rocky wall that divides it from the larger and deeper depression of the Panamint Valley. (See Pl. XV, p. 162.) The camp at the old soda works in the Searles Basin is in the northwest corner of the main desert flat, about 25 miles by road from Searles post office, formerly Garden station, an old stage station of the Overland Route through this part of the desert country. Garden station is now only about a mile east of the branch line of the Southern Pacific Railroad. Searles Lake was reached by the regular stage that runs from Johannesburg past Garden station or Searles to Searles Lake and thence on to Ballarat and Skidoo, and passenger traffic doubtless still goes this way, although the branch railroad is now completed that connects the Searles Basin with the Southern Pacific main line.

During a part of the glacial epoch the Searles Basin was occupied by at least one deep lake, whose traces are still so distinct as to be indisputable. While the waters stood at their highest level the Searles Basin was flooded to a depth of 635 to 640 feet above the present valley bottom, and the lake extended back through the Salt Wells Valley and joined a broad, shallow lake that flooded the greater part of the Indian Wells Valley. When the water level was lowered less than 75 feet, the divide in the volcanic peaks between Indian Wells Valley and Salt Wells Valley became an actual division between two distinct bodies of water, and for a time here also there was an overflow from Indian Wells Valley to the lower waters in the Searles Basin in the same way that Owens Valley overflowed and spilled its waters into Indian Wells Lake.

These changes in drainage are attested by the remnants of ancient shore lines and water channels. Horizontal beaches and shore markings on the more rocky parts of the marginal slopes appear around the present valley, though they are preserved in certain places much more clearly than in others and have been practically removed in still other places by recent erosion. The old shore lines are more or less marked with deposits of calcareous tufa, in some places amounting to very considerable masses and resembling the tufa deposits of the Lahontan, Mono, and Bonneville basins, described by Russell[1] and Gilbert.[2] Calcareous tufa forms conspicuous deposits along several of the more distinct shore lines and coats most of the minor shore benches. It is evident that these deposits are built up from lime precipitated from the entering ground or surface waters, presumably deposited as these solutions became exposed to the air and mingled with the stronger standing waters of the lake.

Owens Lake during a period of former greater water supply overflowed the divide at the south end of its basin, and its surplus waters flooded in turn a succession of lower basins, of which the Searles Basin was one of the largest. The waters of Owens Lake after passing the Haiwee divide dropped about 1,500 feet in about 30 miles to Indian Wells Valley and there spread out in a broad, shallow sheet of water. This lake in turn also overflowed, its water passing by way of Salt Wells Valley and a rock-cut gorge at the lower end of that valley into the Searles Basin. Eventually the waters rose in the Searles Basin to such a height that all three of these valleys were submerged in one continuous body of water. The maximum water level in this basin was clearly determined by the elevation of an outlet pass on the south side of the basin, whence its surplus waters flowed into the extreme south end of Panamint Valley. In the Panamint Basin a history similar in some respects to that of the Searles Basin was repeated. The waters rose until the height of the lowest outlet was reached, and as they evidently remained stationary at about that level for a long period, it is presumed that this level was determined by the overflow of the surplus water.

The record of these ancient lakes is found in various traces left in the present dry valleys. This record, including especially the saline deposits left by the evaporating water, is discussed below. The general features of Indian Wells Valley and Salt Wells Valley are first described, as these valleys were included in the greatest expansion of the ancient Searles Lake.

INDIAN WELLS VALLEY.

Indian Wells Valley, also known as Browns Valley, lies south and southeast of Owens Valley. It is a broad, open stretch of country, mostly filled with a surficial deposit of heavy deep sandy soil. This valley was formerly a part of an extensive lake, whose principal history is very closely linked with that of the deep lake of the Searles Basin. The inlet by which the waters from the Owens Basin entered is in the northwest corner of the valley, and there is a channel of

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[1] Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U. S. Geol. Survey Mon. 11, 1885.

[2] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, 1890. For more details concerning these ancient water lines see Gale, H. S., U. S. Geol. Survey Bull. 580, pp. 251-323, 1915.

overflow to the southeast through the barrier of volcanic peaks that separates Indian Wells Valley from Salt Wells Valley.

The broad Indian Wells Valley is now filled deep with loose sandy materials—a veritable delta deposit. At the edge of the valley farthest from the inlet and nearest the outlet, in the lowest part of the basin, there is a typical mud playa known as China Lake or China Borax Lake. This name was given presumably because the borax works here were formerly operated by Chinese labor. The playa surface is scarcely 30 feet below the low divide traversed by the outlet between it and the Searles Basin. Thus, a rise of waters of more than 30 feet in the China Lake flat would cause an overflow through the pass into the Searles Basin, but there is no record of such an occurrence within historic time. It is difficult to estimate the amount of the filling that may have taken place in Indian Wells Valley, or how deep the original lake in this basin may have been below the fill. However, it seems fair to assume that during the greater part of its history as a lake it served principally as a settling basin for the sand and silt from Owens Valley, which were laid down as a broad delta deposit, so that the clarified water drained through the outlet on the opposite side. That the valley was thus filled nearly to its present level with sediments while the waters continued to overflow seems more likely than that this basin ever served as a concentrating reservoir. The configuration of the basin at the last of the lake periods, when it finally separated from the waters in Searles Lake, was practically what it is to-day, as is shown by the water lines still preserved in the sandy and alluvial slopes about its margin. These lines indicate that the final lake in this basin was not much over 100 feet deep, although it was of broad expanse. The lake in Indian Wells Valley seems therefore to have served one notable function in the system—that of a settling basin, where the bulk of suspended sand and silt was separated out, and only the clarified waters flowed on to the lower lakes. Possibly to this feature chiefly is due the freedom of the deposits of Searles Lake from the admixture with muds that is characteristic of most desert salt deposits.

SALT WELLS VALLEY.

A smaller basin, known as Salt Wells Valley, constituted an arm of the ancient Searles Lake and in lower-water stages formed the channel by which the Indian Wells Valley overflowed into the Searles Basin. It contains a small mud playa but is in effect a part of the drainage area tributary to the present Searles Basin. Salt Wells Canyon, which enters the main Searles Basin, is a gorge cut in granite and basalt. The channel was clearly graded to a steeper slope than that of the present stream channel. The rock-cut gorge is filled with sediments at its lower end, indicating that at some period its grade was directed to a lower level than the present surface of the deposits in the Searles Basin. This channel broadens as it approaches the Searles Lake playa, and the former gorge is filled with the pale-greenish dipping or horizontally bedded, lake-deposited clays or with sand and alluvial wash. This indicates that the former Searles Basin must have been far deeper than the present basin, a conclusion which is also borne out by the record of the deeper borings put down within it.

A large acreage was located for borax early in the seventies in this valley and was worked for a time, but nothing except assessment work is reported to have been done here for several years. It is stated that some salt has been made as a by-product at the borax works. Sodium sulphate occurs as a crust 3 to 10 inches thick over a part of the lake.[1]

AREA OF THE ANCIENT LAKE.

The area of the former Searles Lake at its greatest expansion was about 385 square miles, including both that portion which occupied the Searles Basin and its extension into Salt Wells and Indian Wells valleys. At this time the level of the waters was evidently determined by the height of the outlet pass on the south side of the Searles Basin, by which the surplus waters found their way into the lower Panamint Valley.

THE SALINE DEPOSITS.

The most distinctive feature of this desert basin is the immense sheet of solid white salts that lies exposed in its bottom. It is to this salt deposit that the name Searles Lake (Searles Dry Lake) has generally been applied. So far as known at present the deposit is unique in this country in the variety of its saline minerals. The immense salt fields in Death Valley are less well known and doubtless contain a larger quantity of sodium chloride and possibly other minerals, but they seem to be of the ordinary playa type, and so of a somewhat different class from the Searles Lake saline deposits.

As in other desert basins the valley deposits in the Searles Basin may be distinguished as occupying several more or less distinct areas or zones. These are:

(*a*) The central area of firm crusted salt, constituting what is described hereafter as the main salt deposit. This is estimated at 11 to 12 square miles in area.

(*b*) The playa zone, including the central salt area and a broad surrounding margin of salt-incrusted mud and sand, bare of vegetation and composed of salts and mixed alluvial material washed in toward the center of the basin from the surrounding valley slopes. The area of the playa zone is roughly about 60 square miles.

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[1] Gale, H. S., Salines in the Owens, Searles, and Panamint basins, southeastern California: U. S. Geol. Survey Bull. 580, p. 270, 1915.

(*c*) The alluvial slopes surrounding the playa zone, composed of detrital material washed from the surrounding mountains and spread out in broad, low, flat alluvial fans, the surfaces generally covered with scattered brush.

(*d*) The bare rocky slopes of the bordering mountain ranges which lie beyond and above the alluvial fans and the steeper rock-talus slopes.

The area of salt crust in the Searles Basin is roughly circular, elongated slightly from northwest to southeast and almost central in the basin. It is estimated at 11 to 12 square miles in extent, as determined by the private surveys and the drilling that has been done. Its surface is the lowest part of the basin and the altitude, determined by spirit leveling in connection with the preparation of the Geological Survey map, is 1,618 feet above sea level. In unusually wet seasons surface drainage from the surrounding country sometimes floods the salt surface to a depth of a few inches. Not uncommonly a thin sheet of water, flooded out upon the flat from some local storm, is swept across the surface by the force of the wind, so that perhaps nearly the whole mass of the water is moved from one side of the basin to the other. The surface salt is dissolved to a slight extent by these floods and when it again dries the salt crystallizes with a snowy whiteness that is exceedingly dazzling in the bright sun. Dust storms, which are common in this desert region, scatter more or less dirt over the salt crust, and a certain amount of such material is thus almost constantly mixed with the salt.

The surface of the main or central salt deposit is a firm crust of salt crystals, mostly cubic halite, so hard and compact that it will support the weight of a wagon and team or even of the heavy drill rig. The surface shows a tendency to crack along irregular lines, so that it is divided into cakes or blocks. Flooding and re-solution tend to level inequalities that arise, and the cakes and fractures are not so pronounced a feature here as they are on some salt surfaces of similar type elsewhere.

The depth of the salt is shown by the drillings to be fairly uniform and is reported to range from 60 to more than 100 feet; it probably averages 70 to 75 feet in the main part of the deposit. In the central zone the proportion of mud layers found with the salt is comparatively small, so that the mass is in effect a solid body of salts. At and beyond the margin mud is found not only at the surface but intermingled with the salt deposits in depth, so that a sharp delimitation of the main salt deposit would probably be difficult. It is known, however, that the thick mass of solid salts is much more extensive than is indicated by the surface outline of the central salt area, and that a very considerable thickness of crystalline salts underlies a large area which is represented on the surface by playa mud and salt. Just how far this main salt body extends can of course be shown only by drilling.

The more solid part of the main deposit consists essentially of crystalline salts, in which more or less distinction by layers, from the bottom up, may be recognized, undoubtedly indicating the order of deposition in which the mass was originally laid down. One of the wells drilled through the salt crust on September 20, 1913, was carefully sampled, under the writer's direction, by W. B. Hicks, of the United States Geological Survey, and the samples are now on file awaiting mineralogic and chemical examination. All these samples consist mainly of crystalline salts, more or less completely drained of the brine in which they were naturally immersed.

The deposit of salts is in effect a consolidated mass crystallized from an evaporating mother-liquor brine, in which the salts are still immersed, so that it represents a product of desiccating solutions of which the desiccation has not yet been carried to completion.

The soft mud zone surrounding the main salt deposit contains a very large amount of saline material, which doubtless also includes much crystalline salt. Its surface when dry is crusted with white salt and is not readily distinguishable from the more solid mass of the central salt area, but the proportion of mud mixed with the salts is very evidently greater toward the outer margins of the deposit. The marginal salt and mud zone rises slightly, in general only a few feet, above the level of the central part of the basin, and its surface is more irregular. It is saturated with a dense brine, which makes much of the surface so soft as to be difficult or impossible to cross. The water is evidently seepage from the higher slopes surrounding the flat. The soft ground extends back until the increasing proportion of coarse material renders its surface sufficiently compact to remain firm.

CHEMICAL COMPOSITION OF THE SALINES.

The chemical composition of the salts and brines in the main deposit has been determined by numerous analyses, special attention having been given in the more recent investigations to the brine that permeates the whole deposit rather than to the salts themselves. For the brine these determinations may be summarized in a fairly simple form by the quotation of a few representative analyses, as the composition shown throughout the deposit, whether in samples from different localities or from top to bottom at one locality, seems to be remarkably uniform. In the following table are given six analyses made by Walton Van Winkle, of the United States Geological Survey, from as many samples which were collected from different parts of the deposit:

Composition of brine from Searles Lake, Cal.

(Percentage of ignited residue. Walton Van Winkle, analyst.)

	1	2	3	4	5	6
SiO_2	0.05	0.03	0.00	0.00	0.00	0.03
As	.06	.06	.05	.06	.06	.08
Mg	.00	.00	.00	.00	.00	.00
Ca	.00	.00	.00	.00	.00	.00
Na	33.37	32.57	33.16	33.92	33.23	32.90
K	6.53	7.27	5.98	5.54	6.29	5.69
CO_3	7.37	7.95	6.65	6.89	6.85	6.94
SO_4	12.00	12.49	13.41	11.89	13.79	13.00
Cl	35.97	35.53	36.50	37.13	36.40	36.79
B_4O_7	3.07	1.58	1.77	2.03	2.08	4.14
	98.42	97.48	97.52	97.46	98.70	99.57
Total salts (ignited residue, percentage of original sample)	33.48	33.94	33.30	32.96	33.21	32.88
Specific gravity	1.3002	1.3045	1.2969	1.2935	1.2959	1.2932

Each sample was collected by lowering a stoppered and weighted bottle to a depth of 35 to 40 feet in the brine, and then, by means of a separate cord provided for the purpose, pulling out the stopper and allowing the bottle to fill.

The original brine contains a variable percentage of bicarbonate which is converted to the carbonate form in the anhydrous residue and is so expressed.

Another analysis, made by W. H. Ross in the laboratory of the Bureau of Soils, Department of Agriculture, is probably the most complete statement on record as regards the composition of this brine. It represents the natural solution pumped from well "SE 7." It is given below, and for comparison is added the average of the six analyses already quoted, which corresponds very closely to it.

Chemical composition of salts dissolved in mother-liquor brine of Searles Lake, Cal.

	Average of analyses by Van Winkle.	Analysis by Ross.
Total anhydrous salts (ignited residue)	33.30	[a] 32.85
Specific gravity of brine	1.2974	
Composition of salts (as per cent of anhydrous residue):		
Na	33.19	33.57
K	6.22	6.06
Li		.01
Mg	.00	Trace.
Al_2O_3		.012
Fe_2O_3		.003
SiO_2	.02	.023
Cl	36.39	37.02
Br		.094
I		.004
SO_4	12.76	12.96
CO_3	7.11	6.70
PO_4		.30
As_2O_3	.06	.083
B_4O_7	2.45	3.00
	98.20	99.839

[a] Approximate; the specific gravity of this sample was not determined.

The following notes are added to Mr. Ross's analysis:

Rb, Ba, NH_4, NO_3, Ca, Mn, Cu, none.
Loss on ignition, 0.69 per cent water and organic matter.
Sodium carbonate, 3.04 per cent in original solution.
Sodium bicarbonate, 0.75 per cent in original solution.
Potash, 2.17 per cent in original solution.

The average analysis has been recalculated to the form of hypothetical anhydrous salts which might be derived from such a brine, as follows:

Hypothetical average composition of anhydrous residue of brine from Searles Lake.

Sodium chloride (NaCl)	61.61
Sodium sulphate (Na_2SO_4)	19.22
Sodium carbonate (Na_2CO_3)	12.79
Sodium tetraborate ($Na_2B_4O_7$)	3.23
Potassium chloride (KCl)	12.07
Sodium arsenate (Na_3AsO_4)	.17
	99.09

The composition of the salts has been given by private analyses, made during the testing of the deposit for soda and borax, as follows:

Analyses of samples from well "SE 8," Searles Lake, Cal.

Depth.	Insoluble, mud, etc.	NaCl.	Na_2SO_4.	Na_2CO_3.	$NaHCO_3$.	$Na_2B_4O_7$.	H_2O.
Feet.							
0-18	0.2	79.7	7.6	3.2	0.0	Trace.	3.3
18-25	1.4	44.0	30.5	14.8	2.5	1.0	5.8
25-30	1.4	47.3	28.1	10.6	.0	2.0	10.6
30-35	3.0	42.7	17.1	19.1	5.9	2.0	10.2
35-50	1.4	43.5	22.3	9.5	2.5	5.5	15.3
50-65	Trace.	82.8	10.6	3.2	.8	Trace.	2.6
65-79	Trace.	19.0	7.3	40.3	18.5	.5	14.4

Well "SE 8" is 1 mile due east of well "SE 7," of which the complete brine analysis is given above, and both are situated near the center of the main salt deposit.

In these analyses potash was not determined, and presumably it is expressed as soda in the various combinations given. A single analysis showing the potash content of the salts is given below:

Analysis of a composite of a number of samples from "trona reef," Searles Lake, Cal.

[Made by private chemists.]

Insoluble in water	13.33
NaCl	19.60
Na_2SO_4	5.05
Na_2CO_3	27.60
$NaHCO_3$	20.60
$Na_2B_4O_7$	1.52
KCl	1.50
	89.20

A most significant feature of the chemistry of the deposits is found in the predominant deposition of sodium carbonate and bicarbonate in approximate "trona" proportions at the very bottom of the deposit. There seems also to have been a subordinate recurrence of the same condition at depths of 30 to 40 feet in the central part of the deposit, together with an increase in the amount of sediment (insoluble) contained and apparently a concentration of the borax at or about this general position. It is not shown by this record, but may be noted here, that the mineral hanksite and individual borax crystals, also probably sulphohalite, likewise characterize this zone. This evidence may indicate a temporary interruption of the general process of evaporation while the salt deposition was going on.

The records from wells in different parts of the margin show greater variation. There is commonly a difference in the amount of included sediment at different depths. Possibly some parts of the deposit are richer in borax than others. The principal point that appears to be emphasized, however, is the deposition of the carbonate and bicarbonate at the base of the deposit, and the relation this bears to the evaporation experiment to be referred to presently. There is a relative increase in the sodium sulphate in the upper parts of the deposit and apparently a concentration of sodium chloride at the very top. The experiments of Chatard [1] are particularly significant in considering the origin of the salt deposits at Searles Lake. They are believed to show that these deposits are the normal product of the desiccation of a body of water of the same chemical character as the Owens Lake of the present time.

RED COLOR IN THE SALTS AND BRINE.

The surface salt and the strong brine standing in trenches or in pools about the margin of the salt deposit is characterized by a deep-red color, which is also imparted to some of the salt crystals at the surface of the deposit. The nature of this color has been discussed by Chatard and others, but the following quotation from Lunge [2] is perhaps the latest statement published with reference to its appearance in these particular deposits:

> The red color exhibited by many alkaline salt lakes, which is often also apparent in the salts deposited, is ascribed by Payen[3] to the presence of small crustaceans, *Artemia salina* Leach (*Cancer salinus* Linné), which appear in large masses when the water has attained a density of 1.16 and which are of a gray or greenish color; on further concentration to specific gravity 1.21 they die and form a red froth at the surface. * * * I, for my part, must decline to accept the assumption that the red color is regularly caused by the presence of *Artemia* or other animal organisms, if it is ever due to that cause; for the samples of red water which I had myself taken from the lakes of the Wade Atrun have preserved that color during the many years I have

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[1] Chatard, T. M., Natural soda, its occurrence and utilization: U. S. Geol. Survey Bull. 60, pp. 59-67, 1890.

[2] Lunge, George, Sulphuric acid and alkali, vol. 2, pt. 1, p. 58, 1909.

[3] Payen, Anselme, Annales chim. et phys., 2d ser., vol. 65, p. 156, 1837.

kept those samples. It remains after frequent filtrations. The red filtrate shows nothing under the microscope; the color is at once discharged by adding nitric acid or hypochloride and hydrochloric acid and is evidently caused by organic substances present in solution. There is no iron present.

Perhaps the latest explanation is that it is due to the red chromogenic bacteria which grow in the brines and even in and on heaps of crude salt.[1]

PANAMINT VALLEY.

By H. S. Gale.

THE FORMER LAKE.

While the waters in the Searles Basin stood at their highest level they undoubtedly overflowed by way of the pass at the south end of that basin and entered the larger and deeper basin of Panamint Valley. (See Pl. XV, p. 162.) Here they formed the principal water supply of a lake which received also contributions of the desert drainage tributary to its valley. This immense body of water, which had an origin similar to that of Searles Lake, may have produced in the Panamint Valley saline deposits resembling those in the Searles Basin, but there are many qualifying factors to be considered in offering judgment as to whether such deposits exist there.

Panamint Lake was 60 miles in length from north to south and 5 or 6 miles wide for the greater part of its length, though nearly 10 miles wide in the broader portion of the valley north of Ballarat. It was confined in a long, narrow, deep basin, whereas Searles Lake occupied a broad, oval basin. Panamint Lake narrowed to a point at its south end, and this was not only the point of inlet for the overflow from the Searles Basin but also near the probable outlet during the period of its maximum flooding. The greatest depth of Panamint Lake was probably determined by Wingate Pass, through which an overflow is believed to have passed for some time into Death Valley. Panamint Lake is apparently analogous to Searles Lake, as each lake receives its waters by overflow from a higher basin and each at some stage undoubtedly overflowed to a lower basin. The crusted salt about this basin has been scraped for local domestic and stock use.

SALINES IN PANAMINT VALLEY.

Prospecting in the Panamint Valley for buried saline deposits was begun by private interests in November or December, 1913. One or more shallow holes had been sunk earlier in the year. The more complete exploration of this basin offers a practical and interesting test of the hypothesis of buried salts from the desiccation of a

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[1] Peirce, G. J., in McDougal, D. T., and others, The Salton Sea: Carnegie Inst. Washington Pub. 193, p. 52, 1914.

Quaternary lake that is known to have evaporated and left only an insignificant deposit on the surface.

A saline deposit, if one exists in the Panamint Valley, will doubtless be of much the same type as that of Searles Lake, for it must have been laid down mainly by waters that overflowed from the Searles Basin. As the waters of Searles Lake were supposedly dilute during their highest stages, it seems unlikely that much differentiation could have taken place within them, so that the overflow to the Panamint Lake was not in the nature of a mother liquor.

Some quantitative idea of the interpretations to be placed on the history of the lake may be obtained from the following computations: The water content of the ancient Panamint Lake at its highest level was approximately 85,000,000 acre-feet. If the concentration of the water at this highest level, necessarily a matter of pure assumption, was 300 parts per million of dissolved salts, or about that of the present flow of Owens River, the total quantity of salts dissolved in this ancient body of water would be about 35,000,000 short tons of anhydrous salts. This would be equivalent to a layer of the anhydrous salts 20 acres in extent and 1 foot deep, or with some water of crystallization and mother liquor perhaps the same area to a depth of several feet.

The single filling and evaporation of a lake like that which formerly existed in the Panamint Valley would not necessarily result in the deposition of a large mass of salts when the lake dried up, but such a lake must continue to concentrate waters of the character described for a long period in order to produce a very thick deposit of salines. That such a long-continued concentration actually took place in the Searles Basin is very certain, and there seems to be ample possibility that a similar concentration may have occurred in the Panamint Basin, though definite assumption of its occurrence is scarcely warranted.

PROSPECTS FOR POTASH.

THE DESERT BASINS.

When general interest was first aroused in the subject of potash in the West, the dominant idea in the exploration of the desert basins for saline and potash deposits was based on the assumed former existence of saline lakes, whose waters by evaporation must have left their salts as massive residues. This idea has been referred to as the desert-basin hypothesis.

As a summary it is probably safe to say that commercially valuable concentrations of potash are not generally to be looked for in the desert-basin deposits. Salts deposited by shallow intermittent lakes are not only so mixed with muds as to render their profitable recovery very doubtful, but such deposits are unlikely to retain on a large scale any considerable percentages of potassium in the soluble form. Only in basins where large and deep saline lakes have existed and dried up under favorable conditions are massive deposits of salines free from mixture with mud to be expected. Such conditions are exceptional. Probably few desert saline lakes have in fact dried up so free from the mixture of clay or other sediments that their water-soluble salts have retained the greater part of the potash originally present in the lake water. These exceptional conditions may exist in some places, and it seems that in Searles Lake one such place has been found.

DEATH VALLEY.

Death Valley is known also as the "sink" of Amargosa River, and the salts deposited on its floor are generally considered to have been derived from the drainage waters which have flowed into it. The salt deposits uplifted and exposed to erosion in the neighboring Avawatz Mountains have undoubtedly contributed some of the saline material which has found its way into the Amargosa drainage, and thence into Death Valley, but it is certainly not necessary to assume that the saline material in Death Valley has been derived entirely or even largely from this source. Gale[1] says:

> A vast amount of saline material is accumulated on and beneath the floor of Death Valley. A central area of crusted salt lies in the lowest part of the valley, extending for many miles from north to south. At the very lowest part of the valley or so-called sink there is an irregular area several miles across which is usually a smooth field of snowy-white salt. Occasionally this is flooded by storm waters, which subsequently evaporate and again leave the surface crusted with white salts. Beyond the smooth salt to the north and south are the fields of rough salt. These differ from the area of smooth salt principally in the fact that the salt crust, not having been recently flooded and wholly redissolved, has been gradually broken into cakes and tilted at various angles, probably by expansion due to the growth of crystallization, thus producing a surface so rough that it is extremely difficult to traverse. A rim of soft mud lies between the main salt fields and the valley margin, this part also being occasionally flooded by storm waters and kept wet by the seepage of ground water from the marginal slopes. Beyond the mud rim are sand dunes and alluvial slopes of rock débris, such as characterize these desert regions generally.
>
> The outlines of these types of surface deposits are represented in the accompanying map of a portion of the valley [fig. 11], which is based on data collected by Charles E. Watson for the Geological Survey at the time the wells were being drilled. The location of the wells is also indicated.

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[1] Gale, H. S., Prospecting for potash in Death Valley, Cal.: U. S. Geol. Survey Bull. 540, pp. 407-415, 1914.

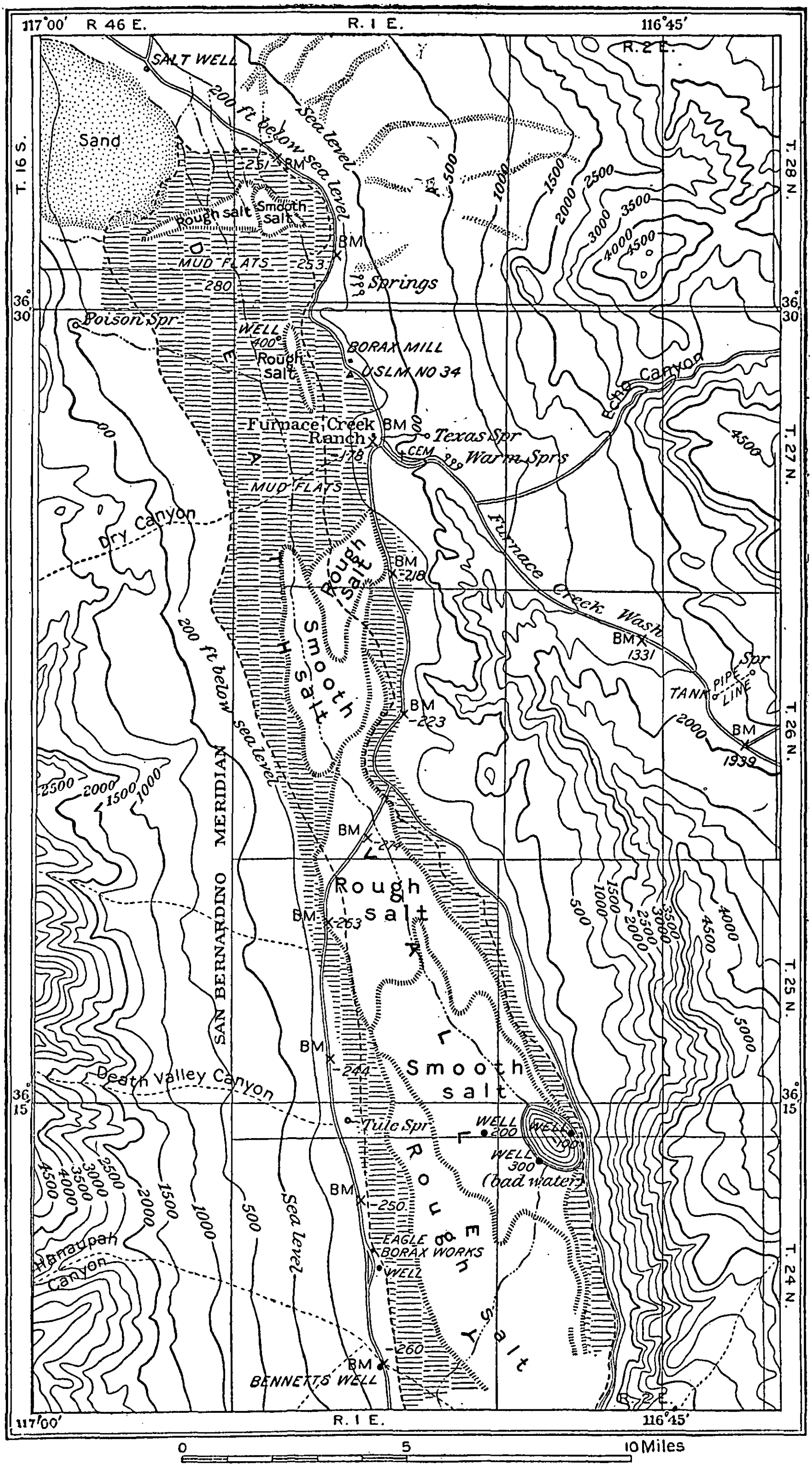

FIGURE 11.—Map showing salt deposits in Death Valley, Cal., and location of wells drilled by the United States Geological Survey. (After H. S. Gale.)

Published analyses[1] of salt in Death Valley are as follows:

Analyses of salt from Death Valley, Cal.

Constituents.	1	2
NaCl	94.54	95.49
KCl	.31	
Na_2SO_4	3.53	2.78
$CaSO_4$	....	.27
$CaSO_4 . 2H_2O$	.79	....
$MgCl_2$	....	Trace.
Moisture	.14	....
Insoluble residue	.50	....
	99.81	98.54

1. Surface salt from the middle of the area of rough salt, on the road between Furnace Creek ranch and Bennetts Well, where the crust is nearly 3 miles wide. M. R. Campbell, collector. Analysis by George Steiger, expressed in percentage of total weight. U. S. Geol. Survey Bull. 200, p. 18, 1902.

2. Deposit 1 to 3 inches thick covering many square miles. Lieut. R. Birnie, collector. Analysis by Oscar Loew, expressed in percentage of anhydrous residue. U. S. Geog. Surveys W. 100th Mer. Ann. Rept. 1876, p. 176.

Explorations of the saline deposits in the floor of Death Valley were recently undertaken by the United States Geological Survey for the purpose of ascertaining whether the strata of the valley contain an appreciable amount of potash salts. In all 83 samples of brines and saline deposits were collected, some of which have been analyzed and the results published.[2] The borings, which were sunk to depths of 100 feet or less, show that the valley is underlain by alternating layers of clay or mud and rock salt. Salt brines were found at several horizons, usually in layers just below beds of crystalline salt and rarely in the mud layers themselves.

The principal constituent of the brines analyzed is sodium chloride, and the potash content is small. Analyses of 28 portions of solid material from different depths in one of the borings (No. 200) in the lowest part of the valley and thought to be fairly representative were also examined. After the moisture was dried out under conditions approximating those normal in the region, the dried material averaged 65 per cent of soluble salts, of which 0.72 per cent was potash, corresponding to 1.13 per cent of potassium chloride.

The log of the well from which the sample was obtained is given on page 179.[3]

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[1] For additional analyses see G. J. Young, Potash salts and other salines in the Great Basin region: U. S. Dept. Agr. Bull. 61, 1914.

[2] Gale, H. S., op. cit., pp. 410-411.

[3] Idem, pp. 412-413.

Log of United States Geological Survey boring No. 200, Death Valley, Cal.

	Thickness.	Depth.
	Feet.	*Feet.*
Salt (6 inches thick on surface)	0.5	
Clay, soft, light brown, containing crystals	3.5	4.0
Salt, very hard	2.0	6.0
Mud, soft, brown, containing coarse crystals	11.0	17.0
Mud, smooth, brown	.5	17.5
Salt, in layers 1 inch thick	.5	18.0
Mud, soft, brown, smooth	3.0	21.0
Mud, light, brown, sticky, containing crystals	3.0	24.0
Mud, soft, brown, containing crystals	3.0	27.0
Salt, hard	2.5	29.5
Clay, tough, brown	.5	30.0
Salt, hard, drilled	1.0	31.0
Mud, soft, brown, containing crystals	.3	31.3
Salt, hard	.7	32.0
Clay, dark, containing crystals	4.5	36.5
Salt, hard	1.5	38.0
Mud, black, containing crystals and hard salt strata 1 inch thick	1.5	39.5
Salt, hard, black	2.0	41.5
Mud, black, containing crystals	1.5	43.0
Salt, hard	.2	43.2
Clay, black, containing crystals	2.3	45.5
Salt, hard, black	.5	46.0
Clay, light gray and black mixed, containing crystals	5.0	51.0
Salt, very hard	1.5	52.5
Clay, dark, containing crystals	.5	53.0
Salt, hard	.5	54.0
Clay, tough, dark	.5	54.5
Salt, very hard, hardest yet encountered, black	15.5	70.0
Clay, tough, dark blue, containing crystals	1.0	71.0
Salt, very hard, black	5.0	76.0
Clay, dark blue, containing crystals	2.5	78.5
Salt, hard, black	1.0	79.5
Clay, dark blue, containing crystals	6.2	85.7
Salt, hard	1.0	86.7
Clay, dark blue, containing crystals	3.8	90.5
Salt, very hard	1.5	92.0
Clay, very tough, dark blue, containing crystals	4.0	96.0
Clay, tough, black, containing crystals	8.0	104.0
Water encountered:		
Water sample No. 1, black salty water, came within 2 feet of the surface		32.0
Water sample No. 2, salty, nearly clear, came within 1 foot of the surface, strong flow; with 8 feet of section pipe on hand pump well flowed 5 gallons in 2 minutes		38.0
Water sample No. 3, seepage water in well after standing overnight		70.0

With reference to the possibility of finding deposits of potash salts deeply buried in the valley, Gale concludes that evidence of former deep submergence of the valley has not been found; that the appearance of the deposits is such as to indicate that they are the result of alternate periods of shallow submergence and desiccation; and hence that there is little justification for any present assumption that important deposits of potash salts lie in the valley.

SALINE VALLEY.

Saline Valley, which was also visited by Gale,[1] is in the west-central part of Inyo County, between the Inyo Mountains on the west and the Panamint Mountains on the east. (See fig. 12.) The salt deposits of the valley occupy the lowest part of the depression, which is without outlet and is completely inclosed by high mountains. The central depression of the valley has without doubt been

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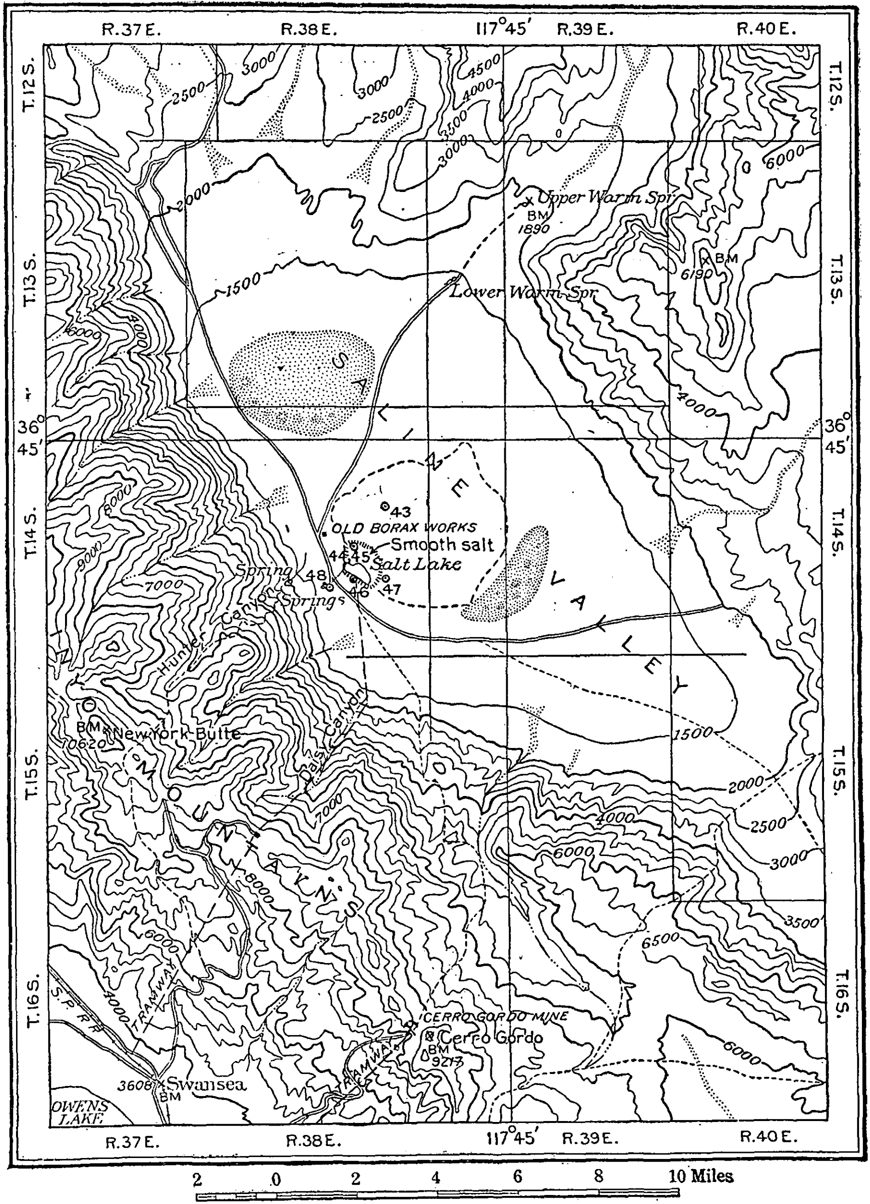
[1] Gale, H. S., Salt, borax, and potash in Saline Valley, Inyo County, Cal.: U. S. Geol. Survey Bull. 540, pp. 416-421, 1914.

occasionally submerged, but perhaps to shallow depths only, as no evidence of former shore lines of considerable height has been observed in the valley. Of the central deposit of mud and salts, approximately 1 square mile is a smooth white crust of salt, including a small open pond of salt water. Adjacent to this smooth crust is a rough expanse of broken and tilted salt-crust blocks, with a sharp



Contour interval 500 feet

FIGURE 12.—Map of Saline Valley and vicinity, Cal., showing location of salt deposits. (After H. S. Gale.)

craggy surface. A stock company has been organized to develop this deposit for the salt it contains, and a production was reported in 1913. The salt from the smooth crust in the lowest part of the valley was sampled as it stood piled in stacks ready for shipment, and the analysis of the samples showed it to contain 98.52 per cent of sodium chloride, and thus to be of high grade for a natural product. The complete analysis of the salt sample is as follows:

Analysis of salt sample from stacks in Saline Valley, Cal.

[R. K. Bailey, analyst.]

Sodium chloride ($NaCl$)	98.52
Sodium sulphate (Na_2SO_4)	1.02
Potassium sulphate (K_2SO_4)	.37
Water	.12
Insoluble	.17
	100.20

The thickness of the deposit is not known, as no drilling to any considerable depth has been done. Shallow holes dug in the surface of the white crust showed a surface thickness of 4 inches of loose-textured, porous white crystalline salt, below which there is a layer of dark-greenish or almost black saline mud several inches thick. Salt layers occur still farther down, but excavation is hindered by freely flowing brine, which fills the holes. Samples of the brine were collected and tested for potash salts, but the results indicated that potash is not present in quantities of commercial importance. It is quite likely that no extensive or deep lake ever existed in this valley and that the salines represent the accumulation from the surrounding and somewhat restricted drainage area. The results of the analyses of the brine collected from this region are given in the table below:[1]

Potash analyses of brine from Saline Valley, Cal.

[Nos. 43-46, R. K. Bailey, analyst; Nos. 47 and 48, W. B. Hicks, analyst.]

Sample No.	Total salts (ignited residue).	Potassium in the total salts expressed as—		
		K.	K_2O.	KCl.
43	29.77	1.29	1.56	2.47
44	28.10	.78	.94	1.48
45	28.05	.81	.99	1.55
46	28.77	1.29	1.56	2.47
47	28.26	.95	1.15	1.82
48	.10	.05	.06	.10

OTHER OCCURRENCES.

Salt strata have been encountered in dug wells at Tecopa, just north of the boundary between Inyo and San Bernardino counties; and the water of Confidence Spring, near "The Narrows," in south

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[1] See also Young, G. J., op. cit., pp. 43-44.

Death Valley, is salty. The niter beds in the canyon of Amargosa River contain some rock salt and numerous layers rich in salt. The name Amargosa River is somewhat misleading, as the river does not often carry enough water to flow on the surface as far as the lowest depression of Death Valley. The waters in the lower courses of the river are decidedly briny; where the stream widens out into the large playa at Resting Springs Dry Lake it leaves fields of salt as well as of borax and niter, and the desert on either side of the river is dotted with patches of salt. Salt Spring, in San Bernardino County, is in the valley of South Fork of Amargosa River, where it turns northwest to join the main Amargosa near the south end of Death Valley.

For lists of the springs which may be fresh, brackish, or salty, the reader is referred to the reports of Bailey and Mendenhall in the bibliography (p. 192).

KERN COUNTY.

CAMERON LAKE.

Cameron Lake is in the southern part of Kern County, in T. 32 S., R. 34 E., between Tehachapi and Cameron stations on the Southern Pacific Railroad. Bailey reports that it is a salt lake about 1 mile square, with a "saline stratum 5 to 6 feet deep." The lake dries up, and during dry seasons a salt crust is left 3 to 4 inches thick.

KANE LAKE.

Kane Lake is about 10 miles southwest of Randsburg, in the eastern part of Kern County, on the road between Mohave and Randsburg. The salt occurs in the bed of a dry lake or sink 6 miles long and 3 miles wide. The lake has no outlet, and the spring and fall rains cover it generally to a depth of 10 inches. About 3,000 acres are reported to be under water when this depth is attained. After the lake has evaporated to dryness, the salt is shoveled up and piled into heaps. Generally two crops a year may be secured, but in some years there is uncertainty about the fall crop on account of the September and October rains.

Two companies have been operating here, but recently the Diamond Salt Co. has bought them out. An artesian well has been sunk to procure water in addition to that supplied by the rainfall, if needed. Only crude solar salt is now produced, but it is planned to ship the crude salt to Los Angeles and there refine it for table and other uses.

OTHER OCCURRENCES.

Castac Lake, in the southwestern part of Kern County, is a shallow lake which in dry seasons is covered with a thick crust of salt. Northward as far as Kern River the entire county is an alkali desert, whose soil is heavily impregnated with salt. At one place, about

14 miles from the Canyon de las Uvas, salt was prepared some years ago. At other dry lakes in different parts of the county salt occurs in appreciable quantities. In the northeast corner of the county a number of wells give the name "Salt Wells Valley" to a considerable area of land.

MONO COUNTY.

Mono Lake is in Mono County, near the Nevada line, at an altitude of 6,730 feet, and is the highest above the ocean of the saline lakes of the Great Basin. Its water is dense and alkaline. Owing to the presence of volcanic rocks in the lake basin alkaline carbonates are abundant in the water, as shown by the following complete analysis made by T. M. Chatard:[1]

Analysis of water of Mono Lake, Cal.

[Grams per liter.]

Silica	0.0700
Calcium carbonate	.0500
Magnesium carbonate	.1928
Potassium chloride	1.8365
Sodium chloride	18.5033
Sodium sulphate	9.8690
Sodium carbonate	18.3556
Sodium bicarbonate	4.3856
Sodium tetraborate	.2071
Alumina	.0030
	53.4729

The results of this analysis show that sodium chloride constitutes nearly 35 per cent of the total solids. Experiments by Chatard on the fractional crystallization of the mineral content of the water gave the results presented below, which show the same general rule of deposition as at Owens Lake. The water used in the experiments had already been evaporated to about one-sixth of its original volume and had a specific gravity of 1.210.

Analyses of salts deposited by fractional crystallization of water of Mono Lake, Cal.[a]

	1	2	3	4	5
Water	12.28	10.98	0.69	4.18	11.31
Silica	.07	.17	.16	....	.13
Calcium carbonate	.05	.14	.05	.07	.02
Magnesium carbonate	.48	.46	.02	....	....
Potassium chloride	.69	.69	.47	.71	15.20
Sodium chloride	19.18	21.34	29.96	60.75	32.36
Sodium sulphate	2.73	14.18	49.13	16.22	6.65
Sodium carbonate	36.87	41.07	18.27	14.22	33.69
Sodium bicarbonate	27.37	10.99	10.03	3.88	.49
	99.72	100.02	99.78	100.03	99.85

[a] U. S. Geol. Survey Bull. 60, p. 66, 1890.

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[1] Chatard, T. M., Analyses of the waters of some American alkali lakes: Am. Jour. Sci., 3d ser., vol. 36, p. 149, 1888; also Natural soda—its occurrence and utilization: U. S. Geol. Survey Bull. 60, p. 53, 1890.

The lake has an area of 85.5 square miles and an average depth of 61.5 feet. From its volume and the mineral content of its water the amount of the various salines which it contains has been estimated. The results indicate the presence in the lake of 86,099,600 tons of common salt and 10,538,100 tons of potassium chloride.[1] Such figures show that the saline reserves in this and other incompletely evaporated or playa lakes of the desert region of California and other public-land States are very large and may prove valuable when transportation facilities have been developed and methods for the extraction of the salts perfected.[2]

RIVERSIDE COUNTY.

The main source of salt in Riverside and Imperial counties, Cal., was Salton Sink, an immense basin in which thousands of tons of water were evaporated annually. This water was supplied by the drainage from the east side of the San Jacinto Range, Carrizo Creek, and a part of the San Bernardino Mountains, and in times of extremely high water the basin served as a reservoir for the excess in Colorado River.[3] According to Mendenhall [4] it receives normally only the occasional overflows from the tributaries of the Colorado. With the flooding of the sink by Colorado River in 1905 and 1906 the salt-producing industry in this region ceased. The sink is now filled by a lake having an area of about 450 square miles and a maximum depth of 67.5 feet.[5] If further inflow is prevented it will only be a decade or so before the original conditions are restored.

The bed of salt, until the last overflow, was extensively exploited by the New Liverpool Salt Co., and shipments were made from Salton by rail.

In 1892 the lake was described as a salt marsh connected by a branch railway with the main line of the Southern Pacific Railroad. The company's works were located about 3,000 feet west of the railroad, on a spur track that extended into the marsh a distance of 10,000 feet. Beyond the end of the track a well was bored by the company to a depth of 300 feet. The topmost material of the well consisted of a layer of black mud 6 inches thick, resting on a crust of sodium and magnesium chlorides, 7 inches thick. On passing through the crust the drill dropped through 22 feet of black ooze containing over 50 per cent of water. This ooze consisted largely of sodium and magnesium chlorides and carbonates, the sodium salts predominating; also fine sand, iron oxide, clay, and organic matter.

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[1] Bailey, G. E., The saline deposits of California: California State Min. Bur. Bull. 24, p. 101, 1902.

[2] See also notes in Young, G. J., op. cit.

[3] Preston, E. B., Salton Lake: California State Mineralogist Eleventh Rept., p. 389, 1893.

[4] Mendenhall, W. C., Some desert watering places in southeastern California and southwestern Nevada: U. S. Geol. Survey Water-Supply Paper 224, p. 10, 1909.

[5] Freeman, W. B., and Bolster, R. H., Surface water supply of the Colorado River basin, 1907–8: U. S. Geol. Survey Water-Supply Paper 249, p. 46, 1910.

The ooze rested on hard clay, through which the drill passed for the remaining distance, 277 feet. In this clay were two or three streaks of cement.[1]

SAN BERNARDINO COUNTY.

Searles Lake is mainly in San Bernardino County, near the corner of Inyo, San Bernardino, and Kern counties, but it has been described under Inyo County for convenience. (See pp. 164–174.)

SALTUS.

In recent years salt has been produced near Saltus (post office, Amboy), a station on the Atchison, Topeka & Santa Fe Railway, in the southeastern part of San Bernardino County. The writer has not visited the locality, and the following notes were orally communicated. The salt occurs in the bottom of an old lake bed in the form of layers of rock salt. To work these layers the overburden, which is approximately 5 feet thick, has to be removed. The upper layer of rock salt is 5 to 7 feet thick, and the interval between the base of this upper and the next underlying bed of salt is about 20 feet. The exact thickness of the lower salt bed is unknown, as it has been penetrated to a depth of only a few feet, and difficulties have been encountered in attempts to work it on account of the water in the intermediate stratum.

AMARGOSA RIVER.[2]

A short stretch of Amargosa River is in San Bernardino County, but most of the river is in Inyo County and in Amargosa Desert, Nye County, Nev. Its source is a group of springs about 17 miles northeast of Bullfrog, Nev. It flows southeast, passing Franklin dry lake, Resting Springs dry lake, and thence through a rugged canyon to a point near Sperry, on the Tonopah & Tidewater Railroad. There it turns southwestward and flows around the south end of the Black Mountains, and then to the northwest into the sink of Death Valley. The term "river" is somewhat misleading. Its total length is about 140 miles, and throughout its course it disappears and reappears, its water being absorbed by the porous beds over and through which it flows. In recent years it has flowed on the surface only a few miles beyond Saratoga Springs, in San Bernardino County, even during the heaviest floods. Though the water in the river is potable near its source, it takes up during its flow large amounts of the various salts, becoming finally heavily charged, a fact which has given the river its name—"Amargosa," meaning bitter in Spanish.

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[1] Preston, E. B., op. cit., p. 388. See also McDougal, D. T., and others, The Salton Sea, Carnegie Inst. Washington Pub. 193, p. 10, 1914.

[2] For analyses of water from Amargosa Valley see Young, G. J., Potash salts and other salines in the Great Basin region: U. S. Dept. Agr. Bull. 61, p. 78, 1914. Analyses are by J. A. Cullen.

In the lower courses, including San Bernardino County, where the water comes to the surface these salts are deposited as white crusts, which contain salt and the borate minerals. These crusts have been removed and marketed, and some of them by natural re-solution and recrystallization have been rendered quite pure.

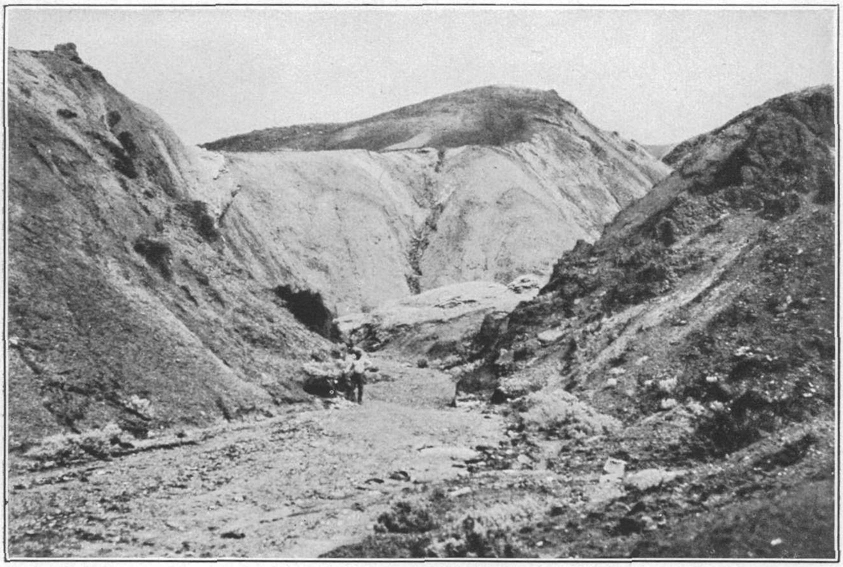
AVAWATZ MOUNTAINS.

Salt occurs as rock salt in upturned beds on the northern slopes of the Avawatz Mountains in San Bernardino County. It outcrops over a large acreage in a zone between 4 and 5 miles long. To judge from the attitude of the beds it must underlie an extensive territory. The salt occurs as a member of a series of saline deposits, consisting essentially of celestite at the base, gypsum, and salt, the entire series being underlain and overlain by lake beds. (See Pls. XIV, *B*, p. 156, and XVI.)

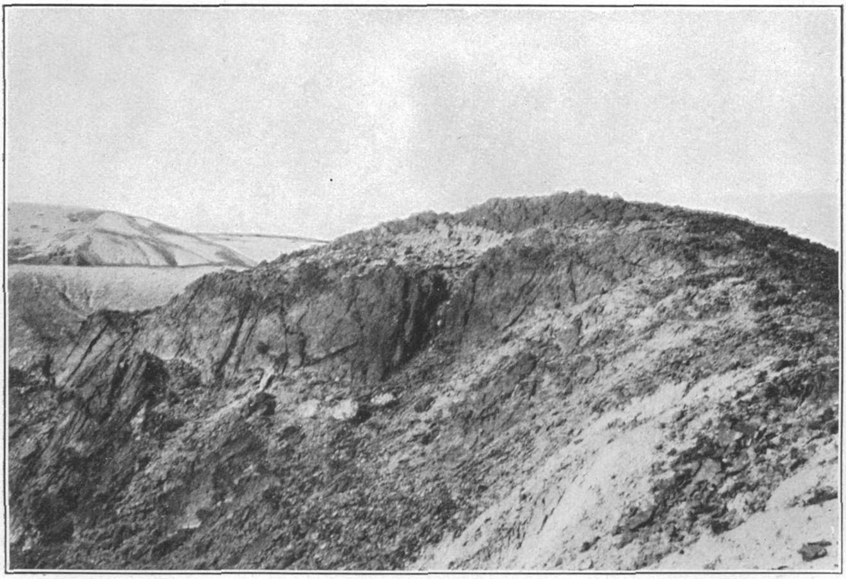
The underlying lake beds are made up chiefly of compacted sands and shales, including conglomerates in places. Celestite is found near the top of the series at the base of the overlying gypsum. A little gypsum is disseminated in part of the lake beds but not enough to make it of any economic consequence. In places sodium sulphate and niter are reported as found respectively in the shales toward the center of the deposits and along what is locally known as "pipe-line wash." The overlying lake beds consist chiefly of gravels and sands and contain a small amount of clay, gypsum, and possibly other salts. In places both the lower and the upper lake beds are characterized by the rather brilliant hues of the shales composing them, white, maroon, yellow, rose, and green being not uncommon colors.

The saline deposits and their underlying and overlying lake beds lie between (1) a basement complex of sedimentary rocks, which have been in part metamorphosed and intruded by igneous rocks, and (2) gravel beds of unknown thickness, which cover the economic deposits in part, form alluvial cones and fans, and extend into the valley on the north side of the mountains. In general the surface of the gravels, especially away from the edge of the foothills, is very smooth, this smoothness characterizing also the surface of the alluvial fans.

The salt layers proper, as would naturally be expected, are not sharply demarked in all places from the underlying gypsum layers. The line of division comes most naturally in clayey sediments containing both gypsum and salt between the main deposits of salt and of gypsum. There is also a transitional zone between the salt deposits and the overlying shales and sands of the upper lake beds, but the main salt body is distinctive. The salt has been leached in places and is covered with a mantle of reddish saline clays. Very little is exposed at the surface, but some of it approaches close to the surface and is distinguished by a peculiar "steplike" structure, by



A. HOGBACK OF CELESTITE WITH GYPSUM IN BACKGROUND, AVAWATZ SALT & GYPSUM CO., SAN BERNARDINO COUNTY, CAL.



B. BEDDED STRUCTURE IN CELESTITE, AVAWATZ SALT & GYPSUM CO., SAN BERNARDINO COUNTY, CAL.

the formation of hard crusts, or by saline efflorescences. Detailed measurements of thickness are difficult to make until developments have progressed farther than at present.

The quantity of rock salt present must be very great. Where it has been worked its purity has increased with depth. Some chemical analyses show that it is 98 per cent pure. It is massively crystalline. Its color is generally brownish near the surface, the discoloration being usually due to reddish-brown clay, the color of which is in turn due to iron oxide.

DANBY.

Salt has been mined 30 miles southeast of Danby, a station on the Atchison, Topeka & Santa Fe Railway, in the southeastern part of San Bernardino County, in T. 7 N., R. 16 E., on a dry lake known as Danby Lake. The old mines are 6 miles from the south end of Old Womans Mountain. The salt lies in two beds, each ranging from a few inches to several feet in thickness, separated by a thick layer of clay and protected by a layer of sand and dust. The salt bed has been developed over a tract covering many acres, which includes, however, only a small part of the deposits. When the mines were worked, the salt was hauled in traction wagons to Danby, where it was sold to chloridize silver ore. The shafts are said to have passed through salt 22 feet thick in one place and 35 feet in another. The salt was said to be 98 per cent pure. A small house built of rock salt has been erected at the lake.

MOHAVE RIVER AND SINK.

The Mohave River rises in the San Bernardino Mountains, flows north and northeast through Barstow and Daggett along the line of the Atchison, Topeka & Santa Fe Railway, thence more nearly to the east, following the Los Angeles & Salt Lake Railroad to Soda Lake, which is the sink of Mohave River, otherwise known as Mohave Sink. Silver Lake, north of Soda Lake, is in the basin of this river and the divide between Silver Lake and Silurian Dry Lake,[1] which is the source of the south fork of Amargosa River, is only 30 feet high and consists of sand, the two river systems being separated by this low, frail barrier. Mohave River is about 100 miles long and, except during flood season, has little surface flow, and then only in places where ledges lie athwart its course and force the water to the surface. The water of the river is saline but probably not so saline as that of Amargosa River. Saline efflorescences occur all along its course.

Soda Lake or Mohave Sink during the wet season contains water which on evaporation during the dry season leaves a crust of saline minerals, principally salt, sodium carbonate, and sodium sulphate, and small amounts of potash salts, borates, bicarbonates, and silica.

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[1] Mendenhall, W. C., Some desert watering places in southeastern California and southwestern Nevada: U. S. Geol. Survey Water-Supply Paper 224, p. 18, 1909.

During the wet season the degree of concentration of the solution has been found to range from 282 parts per 100,000 to complete saturation. The area of the sink is about 80 square miles.

Some salt has been made here by diverting water from the surrounding hills to certain parts of the lake. The salt is dissolved, and the brine is conveyed to vats and there evaporated. Only coarse salt has been marketed from the region.

Samples of brine have been collected by H. S. Gale from Soda Lake or the sink of the Mohave River, about 30 miles north of Ludlow, Cal. The analyses of these samples are given below. They show the saline material to consist principally of chlorides, sulphates, carbonates, and borates of sodium, and a small amount of potash. The analyses by R. K. Bailey do not indicate the presence of lime magnesium salts, but the analysis by Oscar Loew[1] shows considerable quantities of these bases. Loew's solutions were very dilute compared with those collected by Gale, but, as stated above, the degree of concentration of the solutions occurring in Soda Lake varies greatly, according to the season. The concentration of Loew's sample was approximately only one one-hundredth of that of the samples collected by Gale. The results of the analyses made in the Survey laboratory and Loew's results are as follows:

Analyses of brines from Soda Lake, San Bernardino County, Cal.

Radicles in grams per liter.

	104	105
K	0.009	0.01
Na	142.75	145.28
Ca	....	....
Mg	....	....
Cl	155.75	148.68
SO_4	65.00	74.59
CO_3	12.29	8.69
HCO_3	3.00	2.83
B_4O_7	2.62	2.39
	381.419	382.47

Radicles in percentage of anhydrous residue.

	104	105
K	0.002	0.002
Na	37.43	37.98
Cl	40.84	38.90
SO_4	17.05	19.50
CO_3	3.22	2.25
HCO_3	.78	.74
B_4O_7	.68	.63
	100.002	100.002

Combinations in grams per liter.

	104	105
KCl	0.01	0.01
NaCl	256.69	250.99
$CaSO_4$	None.	None.
$MgSO_4$	None.	None.
Na_2SO_4	96.14	110.32
Na_2CO_3	21.62	15.36
$NaHCO_3$	4.14	3.93
$Na_2B_4O_7$	3.40	3.10
	382.00	383.71

Combinations in percentage of anhydrous residue.

	104	105
KCl	0.01	0.01
NaCl	67.19	65.41
$CaSO_4$	None.	None.
$MgSO_4$	None.	None.
Na_2SO_4	25.16	28.75
Na_2CO_3	5.67	4.00
$NaHCO_3$	1.08	1.02
$Na_2B_4O_7$	.89	.81
	100.00	100.00

104. Brine from Soda Lake, San Bernardino County, Cal. Collected by H. S. Gale; R. K. Bailey, analyst. Specific gravity, 1.25.

105. Brine from Soda Lake, San Bernardino County, Cal. Collected by H. S. Gale; R. K. Bailey, analyst. Specific gravity, 1.26.

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[1] U. S. Geog. Surveys W. 100th Mer. Ann. Rept. for 1876, p. 196.

Analysis of water from the saline flats of Mohave River or Soda Lake, San Bernardino County, Cal.

[Parts per 100,000 parts of solution. Oscar Loew, analyst.]

Sodium chloride (NaCl)	170. 8
Sodium sulphate (Na_2SO_4)	63. 1
Calcium sulphate ($CaSO_4$)	21. 2
Magnesium sulphate ($MgSO_4$)	8. 5
Organic matter	19. 0
Potassium	Trace.
Lithium	Trace.
Phosphoric acid	Trace.
Silicic acid	Trace.
	282. 6

BITTER SPRINGS.

Bitter Springs, San Bernardino County, at the southeast end of Bitter Lake, in T. 13 N., R. 5 E. San Bernardino meridian, contain salt and sodium sulphate.

DAGGETT.

Beds of salt mixed with sand underlying the desert in the vicinity of Daggett, San Bernardino County, are reported to have been utilized years ago by silver miners. Salt is said to be associated with the borate minerals of the Calico district,[1] north and northeast of Daggett.

OWL SPRING DISTRICT.

The Owl Spring district is in the northwestern part of San Bernardino County, between the west end of Avawatz Mountains and the east flank of Owl Mountains, and was named from the well-known "Owl Hole" or "Owl Spring." The southwestern or higher part of the district, which abuts the mountains, contains colemanite and other borates, and the northeastern part contains deposits of rock salt and heavy salt crusts. Some niter also has been found.

OTHER LOCALITIES.

Other localities in San Bernardino County where salt is known to occur are the Salt Springs on the south fork of Amargosa River, at the southeast end of Death Valley; near Saratoga Springs, 14 miles northwest of Salt Springs (here the borax beds contain 20 per cent of salt); and Valley Springs, about 8 miles northwest of Saratoga Springs, whose water is so salty as to be undrinkable.

Valley Springs are probably formed by a part of the water of Amargosa River coming to the surface, as a rock reef extends across the valley and is exposed half a mile below the springs. An analysis of the water from the springs is as follows:

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[1] Bailey, G. E., The saline deposits of California: California State Min. Bur. Bull. 24, p. 128, 1902.

Analysis of water from Valley Springs, Cal.

[Grams per liter; Thomas Price, analyst.]

Sodium chloride ($NaCl$)	1,840.72
Sodium carbonate (Na_2CO_3)	1,724.11
Sodium sulphate (Na_2SO_4)	651.02
Sodium sulphide (Na_2S)	46.34
Potassium chloride (KCl)	132.30
Silica (SiO_2)	14.28
Organic matter	13.48

Willards Lake is in the northwestern part of San Bernardino County, in Tps. 30 and 31 S., R. 42 E. Mount Diablo meridian. The bed of the lake, like most lake beds in this region, is impregnated with salt, and the shore is marked with white crusts. Willard's well is at the northeast end of the dry lake and contains a good supply of slightly brackish water.

SAN LUIS OBISPO COUNTY.

Soda Lake or Salt Lake, in Carrizo Plain, contains important deposits of sodium sulphate, with which small amounts of ordinary salt are associated. Carrizo Plain is near the eastern boundary of San Luis Obispo County, and the lake is in T. 31 S., Rs. 19 and 20 E. (See fig. 13.) The lake receives the drainage of the plain and the surrounding mountain slopes. The saline deposits are estimated to cover an area of 2,800 to 3,000 acres, and they have the following composition:

Analysis of salt crust from Soda Lake, Cal.

[George Steiger, analyst.]

Insoluble matter	0.40
H_2O	3.65
Na	30.10
K	.23
Ca	.32
Mg	1.00
Al	.02
SO_4	55.29
Cl	9.27
	100.28

Exploitation of the deposits for sodium sulphate was undertaken, but operations were discontinued a few years ago and have not been resumed. Gale[1] reports that soluble potash salts are not associated with the sodium sulphate in sufficient quantity to be commercially significant.

Water from the following springs in the county has been analyzed and found to contain salt: Near El Paso del Robles—Mud Spring,

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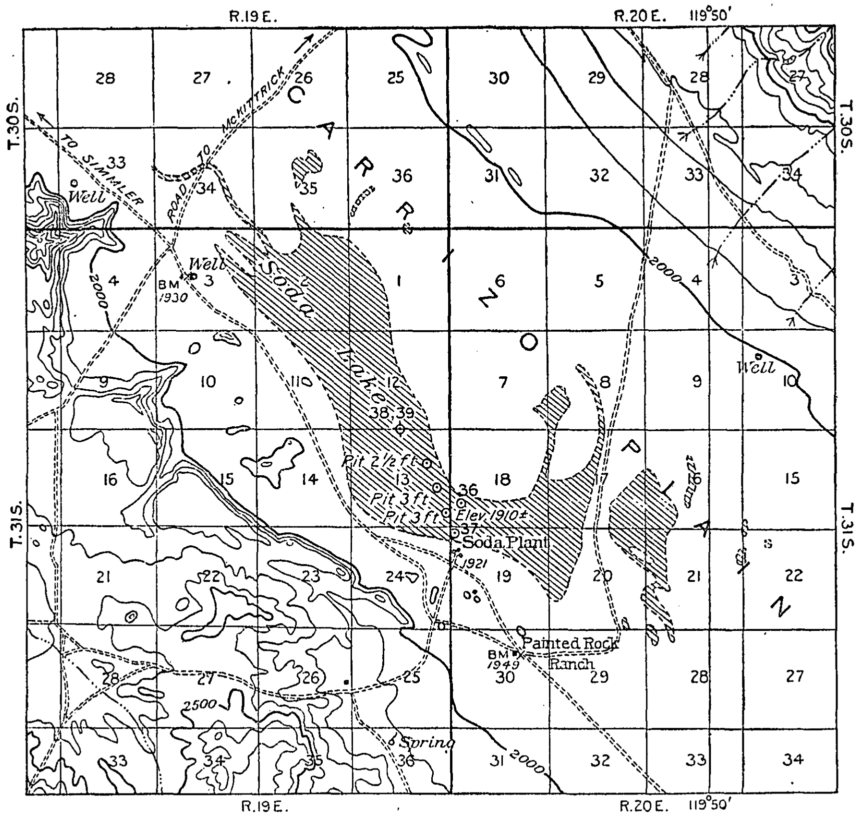
[1] Gale, H. S., Sodium sulphate in the Carrizo Plain, San Luis Obispo County, Cal.: U. S. Geol. Survey Bull. 540, pp. 428-433, 1914. Arnold, Ralph, and Johnson, H. R., Sodium sulphate in Soda Lake, Carrizo Plain, San Luis Obispo County, Cal.: U. S. Geol. Survey Bull. 380, pp. 369-372, 1909.

Sulphur Spring, Soda Spring, Garden Spring, Sand Spring, White Sulphur Spring, Iron Spring, and Congress Spring; at San Luis Obispo—Sycamore Spring.

OTHER COUNTIES.

Other places in the State where salt has been found in small quantities are as follows:

Calaveras County.—Salt springs occur on Mokelumne River, 6 miles south of Silver Lake.



Contour interval 100 feet

FIGURE 13.—Map of Soda Lake, San Luis Obispo County, Cal.

Contra Costa County.—Alhambra Mineral Springs.

Humboldt County.—Eureka Springs.

Lake County.—Allen Spring, Borax Lake, Lake Hachinhama, Hot Borate Spring, Clear Lake, Howard Spring, and Siegler Spring.

Los Angeles County.—According to G. E. Bailey[1] large salt springs are found 14 miles from the city of Los Angeles, but a more exact location is not given.

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[1] Op. cit., p. 136.

Modoc County.—Near Cedarville.

Napa County.—Aetna Springs, Calistoga Springs, White Sulphur Springs.

Placer County.—Salt springs are reported to exist near the Clipper Gap iron mine.

San Benito County.—Andersons Springs.

Santa Clara County.—Pacific Congress Springs, Alum Spring, Azule Spring, Blodgett Spring, near Gilroy, New Almaden Spring.

Shasta County.—Salt was made at one time on Salt or Stinking Creek, 12 miles east of Redding.

Siskiyou County.—Strong brine is reported to flow from a well near Yreka 675 feet deep.

Solano County.—Tolenas Springs.

Sonoma County.—Santa Rosa Spring, Skaggs Springs, White Sulphur Springs.

Tehama County.—Tuscan Springs, Little Salt Creek.

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The chapters on salt in the volumes of Mineral Resources of the United States published by the Geological Survey contain data on the occurrence and technology of salt in California and the United States in general.

ORIGIN AND FORMATION OF SALINE DEPOSITS.

AGE OF SALINE DEPOSITS.

The deposition of salt has been taking place probably during all geologic ages since the early Cambrian, and the process is observable at the present time. Many of the most extensive deposits of rock salt in the United States, like those of western New York and of certain parts of Michigan, were formed during late Silurian time. On the other hand, most of the deposits in the desert basins of the West represent accumulations during Quaternary time.

The following table represents the geologic distribution of salt in the United States:

Geologic distribution of saline deposits and brines.

Time.		Locality.
Recent.		Salt formed or forming in inland seas: Great Salt Lake, Utah; Lake at Zuni, N. Mex.; Owens, Searles, and Mono lakes, Cal.; alkali lakes of Oregon; salt plains or marshes in Oklahoma; trans-Pecos region of Texas, Nevada, New Mexico, Utah, California; widely scattered salt springs in Western States.
Tertiary.		Salt domes of Louisiana and Texas (part of Louisiana deposits are Quaternary and possibly late Cretaceous); deposits near Idaho-Wyoming border; Virgin River valley, Nev.
Jurassic.		Sevier Valley, Utah.
Carboniferous.	Permian.	Kansas, Oklahoma. northwestern and western Texas, eastern New Mexico.
	Pennsylvanian.	Along Ohio River near Pomeroy, Ohio, and Mason and Hartford, W. Va.; Malden, W. Va.
	Mississippian.	Saginaw Valley, Mich.; Saltville, Va.; Pittsburgh, Pa.
Silurian.		New York, Michigan (excluding Saginaw Valley), northern Ohio.

GENERAL PRINCIPLES OF DEPOSITION.

If a saturated solution of a salt is concentrated by evaporation, part of the salt is deposited in crystalline form until the solution has again reached equilibrium of saturation. Different salts possess different degrees of solubility, or in other words, different amounts of them saturate a given amount of water at a given temperature. Therefore, if a solution containing equal amounts of several salts is gradually concentrated by evaporation one salt reaches its point of saturation and begins to crystallize before the others, forming a deposit of that salt; subsequently another salt reaches its point of saturation and forms a deposit mixed with more or less of the first salt, which is still depositing. Finally, after all the water except that retained in the crystals has been evaporated, a series of deposits, remains, grading from the deposit of the salt which first reached saturation at the bottom through various proportions of the others to a deposit of the most soluble salt at the top. If the supernatant liquid is removed before the second salt reaches its point of saturation, the deposit of the first salt is only slightly contaminated by adhering solution and can be rendered very pure by being dissolved in fresh water and recrystallized. This is the principle of the ordinary process of purification by fractional crystallization. If, on the other hand, more of the original mixed solution is added before the second salt begins to crystallize, the concentration of the first salt is decreased less than that of the others, and the deposition of it is thereby retarded less; consequently a thick deposit of the first salt may gradually be formed by continuous evaporation and successive additions of mixed solution, until finally the concentration of the other salts in the solution becomes so great that they also begin to deposit. This is the principle of separation followed in the grainer process. These fundamental processes, which can be demonstrated in any laboratory, are generally believed to have been followed in the formation of natural saline deposits.

Sea water is the most abundant natural saline solution, and it is generally believed that most of the great natural saline deposits of the world have been formed in accordance with the principles just outlined by evaporation of oceans or of sea water in semidetached arms of oceans. Whether the sea water from which such depositions have occurred had the same composition as the present ocean is conjectural, though many natural conditions support that common belief. According to Dittmar and others (see p. 219) the mineral matter in sea water has in round numbers the following composition:

Approximate average composition of the mineral matter in sea water.

Radicles.		Conventional combinations.	
Chloride (Cl)	55.3	Sodium chloride ($NaCl$)	77.8
Sodium (Na)	30.6	Magnesium chloride ($MgCl_2$)	10.9
Sulphate (SO_4)	7.7	Magnesium sulphate ($MgSO_4$)	4.7
Magnesium (Mg)	3.7	Calcium sulphate ($CaSO_4$)	3.6
Calcium (Ca)	1.2	Potassium sulphate (K_2SO_4)	2.5
Potassium (K)	1.1	Magnesium bromide ($MgBr_2$)	.2
Carbonate (CO_3)	.2	Calcium carbonate ($CaCO_3$)	.3
Bromide (Br)	.2		100.0
	100.0		

The order and the magnitude of natural saline deposits conform in general to the relative abundance and solubility of salts indicated in this table. Sodium chloride, the most abundant salt in sea water, is most abundant in saline deposits, and calcium sulphate, relatively small in quantity in sea water but also very low in solubility, ranks next in abundance in deposits. The salts of magnesium and potassium, more especially the chlorides, are very soluble and are present in small proportion and consequently are less abundant in deposits. The order of deposition in general is in reverse order of solubility, but the presence of several compounds in the solution and the continually changing concentration of them affects materially their solubility and consequently their rate of deposition. The values in the following table show that calcium sulphate, for example, is relatively insoluble in pure water but is much more soluble in solutions containing chlorides. Mass action and the crystallization of double salts also increase the complexity, so that the order and other phenomena of the deposition become extremely complicated.

The study of the solubility of definite salts in solutions containing various other salts constitutes a branch of physical chemistry. The results are usually expressed by curves. Examples of such curves may be found in any work on the phase rule,[1] which deals especially with the character and composition of the solid phases or salts that may be formed at certain temperatures. Curves showing the solubility of all common salts in pure water at different temperatures may be found in the physicochemical tables of Landolt-Börnstein-Roth. The solubilities of oceanic salts were determined by Van't Hoff, whose results have been published in special papers. Illustrations of all these solubility measurements may be found in books on the phase rule.

In the following table are given the solubilities of certain salts, most of which are present in ocean water and enter in varying quantity into the saline deposits resulting from either the complete or partial desiccation of such water.

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[1] For example, Findlay, Alexander, The phase rule and its applications, Longmans & Co., 1904.

Solubility of certain salts.[a]

Salt.	Temperature.	Amount of pure compound without water of crystallization—	
		Dissolved in 100 grams of water.	Dissolved in 100 cubic centimeters of the solution.
	° *C.*	*Grams.*	*Grams.*
Sodium chloride (NaCl)	0	35.7	
Do	10	35.8	
Do	25	36.12	
Do	50	37.0	
Do	100	39.8	
Sodium sulphate ($Na_2SO_4.10H_2O$)	0	5.0	
Do	25	28.0	
Sodium sulphate ($Na_2SO_4.7H_2O$)	0	19.5	
Do	25	53	
Sodium bromide (NaBr)	0	66	
Do	20	77	
Sodium iodide ($NaI.2H_2O$)	0	158.7	
Do	25	184.2	
Potassium chloride (KCl)	0	27.6	
Do	25	35.5	
Potassium sulphate (K_2SO_4)	0	7.35	
Do	25	10.75	
Potassium bromide (KBr)	0	53.5	
Do	25	67.7	
Potassium iodide (KI)	0	127.5	
Do	25	148	
Calcium chloride ($CaCl_2.6H_2O$)	0	59.5	
Do	20	91.0	
Calcium sulphate ($CaSO_4.2H_2O$)	0		0.1759
Do	25		.2080
Do	25		[b] .426
Do	25		[c] .569
Do	25		[d] .1620
Do	25		[e] .1471
Do	26		[f] .666
Do	26		[g] .650
Magnesium sulphate ($MgSO_4.7H_2O$)	0	26.9	
Do	25	38.5	
Magnesium chloride ($MgCl_2.6H_2O$)	0	52.8	
Do	25	56.7	
Magnesium bromide ($MgBr_2.6H_2O$)	0	91.9	
Do	25	97.6	
Magnesium iodide ($MgI_2.8H_2O$)	25		[h] 54.4

[a] Seidell, Atherton, Handbook of solubilities, New York, 1907.
[b] Solution containing 8.5 grams per liter of $MgCl_2$.
[c] Solution containing 19.8 grams per liter of $MgCl_2$.
[d] Solution containing 3.20 grams per liter of $MgSO_4$.
[e] Solution containing 10.64 grams per liter of $MgSO_4$.
[f] Solution containing 91.15 grams per liter of NaCl.
[g] Solution containing 264.17 grams per liter of NaCl.
[h] Dissolved in 100 grams of the aqueous solution.

Calcium carbonate may be ignored in this discussion, as it is not strictly to be considered among the salines, and its manner of deposition is radically different from that of other substances.[1]

The physicochemical principles just outlined have been applied in discussing the formation of saline deposits. The first theory here summarized and the one that has obtained the widest acceptance is the bar theory of Ochsenius, by which he explains the formation of the

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[1] Vaughan, T. W., Preliminary remarks on the geology of the Bahamas, with special reference to the origin of the Bahaman and Floridian oolites; Carnegie Inst. Washington Pub. 182, pp. 47-54, 1914; also The building of the Marquesas and Tortugas atolls and a sketch of the geologic history of the Florida reef tract: Idem, pp. 55-67. Drew, G. H., On the precipitation of calcium carbonate in the sea by marine bacteria: Idem, pp. 7-45

well-known deposits at Stassfurt, Germany. Russell's discussion of an important corollary of the bar theory, the desiccation theory, explaining the process of burial of salines, particularly in the Great Basin of the United States, is next quoted. This discussion is followed by general consideration of the origin of brines, the origin of rock salt in the Salina of New York, Ontario, and Michigan, and references to various types of saline deposits with their essential peculiarities. Finally, the stratigraphy and mineralogy of the great potash beds of Germany are reviewed, as these deposits offer the largest and most nearly complete record of saline deposition thus far discovered.

THE BAR THEORY OF OCHSENIUS.

The theory developed by Ochsenius[1] in regard to the origin of the Stassfurt deposits is known as the "bar" theory. Ochsenius maintained that deposits of such magnitude, purity, and uniformity of development as those in the Permian section at Stassfurt, Germany, could be produced only by overflowing of the sea into shallow coastal lagoons and subsequent evaporation of the sea water and the deposition of its saline content.

The salts dissolved in sea water are of the same chemical nature as those in the Stassfurt deposits. Sea water contained, however, less than 4 per cent of salts, and consequently the evaporation of a single body of sea water, even of great depth, could leave a saline deposit of relatively slight thickness; therefore the origin of a series of deposits like those at Stassfurt, with a thickness of 3,000 to 4,000 feet, can be postulated only on the theory of periodic additions of sea water. Ochsenius asserts that at least 40 periods of deposition must have occurred in order to produce only the average thickness of the Stassfurt deposits.

The inland sea or lagoon in which the deposits of salts are supposed to have formed is assumed by Ochsenius to have been cut off from the ocean by a bar of such width and height that only so much sea water could flow into the inclosed sea as could be evaporated from its surface. To accomplish the evaporation a climate with small rainfall and conditions of drainage that preclude the inflow of much fresh water are postulated. If the bar were too low, as in the Strait of Gibraltar, an outward undercurrent would result from the inflowing superficial current, and the more strongly concentrated solutions, which would sink by virtue of greater specific gravity, would flow back into the open ocean. If the bar were too high, continuous union of the inland sea and the ocean would be lacking. But under the conditions postulated by Ochsenius all the ocean water entering the inclosed basin would leave its saline content during each period of

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[1] Ochsenius, C., Die Bildung der Steinsalzlager und ihrer Mutterlaugensälze, Halle, 1877.

evaporation, and deposits would form whose thickness would be dependent only on the duration of the process and the depth of the inclosing basin. In the lowest part of the deposit calcium and magnesium carbonates would form. The point of saturation of the solution for calcium sulphate would next be reached, and its separation would follow. Then sodium chloride, or common salt, would separate. Thus it is explained why rock salt usually rests on a layer of gypsum or anhydrite, as well as why rock salt is found interbedded with those minerals. The thickness of the mass of precipitated salts and the quantity of the more soluble potassium and magnesium salts in the supernatant bittern would increase as evaporation proceeded. If no special conditions existed after the upper surface of the bittern reached the top of the dam or bar, a further rise in the former (corresponding to a fall in the bar) would cause a reflux of the heavy mother liquors into the open ocean, as at the Strait of Gibraltar. In this manner is explained the absence of potash and magnesium salts from the deposits of anhydrite and rock salt of various geologic ages.

In its fundamental principles the bar theory of Ochsenius furnishes at least a logical explanation of the primitive origin of the Permian salt deposits. The progress of geologic disclosures and the more recent chemical investigations of Van't Hoff and his associates have, however, added greatly to conceptions of the mode of formation of the Permian series. It should be added that Ochsenius's conception of the primitive mode of origin of the Stassfurt series did not meet with universal acceptance. It was sharply criticized by J. Walther[1] and E. Erdmann.[2]

Another theory, advanced by Walther, explains them by lixiviation of the saline contents of sedimentary rocks and accumulation of the resulting solutions in desert basins. The massiveness and homogeneity of the Stassfurt deposits, their chemical structure as a whole, and the entire lack of clastic sediments from which the salts might have been derived are weighty points in opposition to Walther's theory. It was held to be untenable and was ably disputed by Ochsenius himself.

DESICCATION THEORY.

Deposits of salt resulting from the evaporation of inclosed seas or lakes are not uncommon. The salt fields in Osobb Valley, Nev., the saline deposits left by the evaporation of Middle Lake in Surprise Valley, Cal., in 1872, and the broad salt field covering the desiccated basin of Sevier Lake, Utah, are examples. Russell[3] states, however, that deposits of this character which have resulted directly from the

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[1] Das Gesetz der Wüstenbildung, Berlin, 1900; Ochsenius's answer to Walther's criticism, Centralbl. Mineralogie, pp. 551-557, 1902; Walther's rejoinder Centralbl. Mineralogie, p. 211, 1903.

[2] Zeitschr. angew. Chemie, vol. 21, p. 1265, 1908; vol. 22, p. 238. 1909.

[3] Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U. S. Geol. Survey Mon. 11, p. 223, 1885.

evaporation of the former Lake Lahontan are nowhere to be found in the deposits of the Lahontan basin. He says:

> The accumulations of common salt, sulphate of soda, etc., occurring in considerable quantities at certain localities have in all cases been deposited since the evaporation of the former lake. In some instances these accumulations are due to the leaching of saline clays and the evaporation of the resultant brine in restricted areas, as in the case of the salt fields in Alkali Valley; at other times saline deposits of considerable thickness have resulted from the evaporation of spring waters. Over very large areas the Lahontan beds are frequently whitened with a saline efflorescence, which also owes its accumulation to secondary causes.
>
> Wherever the Lahontan sediments have been examined they have been found more or less highly charged with salts of the same character as those that were most common in the waters of the former lake. The total quantity of saline matter thus imprisoned is certainly very great and is assumed to represent the more soluble substances contributed to Lake Lahontan.
>
> The apparent anomalous phenomena of the dessiccation of a great lake without leaving a surface deposit of salt seems explicable in only one way. Adopting the suggestion advanced by Gilbert[1] in explanation of some portion of the history of Lake Bonneville, the absence of saline deposits is accounted for by the hypothesis that they were buried and absorbed by lacustral clays and playa deposits during periods of desiccation.
>
> The freshening of a lake by desiccation may be illustrated in all its stages in the various basins that have been examined in the far West. A lake after a long period of concentration becomes strongly saline, and finally evaporates to dryness, leaving a deposit of various salts over its bed. During the rainy season the bottom of the basin is converted into a shallow lake of brine which deposits a layer of sediment; on evaporating to dryness during the succeeding arid season, a stratum of salt is deposited, which is, in turn, covered by sediment during the succeeding rainy season. This process taking place year after year results in the formation of a stratified deposit consistof salts and saline clays in alternating layers. The saline deposits may thus become more and more earthy until the entire annual accumulation consists of clays. The site of the former lake then becomes a playa. A return of humid conditions would refill a basin of this character and might form a fresh-water lake, the bottom of which would be the level surface of the submerged playa.
>
> The larger lakes of the Lahontan basin, as well as a number of less importance in eastern Nevada and southern Oregon, are without outlet. They occur in basins that in almost all cases were occupied by much larger water bodies during the Quaternary, which, like their modern representatives, never overflowed. From the long period of evaporation that has taken place one would expect the existing lakes to be dense mother liquors. The fact is, however, that they are but slightly charged with saline matter, and in some instances are sweet to the taste and sufficiently fresh for all culinary purposes. In many localities the lacustral beds surrounding and underlying the present lakes are highly charged with soda salts, which rise to the surface during the dry season as efflorescences. As these lake basins were never filled to overflowing, we are forced to conclude that influx was counterbalanced solely by evaporation, and that during periods of extreme desiccation the saline deposits became buried and absorbed by the marls and clays which accumulated in the valleys.

Russell further develops this theory in a later contribution:[2]

> As shown by the average composition of river water, about one-half of the total solids carried in solution by surface streams is calcium carbonate. This is the most

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[1] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, p. 208, 1890.

[2] Russell, I. C., Present and extinct lakes of Nevada: Nat. Geog. Soc. Mon., vol. 1, No. 4, pp. 101-132, 1895.

difficult of solution of any of the salts ordinarily found in such waters, and the first to be precipitated when concentration by evaporation takes place. The more soluble salts consist mainly of sodium sulphate, sodium carbonate or bicarbonate, sodium chloride, magnesium, potash, iron, etc.

The amount of these more soluble substances carried into Lake Lahontan must therefore have been about equal to the amount of calcareous tufa precipitated. As the lake never overflowed, these salts must still exist in its now nearly desiccated basin; yet, in riding through the valleys that were formerly flooded, no deposits of the salts referred to can be found at all commensurate with the vast quantity of calcium carbonate that attracts one's attention. The disappearance of the salts referred to seems to be satisfactorily explained in the following hypothesis:

After the last great rise of Lake Lahontan there was a long-continued episode during which its basin was more arid than at present. Evaporation during that time is thought to have been equal to precipitation, and the residual lakes were reduced to the playa condition—that is, the remants of the great lake gathered in the lowest depressions of its basin were annually or occasionally evaporated to dryness, and their contained salts were precipitated and either absorbed by the clays, etc., deposited at the same time, or buried beneath such mechanical deposits. The process may be observed in action in many of the valleys of Nevada in which ephemeral lakes occur. The broad, naked playas of Black Rock, Smoke Creek, and Carson deserts, as well as the level floors of the basins occupied by Pyramid, Winnemucca, and Walker lakes, are in support of this hypothesis. Should the lakes just mentioned be evaporated to dryness, playas would be left similar to those in neighboring valleys of less depth. It is beneath the level floors of these valleys and lake basins that the more soluble salts once dissolved in the waters of Lake Lahontan are buried. Borings at certain localities might reveal the presence of strata of various salts, but in most cases they are probably disseminated through great thicknesses of clay, sand, and other mechanical sediments.

Deposits of salt and gypsum must have formed in past geologic epochs by direct deposition from original solution or by leaching from other salt beds or diffused salts in adjoining areas, followed by deposition. Deposits formed by the first method may be termed primary and those formed by the last method secondary. The existence of such deposits therefore indicates the former presence of continental seas or of arms of the ocean which were separated from it by the uplifted parts of the earth's crust or by bars or reefs. The saline content of such waters has been increased by influxes from the sea or from streams. A necessary further condition is evaporation in a comparatively rainless climate like that in many deserts of the world to-day. All these conditions have doubtless existed in some part of the earth's surface ever since continents have existed and have been subject to oscillation.

The salt domes of Louisiana and Texas are most probably examples of secondary deposits formed by subterranean leaching of other deposits. The salt in these domes was derived by leaching of older salt deposits and was later redeposited or crystallized from ascending solutions among Tertiary, Quaternary, and possibly late Cretaceous beds. The age of the rocks from which this salt was derived is not known, but it may have been late Paleozoic or early Mesozoic. The beds of rock salt in southwestern Virginia also are secondary.[1]

The most instructive example of what is usually considered, at least in its main features, as a primary saline deposit is that known as the Stassfurt deposit, in which the complete or nearly complete series of salts was formed and has been preserved so perfectly and on so grand a scale that the deposit constitutes the only important source of potassium salts now known in the world. The only other noteworthy occurrences of potassium or mother liquor salts are those at Kalusz and Stebnik in Galicia, and those in Alsace.[2] The deposits in Spain and Chile are not well known, and only a few commercial reports have been issued with regard to them.[3]

FORMATION OF ROCK SALT IN MICHIGAN, NEW YORK, AND ONTARIO.

The formation of rock salt has been explained by two hypotheses, one assuming it to be of marine origin and the other to be of continental origin. The marine origin of salt beds has already been outlined as the bar theory (pp. 197–198).

The continental theory has been stated by Grabau and Sherzer[4] in accounting for the deposits of rock salt in the Salina formation of Michigan, New York, and Ontario. After the disappearance of the Niagaran sea from continental North America and during the ensuing arid period, the deposition of Salina muds began in the Michigan-Ontario-New York area, which consisted of one or more basin-shaped depressions. As these muds were derived from the Niagaran rocks, which are largely calcareous, the deposits were likewise calcareous, though the argillaceous sediments are abundant, especially in Michigan. During exposure of these limestones, which were impregnated with a small percentage of saline matter, salt and gypsum appeared on them as an efflorescence, which during rainy periods was dissolved and washed toward the center of the basin, where it was deposited by evaporation just as salt is being deposited in the desert basins of to-day. Before that time the Salina sea had occupied only the deeper basin where rock salt is now found. The general conclusion is drawn by Grabau and Sherzer from their calculations that the Niagara rocks alone were able to furnish all the salt that exists in the Salina of New

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[1] Stose, G. W., Geology of the salt and gypsum deposits of southwestern Virginia: U. S. Geol. Survey Bull. 530, p. 255, 1913.

[2] Boeke, H. E., Uebersicht der Mineralogie, Petrographie, und Geologie der Kalisalz-Lagerstätten, Berlin, 1909. Die Kalibergwerke im Oberelsass; abstracted from Jahresb. der Industriellen Gesell. von Mülhausen, im Elsass, Strassburg, 1913.

[3] Hurst, C. B., U. S. Consul General, Barcelona, Spain: Supplement to Commerce Reports No. 15 C, July 10, 1915. Salcedo, S., Eng. and Min. Jour., vol. 100, p. 218, Aug. 7, 1915.

[4] Grabau, A. W., and Sherzer, W. H., The Monroe formation of Michigan and adjoining regions: Michigan Geol. and Biol. Survey, Pub. 2, Geol. ser. 1, pp. 235-236, 1910.

York, Ontario, and Michigan. Turrentine,[1] however, believes that certain assumptions made by Grabau and Sherzer unnecessarily introduce doubtful elements.

If the theory propounded by Grabau and Sherzer is correct there appears to be no hope of finding potash salts in the Salina of either New York or Michigan, unless such salts were occluded and later deposited with the common salt in the Niagaran. In view, however, of the explanation given by Grabau and Sherzer that the salt and gypsum in the Salina deposits represent the old sea salt imprisoned in the Niagaran and earlier marine strata at the time of their formation under the sea and their statement that the beginning of the period during which the Salina deposits were formed was characterized by the withdrawal of the widespread Niagaran sea it appears to be a warrantable assumption that desiccation of the Niagaran sea may not have proceeded to the point where potassium salts would have been deposited. It is interesting to note in connection with this discussion that the upper strata of the salt beds in New York contain a larger proportion of magnesium chloride than the lower strata,[2] a condition that indicates final deposition from the mother liquor.

THE DEAD SEA.

The Dead Sea in Palestine furnishes a present-day example of an inclosed sea that is becoming more strongly saline by the influx of salts dissolved in its affluents. Its water is a bittern, the result of evaporation during a long period. Its large content of magnesium chloride ($MgCl_2$) proves that much of its sodium content has already separated. Since this body of water has inflowing streams and no outflowing streams, the water added to it is expelled only by evaporation, which leaves behind the salts carried in solution. The River Jordan, the principal affluent, is rich in dissolved salts obtained by the leaching of sediments in the area from which it flows. It is particularly rich in sodium and magnesium chlorides, containing in 100,000 parts, 52 parts of sodium chloride and 32 parts of magnesium chloride. From this river water the sodium chloride will separate first, leaving calcium chloride and magnesium chloride behind. As soon as the river water reaches its destination, it loses sodium chloride at the same rate at which it takes up magnesium chloride. In the Dead Sea, therefore, there has resulted a mother liquor, which at a depth of 650 feet contains in every 100 parts 25.3 parts of dissolved salts, which reduced to percentages are as follows:

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[1] Turrentine, J. W., The occurrence of potassium salts in the salines of the United States: U. S. Agr. Dept. Bur. Soils Bull. 94, p. 22, 1913.

[2] Merrill, F. J. H., Salt and gypsum industries in New York: New York State Museum Bull. 11, p. 62, 1893.

Salts dissolved in water of Dead Sea.

Sodium chloride (NaCl)	25.2
Magnesium chloride ($MgCl_2$)	64.75
Potassium chloride (KCl)	3.4
Calcium chloride ($CaCl_2$)	4.3
Magnesium bromide ($MgBr_2$)	2.0
Potassium sulphate (K_2SO_4)	.3
	99.95

Complete evaporation of this body would yield a saline deposit consisting principally of magnesium chloride, with which would be associated sodium, calcium, and potassium chlorides and smaller amounts of bromides and sulphates.

KARABOGHAZ GULF.

Continuous deposition of salt in a partly inclosed arm of a sea is now taking place in the Karaboghaz, a gulf on the eastern side of the Caspian Sea. Though the water of the Caspian Sea contains only 1.3 per cent of saline matter, the water of the gulf contains 28 per cent.[1] Water continuously flows from the sea into the gulf and is there evaporated. A continually thickening layer of rock salt and Glauber salt is forming on its bed, and a gypsum crust is forming along its shore.

THE STASSFURT DEPOSITS.

EXTENT AND DEVELOPMENT.

The term Stassfurt deposits is misleading, as the German potash deposits are of much broader areal distribution than the territory near Stassfurt. They occur in a large area in middle and northern Germany and also on the lower Rhine.[2]

Geologically the city of Stassfurt is in the southeastern part of the Magdeburg-Halberstadt-Zechstein Basin. The natural boundary of this basin on the south is the Harz Mountains and on the north or northeast is the Flechtinger Höhenzug. The basin is open to the west. Geographically the city is in the central part of Germany, at the northern border of the Duchy of Anhalt, not more than 20 miles from Elbe River.

Mining operations were commenced about 1857, and the first two mines on the so-called Stassfurt saddle are those of Heydt and Leopoldshall. The potash industry developed rapidly during the last quarter of the nineteenth century; shafts were sunk north and

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[1] Analyses by C. Schmidt, Acad. Sci. St.-Pétersbourg Bull., vol. 24, p. 177, 1878; quoted by Clarke, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 616, p. 166, 1916.

[2] The plates contained in Deutschlands Kalibergbau, Berlin, 1907, give a good idea of the areal extent and the degree of exploitation of the German deposits of potash salts up to that year.

south of the Harz Mountains; operations were pushed into the province of Hanover, and during the last few years they have extended into the northern and northwestern parts of that province. East of the Flechtinger Höhenzug deposits of potash have been encountered in a number of borings, among which are those at Sperenberg and Rüdersdorf, near Berlin. In northern Germany deposits of potash salts are known and are worked at Ilssenitz and Friedrich Franz (Lübtheen), in the northwest corner of Mecklenburg-Schwerin.

ZECHSTEIN SECTION.

Only the saline series of the Stassfurt-Egeln saddle corresponds completely with the theoretical arrangement of salts deposited from evaporated sea water. It is, therefore, a singular coincidence that these salts should have been discovered in true theoretical arrangement in the small area in which the industry had its beginning and in which, therefore, the deposits were first studied and are best known. Hence the Stassfurt type of the immense Zechstein (Upper Permian) deposits may be considered the primary type, of which all other deposits are modifications. The section of the Zechstein deposits at Stassfurt from the lower boundary of the Buntersandstein (lower Trias) downward is as follows:

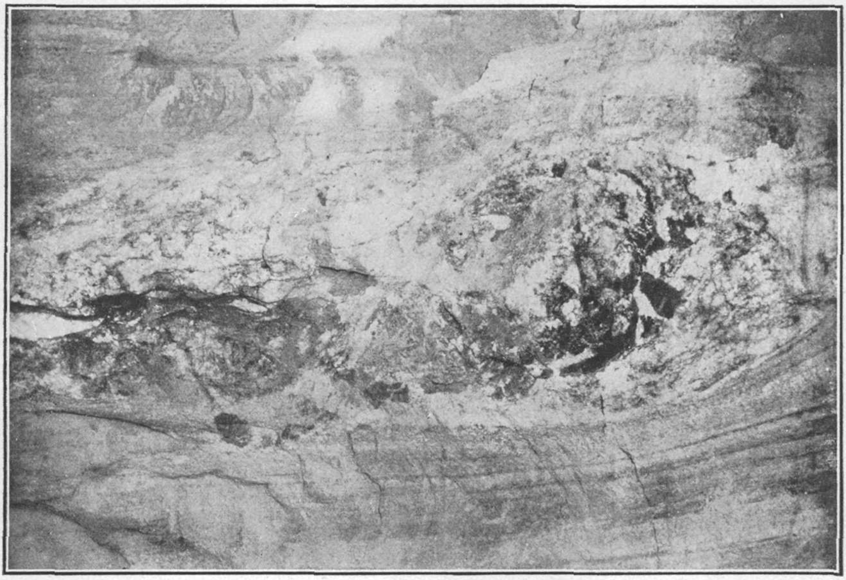
Section of saline deposits at Stassfurt, Germany.[a]

Material.	Thickness.
	Meters.
1. Massive red clay; contains nodules of anhydrite and streaks of rock salt. At its lower boundary occurs a layer of anhydrite 0.3 meter to 3 meters thick	20–30
2. Rock salt	50
3. Anhydrite; contains scattered crystals of rock salt	1–5
4. Massive red clay; contains nodules of anhydrite and streaks of rock salt	5–15
5. Younger rock salt	100–150
6. Younger anhydrite (Hauptanhydrite)	40-90
7. Gray saline clay	4–10
8. Carnallite region (Kalimutter layer)	30-40
9. Kieserite region	20–40
10. Polyhalite region	40-60
11. Older rock salt (anhydrite region)	300–500
12. Older anhydrite; interbedded with bituminous dolomite rock (stinkstone) and one or two layers of rock salt, aggregating in thickness 10-15 meters	70–100
13. Zechstein chalk or limestone	4–10
14. Cupriferous slate, Zechstein conglomerate	0.5–4

[a] Everding, H., Deutschlands Kalibergbau, Berlin, p. 36, 1907. This section agrees in its main features with that of C. Reimann, Die Geologie der deutschen Salzlagerstätten, Stassfurt, p. 20, 1908. See also the section of L. Loewe, Zeitschr. prakt. Geologie, 1903, pp. 332–333.

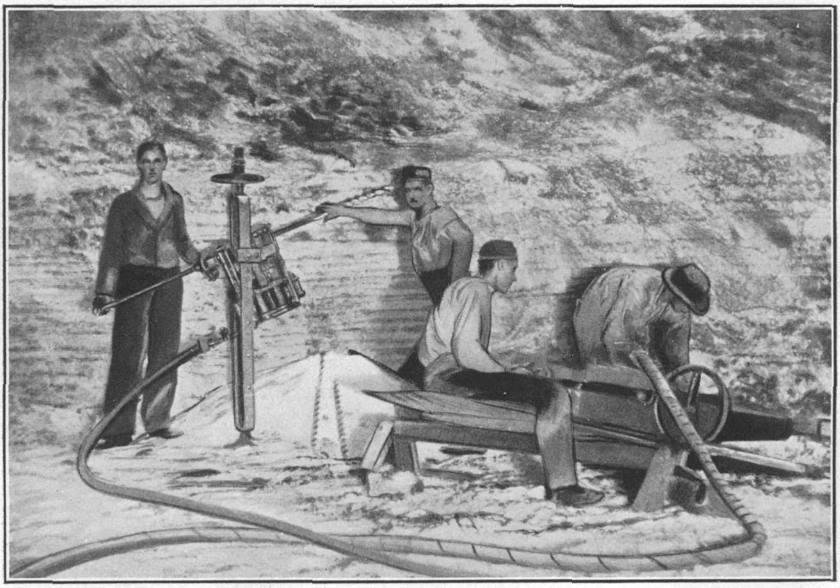
This section may be compared with the diagram (fig. 14) representing a section in the shaft of the Ludwig II mine at Stassfurt.

The Zechstein limestone (13), the principal member of the lower part of the section, is a purely marine formation. The deposits above it, with the exception of the intermediate beds of clay (4 and 7), represent materials precipitated from evaporated sea water. The beds of clay indicate interruptions in the process of desiccation, during which there were influxes of muddy water containing suspended



A. BED OF "MIXED SALT," LIVONIA SALT MINE, LIVONIA, N. Y.

From Report of New York State Geologist, 1896 (Pl. I).



B. STRATIFIED SHALE AND SALT, BEVIS ROCK SALT CO.'S MINE, LYONS, KANS.

Photograph by Sam Ainsworth.

material that formed layers of clay or shale. Such intermediate layers are characteristic of salt deposits and have been observed in the salt mines of New York, Kansas, and other States.[1] (See Pl. XVII.)

The older saline series begins with the masses of anhydrite (12) of the middle Zechstein, most of the middle portion of which is the so-called older rock salt (11). The end member of the middle Zechstein is the carnallite region (8). In the section (fig. 14) gray saline clay (7) is represented overlying the carnallite region.

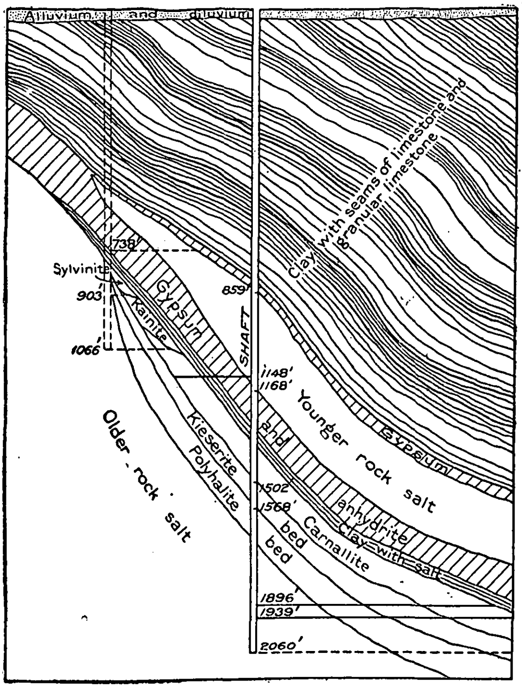


FIGURE 14.—Section of shaft in German potash mine, Ludwig II, Stassfurt, Germany. (After a figure in "The Stassfurt industry," published by the German Kali Works.)

At Douglashalle a layer of salt intervenes between the carnallite and the clay. In parts of the field kainite overlies the carnallite and is in turn overlain by sylvinite, as is illustrated in the section at the Ludwig II mine (fig. 14). The total thickness of the older rock salt (11), the polyhalite region (10), and the kieserite region (9) is estimated by Loewe[2] to range from 150 to 1,000 meters. As the older rock salt is impregnated with anhydrite, it is designated the anhydrite region in the section. The gypsum bands are interpreted as annual deposits (Jahres Ringe) due possibly to seasonal variations in temperature or to alternating drought and rain.

Above the intermediate layer of saline clay (7) there follows a younger series of salts, beginning with another massive deposit of anhydrite (6), and continuing upward with rock salt (5). Unlike the lower series it is not capped by a zone of potash salts but is overlain by a bed of red clay permeated with nodules of anhydrite (4). Above this intermediate clay anhydrite (3) and rock salt (2) are again repeated. This youngest and comparatively thin bed of salt is not succeeded at Stassfurt by mother-liquor salts but is capped by

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[1] Luther, D. D., The brine springs and salt wells of the State of New York and the geology of the salt district: New York State Geologist Sixteenth Ann. Rept., pp. 175-226, 1899.

[2] Loewe, L., Zeitschr. prakt. Geologie, 1903, p. 333.

a deposit of red clay containing anhydrite nodules and having a thin layer of anhydrite at its base. The red clay is overlain by clay sediments of the lower Buntersandstein.

MINERALOGY.

The number of minerals mined on a commercial scale at Stassfurt is small compared with the total number found there. Thus far approximately 30 minerals have been found. They comprise chiefly the chlorides and sulphates, the main mineral constituents of sea water, as shown in the list below: [1]

Minerals in the saline deposits, Stassfurt, Germany.

Abundant and widely distributed minerals.

Anhydrite	$CaSO_4$.	Rock salt	$NaCl$.
Gypsum	$CaSO_4.2H_2O$.	Sylvite	KCl.
Kieserite	$MgSO_4.H_2O$.	Carnallite	$MgCl_2.KCl.6H_2O$.
Kainite	$MgSO_4.KCl.3H_2O$.		

Less abundant minerals.

Langbeinite	$K_2SO_4.2MgSO_4$.	Bischofite	$MgCl_2.6H_2O$.
Schoenite	$MgSO_4.K_2SO_4.6H_2O$.	Tachydrite	$CaCl_2.MgCl_2.12H_2O$.
Polyhalite	$MgSO_4.2CaSO_4.K_2SO_4.2H_2O$.	Boracite	$2Mg_3B_8O_{15}.MgCl_2$.

Rare minerals or minerals only locally abundant.

Glaserite	$KNa)_2SO_4$.	Krugite	$MgSO_4.4CaSO_4.K_2SO_4.2H_2O$.
Reichardite	$MgSO_4.7H_2O$.	Rinneite	$FeCl_2.3KCl.NaCl$.
Leonite	$MgSO_4(KNa)_2SO_4.4H_2O$.	Ascharite	$MgBO_3H$.
Astrakanite	$MgSO_4.Na_2SO_4.4H_2O$.		
Glauberite	$CaSO_4.Na_2SO_4$.		

Very rare minerals.

Loewite	$MgSO_4.Na_2SO_4.2\frac{1}{2}H_2O$.	Pinnoite	$MgB_2O_4.3H_2O$.
Vanthoffite	$MgSO_4. 3Na_2SO_4$.	Kaliborite	$KMg_2B_{11}O_{19}.9H_2O$.
Syngenite	$CaSO_4.K_2SO_4.H_2O$.	Sulfoborite	$Mg_6B_4O_{10}(SO_4)_2.9H_2O$.
Keonenite	$Al_2O_3.3MgO.2MgCl_2.6(or\ 8)H_2O$.		

The researches [2] of Van't Hoff and those of Precht and Boeke on the iron salts indicate that several more minerals (as listed below) may be found in the Stassfurt deposits. Some of them have already been found at other places.

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[1] Boeke, H. E., Uebersicht der Minerologie, Petrographie, und Geologie der Kalisalz-Lagerstätten pp. 10-11, 1909.

[2] Collected in Zur Bildung der ozeanischen Salzablagerungen, vols. 1 and 2, 1905 and 1909; also in Deutsch. chem. Gesell. Ber., vol. 12, p. 557, 1879; vol. 13, p. 2326, 1880. In part in K. Akad. Wiss. Berlin Sitzungsber., 1909, pp. 632-638; Kali, vol. 3, p. 147, 1909.

Minerals possibly present in the deposits at Stassfurt, Germany.

Sulphates.	Borates.	Chlorides.
Thenardite (Na_2SO_4).[a]	Tincal ($Na_2B_4O_7.10H_2O$).[a]	Tetrahydrated ferrous chloride ($FeCl_2.4H_2O$).
Hexahydrated magnesium sulphate ($MgSO_4.6H_2O$).	Octahedral borax ($Na_2B_4O_7.5H_2O$).	Dihydrated ferrous chloride ($FeCl_2.2H_2O$).
Potassium pentacalcium sulphate ($K_2SO_4.5CaSO_4.H_2O$).	Boronatrocalcite ($NaCaB_5O_9.8H_2O$).[a]	Ferrous magnesium chloride ($MgCl_2.FeCl_2.8H_2O$).
	Tetrahydrated sodium calcium borate ($NaCaB_5O_9.4H_2O$).	Douglasite ($FeCl_2.2KCl.2H_2O$).[b]
	Colemanite ($Ca_2B_6O_{11}.5H_2O$).[a]	
	Pandermite ($Ca_8B_{20}O_{38}.5H_2O$).[a]	

[a] Found in natural deposits at other places.
[b] Believed by Precht to be a mixture of rock salt, sylvite, and 3.5 per cent ferrous chloride.

Of the 28 saline minerals named above only 5 constitute the mass of the Stassfurt deposits[1]—rock salt, kieserite, sylvite, carnallite, and kainite. Kainite is limited almost entirely to the zone of alteration at the apices or saddles (hutzonen) of the Zechstein beds that are buried under and folded with the overlying Mesozoic rocks. The other salts also are found in these cap zones, but they occur as well in the deeper Zechstein deposits. The structure and appearance of the salts in the cap zones are, however, very different from those of the more deeply buried salines. The salts in the cap zones are usually believed to be secondary and those in the regular Zechstein series to be primary; some investigators believe, however, that changes took place in the Zechstein in the originally deposited salines, and if that is true they likewise may be considered truly secondary.

Dolomite (calcium-magnesium carbonate) occurs in the footwall of the salt deposits, but not a trace of it has been found in the salts themselves. Bromine accompanies the chlorine, particularly in the minerals bischofite, carnallite, and sylvite. Iron and aluminum are present and impart to the salts with which they are associated the hues peculiar to their compounds. Minerals that are usually colorless are reddened by ferric oxide (Fe_2O_3) or blackened by magnetite Fe_3O_4). Aluminum silicate or clay gives its characteristic gray shade to the minerals that it accompanies. Considerable quantities of iron occur locally in the form of the mineral rinneite, and aluminum occurs in the salt clay and in the efflorescences of the mineral koenenite ($Al_2O_3.3MgO.2MgCl_2.8H_2O$).

Iodine, boron, and silicon are minor constituents of sea water. The first element is found in small quantity at Stassfurt, and boron in the form of borates occurs in somewhat larger but insignificant amounts. Silica occurs as microscopic crystals of quartz in the residue from the solution of some of the salts; it is present of course in large quantities in the salt clay. Not a trace has been found of many of the elements that are present in sea water.

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[1] Everding, H., Zur Geologie der Zechsteinsalze: Deutschlands Kalibergbau, Berlin, pp. 29–34, 1907.

If the final bittern was deposited by evaporation it would seem that the presence of such easily detected elements as manganese, copper, and phosphorus could be established; the condition of the deposit indicates, however, that the final bittern flowed back into the open ocean. The conditions for finding some of the less abundant elements are more propitious, either because they are present in such form as to separate readily from the material associated with them—rubidium, caesium, lithium, thallium, and ammonium—or because the most refined methods were employed in searching for them, as for silver and gold. Celestite, rutile, sulphur, and pyrite are present. The two latter minerals were apparently produced from the sulphates as a result of reduction by organic matter.

The two types of secondary alteration indicated below are separated by a long time interval, which is represented by the entire Triassic, Jurassic, and part of the Cretaceous. The saline compounds that were formed during the two periods of alteration are alike in chemical composition but different in structure and appearance as well as in position. To call them both secondary, therefore, is confusing, for the decision whether a deposit is secondary in one sense or the other or whether it is primary is of great practical importance in judging a deposit, in placing it in the geologic section, and in locating shafts for mining operations. It is highly desirable to replace the ambiguous designations by terms that will closely indicate the genetic relations between the original form and the alteration forms. To meet this difficulty certain German scientists have proposed the terms, mother formation, descendant formation, and posthumous formation. Mother formation (Mutterbildungen) is used to indicate those saline deposits whose composition and structure indicate that they must have been produced directly by evaporation of an inclosed body of sea water; subordinate to this are "mother rock salt" (Muttersteinsalz) "mother potash salt" (Mutterkalisalz), and "mother saline series" (Muttersalzfolge), whose meanings are obvious. Descendant formation (deszendente Bildungen) is applied to those deposits which resulted from the transformation or alteration of the mother formation immediately after its precipitation and during Zechstein time; the materials comprising the formation are called the descendant salts (Deszendenzsalze), and the period of their origin the descendant period (Deszendenzperiode). Posthumous formations are those salts that are regarded as having originated in post-Permian time, after the mother formations and the descendant formations had been covered by Mesozoic rocks; they have been involved in the folding and faulting of the Mesozoic cover. The salts occurring in the cap zones belong to the posthumous formation.

The rock salt, kieserite, sylvite, and carnallite at Stassfurt occur in the three groups of formations just defined. To assign a salt to the proper period of origin its structure, petrographic character, and other characteristics must be ascertained, as well as the paragenesis of its associated minerals. Rock salt, for example, separated originally as mother rock salt. It may have recrystallized as rock salt during the descendant period, and later it may have recrystallized again as posthumous salt. Chemically the salt remained the same throughout the different periods but petrographically the mother, the descendant, and the posthumous rock salts are distinct. These relations are true not only regarding the simple minerals like rock salt but also regarding the more complex minerals, whose molecules are made up of molecules of several earlier minerals. Only a study of the petrography and the geologic relations of the formation in which the minerals are situated furnishes a basis for a conclusion as to the type of saline.

The most important potassium minerals both practically and scientifically in the Stassfurt deposits are sylvite and carnallite. Distinctive names have been applied to mixtures of sylvite with other minerals. The mixture of sylvite and rock salt is called sylvinite, and the mixture of sylvite, rock salt, and kieserite is called hartsalz. No such easy classification of carnallite and its associated minerals has won widespread usage. Despite the fact that one of the principal mixtures found in the Stassfurt deposits consists of rock salt and kieserite and 55 per cent of carnallite, the term carnallite is usually applied to it, a mixture of carnallite and rock salt is also known as carnallite, and lastly the pure mineral itself is known as carnallite. These confusing uses of the term have led Everding[1] to suggest a nomenclature like that of sylvite and its associated minerals. He proposes the name carnallitite for the mixture of carnallite and rock salt, and the name hauptsalz for the mixture of carnallite, rock salt, and kieserite, which is the principal product of the potash mines. The term carnallite is thus restricted to the mineral itself. The posthumous mineral kainite occurs in the cap zone intergrown with rock salt. Everding has proposed the term kainitite for this mixture to distinguish it from the simple mineral itself.

The most abundant accessory minerals in the potash deposits are anhydrite, boracite, langbeinite, schoenite, and bischofite. Particles of clay are distributed throughout the formations. Rock salt and anhydrite are disseminated in all the saline layers below the main potash-bearing beds. Polyhalite is limited chiefly to the compact layers below the potash minerals.

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[1] Deutschlands Kalibergbau, p. 33, Berlin, 1907.

INVESTIGATIONS.

The researches of Van't Hoff and Usiglio have thrown much light on the chemical conditions under which the Stassfurt salts were formed. The investigations of Van't Hoff and his associates, among whom are many Americans, have been conducted by a society formed for that purpose. The publications of its members have been specially listed.[1] Many elaborate researches have been conducted and many are still in progress.[2]

Study of the scientific results obtained at Stassfurt will undoubtedly yield information that will be extremely valuable in the search for potash salts in this country. The work of Van't Hoff [3] on the conditions under which the minerals were deposited is of special interest, and the studies and descriptions of Erdmann [4] are also helpful, as are those of Precht, Pfeiffer, Muspratt, Fürer, Ost, Kubierschky, and Ehrhardt. The lectures of Van't Hoff[5] delivered at the University of Chicago in 1901 and printed in English should also be consulted. Those especially interested will be obliged to consult the German technical literature, in which practically all the researches have first appeared. An article on the subject has been published by Turrentine.[6]

CHEMICAL COMPOSITION OF SALINE MATERIALS.

SCOPE OF ANALYSES.

Nearly all of the analyses in the following pages were made in the course of a cooperative search for commercially valuable deposits of potash salts in the salt fields of the eastern United States. The field studies and collections were made chiefly by the United States Geological Survey and the analyses by the Bureau of Soils, Department of Agriculture. Besides these data analyses of certain samples of eastern brines and western saline material collected by the writer and examined by W. B. Hicks and R. K. Bailey, of the United States Geological Survey, are reported, together with special tests by the Bureau of Soils of bitterns from solar-salt refineries on the Pacific coast. The analyses of sea water and of the water of Great Salt Lake are quoted from Clarke.[7]

The analyses as a whole represent the most complete and most reliable tests yet made to show the proportions of the chief constituents of American salines. There are many brines in the eastern United

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[1] See the bibliography in Deutschlands Kalibergbau, pp. 137-183, Berlin, 1907.

[2] K. Akad. Wiss. Berlin Sitzungsber., No. 39, p. 772, 1910.

[3] Van't Hoff, J. H., Zur Bildung der ozeanischen Salzablagerungen, Braunschweig, 1905.

[4] Die Chemie und industrie der Kalisalze: Deutschlands Kalibergbau, Berlin, 123 pp., 1907.

[5] Van't Hoff, J. H., Physical chemistry in the service of the sciences, Chicago, 1903.

[6] Turrentine, J. W., The occurrence of potassium salts in the brines of the United States: U. S. Dept. Agr. Bur. Soils Bull. 94, pp. 81-88, 1913.

[7] Clarke, F. W., The data of geochemistry, 3d ed.: U. S. Geol. Survey Bull. 616, 1916.

States whose composition is not given, chiefly because they are too weak to be worth consideration as sources of either sodium chloride or potassium compounds. Though many saline deposits in the western deserts have been analyzed they have not yet attained commercial importance as sources of salt. Briefly the analyses in the following tables represent all the present centers of production of salt in the eastern United States.

COLLECTION OF SAMPLES.

Most of the samples were collected personally by the writer or by J. W. Turrentine, of the Bureau of Soils, and unless it is otherwise specified in the notes following the analytical tables the writer was the collector. In the summer of 1911, after correspondence with all the salt producers and many well drillers of the country, many samples of brine and bittern, collected according to explicit directions in special containers furnished by the Geological Survey, were forwarded for analysis.

ANALYTICAL METHODS.

GENERAL FEATURES.

The chemical work, except that done in the laboratory of the United States Geological Survey by W. B. Hicks and R. K. Bailey, was performed under the immediate supervision of J. W. Turrentine by J. A. Cullen, R. F. Gardiner, and A. R. Merz in the laboratories of the Bureau of Soils, Department of Agriculture. The following notes regarding the analytical methods have been taken from an article by Turrentine.[1] The methods recommended by the Association of Official Agricultural Chemists for the analysis of mineral waters were generally employed in the determination of iron, aluminum, calcium, magnesium, sodium, potassium, and sulphate, but certain modifications tending to abbreviate the analytical processes were introduced where they were expedient.

PREPARATION OF THE SOLUTION.

After the sample of brine had stood until all sediment had settled, 10 cubic centimeters of the clear supernatant liquid was transferred by means of a dry calibrated pipette to a 200 cubic centimeter graduated flask, which was then filled to the mark with distilled water. Aliquot portions of this solution were taken for the various determinations.

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[1] Turrentine, J. W., The occurrence of potassium salts in the salines of the United States; U. S. Dept. Agr. Bur. Soils Bull. 94, pp. 47-52, 1913; also Composition of the salines of the United States: Jour. Ind. and Eng. Chemistry, vol. 4, pp. 828, 885, 1912; vol. 5, p. 19, 1913.

TOTAL DISSOLVED SALTS.

A convenient volume of the dilute solution was evaporated to dryness in a weighed platinum dish, and the residue was heated to constant weight at 105° C., cooled, and weighed. This estimate is not reported but was used as a check on the analysis.

IRON AND ALUMINUM.

If the brine was colored, iron and aluminum were estimated; if it was colorless, they were not estimated.

An aliquot portion of the dilute solution was treated with ammonium chloride and heated to boiling. Ammonium hydroxide was then added, a drop at a time, until an excess of the reagent was barely perceptible to the smell, after which the solution was boiled until the odor of ammonia had practically diasappeared. The precipitate was then separated by filtration, washed with hot water, ignited, and weighed as ferric oxide and alumina ($Fe_2O_3+Al_2O_3$). The filtrate was used for the determination of calcium and magnesium.

Another aliquot portion of the diluted brine was treated with 2 or 3 cubic centimeters of concentrated sulphuric acid and evaporated to a sirupy consistency. The solution was then diluted with water, reduced by means of metallic zinc, and filtered. The quantity of iron (Fe) in the filtrate was estimated by titration with a standard solution of potassium permanganate, and the content of aluminum was calculated by difference.

CALCIUM AND MAGNESIUM.

The filtrate from the precipitation of iron and aluminum was treated with ammonium hydroxide and ammonium oxalate and allowed to stand overnight. The precipitate was then separated by filtration, washed twice with hot water by decantation, dissolved in hydrochloric acid, and reprecipitated by ammonium hydroxide and a little more ammonium oxalate. After the solution had stood overnight the precipitate was separated by filtration and washed on the paper previously used. The precipitate was ignited, blasted, and weighed as calcium oxide, from which calcium (Ca) was calculated. After the combined filtrates had been evaporated to dryness in platinum the greater part of the salts of ammonium was volatilized by heating and the residue was dissolved in dilute hydrochloric acid. After filtration the filtrate was made slightly ammoniacal, and enough solution of sodium phosphate was added, drop by drop, to precipitate all the magnesium, and finally, drop by drop, 10 cubic centimeters of concentrated ammonium hydroxide was added. The solution was allowed to stand overnight. The precipitate was then separated by filtration, washed with 2.5 per cent ammonium hydroxide until it was free from chlorides, then dried, blasted, and weighed as magnesium pyrophosphate, from which magnesium (Mg) was calculated. This procedure for separation of calcium and magnesium is not applicable in the presence of weighable amounts of the phosphate radicle, but no difficulty was experienced from that source in these analyses.

SULPHATE.

Another portion of the diluted brine was acidified with hydrochloric acid and treated while boiling with hot dilute solution of barium chloride. After the precipitate had completely formed it was separated by filtration, washed, ignited, and weighed as barium sulphate, from which sulphate (SO_4) was calculated. The filtrate was used for estimation of the alkalies.

SODIUM AND POTASSIUM.

The filtrate from the determination of sulphate was evaporated to dryness and the residue was dissolved in a little water. If the presence of lithium was suspected, a spectroscopic test for the characteristic lithium lines was made on this solution. Though traces of lithium were found in some samples, none contained enough to justify quantitative estimation.

A solution of barium hydroxide was then added to the solution and the insoluble precipitate was filtered off and washed thoroughly with hot water. The combined filtrate and washings were treated with ammonium hydroxide, ammonium carbonate, and a little ammonium oxalate, and were allowed to stand overnight to precipitate calcium and barium. This precipitate was filtered off and thoroughly washed. The filtrate and washings were evaporated to dryness and the residue was dried in an oven. The salts of ammonium were then driven off by gentle heating. The residue was extracted with water, and the solution was filtered through a small filter and washed with as little water as possible. The filtrate and washings were evaporated to a small volume and again treated with a drop of ammonium hydroxide and 2 or 3 drops of ammonium carbonate and ammonium oxalate. If any precipitate appeared, the filtration and precipitation were repeated. In every analysis the solution was filtered from the magnesium hydroxide that was precipitated on concentrating the solution. The filtrate was evaporated to dryness in platinum and all ammonium was expelled by heating to a little below redness. The residue was then dissolved in a little water, the solution was filtered through a small filter, washed with as little water as possible, evaporated to dryness, and again heated in platinum to a temperature slightly below red heat. By this procedure all the magnesium was removed. The residue was dissolved in a little water, the solution was filtered into a weighed platinum dish, a few drops of hydrochloric acid was added, and the solution was evaporated to dryness. This final residue was dried in an oven, heated to a little below redness, cooled, and weighed as the combined chlorides of potassium and sodium.

The contents of the dish were dissolved in hot water and transferred to a porcelain dish. A small amount of chlorplatinic acid was added, and the solution was evaporated nearly to dryness. The residue was extracted with 80 per cent alcohol. A yellow color of the alcoholic solution indicated that sufficient excess of chlorplatinic acid had been added; otherwise more was added until the yellow color persisted. The precipitate was filtered out in a weighed Gooch crucible and washed thoroughly with 80 per cent alcohol and with a 20 per cent solution of ammonium chloride that had been saturated with potassium chlorplatinate. After a final washing with alcohol the residue was dried to constant weight at 100° to 102° C. and weighed as potassium platinic chloride. The contents of sodium (Na) and potassium (K) were then calculated from the weight of the combined sodium and potassium chlorides and the weight of the potassium platinic chloride.

BROMINE.

A proper amount of the diluted brine was rendered alkaline by sodium carbonate and evaporated to dryness. An aliquot portion of the alkaline filtrate obtained by extracting this residue was then evaporated to dryness on the steam bath. The residue was treated with 2 or 3 cubic centimeters of water and enough absolute alcohol to make the percentage of alcohol about 90, and the solution was then boiled and filtered. Treatment of the residue with 90 per cent alcohol was repeated once or twice. The filtrates with 2 or 3 drops of a solution of sodium hydroxide were then evaporated to dryness. The process of extracting with 90 per cent alcohol was repeated on the new residue, and the extract filtered from the undissolved portion was treated with a drop of sodium hydroxide and evaporated to dryness. The residue was dissolved in a little distilled water, acidified with a little sulphuric acid (1 to 5), 3 or 4 drops excess being added, and transferred to a small flask. Freshly prepared chlorine water was added to it; usually 2 to 8 cubic centimeters of a saturated solution of chlorine was sufficient to set free the bromine. Care must be taken not to add too great an excess of chlorine, which might cause the formation of a bromochloride that would spoil the color reaction. The best results are obtained by adding approximately the same excess of chlorine to the standards as to the sample. This may be accomplished by adding 1 cubic centimeter of chlorine at a time and shaking between additions. After a little practice one can determine approximately when the chlorine ceases to set bromine free. After all the bromine had been thus set free 5 cubic centimeters of freshly purified carbon bisulphide was added to the contents of the flask, which was thoroughly shaken. The water solution was separated from the carbon bisulphide by filtration through a moistened filter, and the contents of the filter were washed two or three times with water and then transferred to a 12 cubic centimeter Nessler tube by means of about 1 cubic centimeter of carbon bisulphide. This extraction of the filtrate was repeated twice, with 3 cubic centimeters of carbon bisulphide each time. The combined carbon bisulphide extracts usually measured 11.5 to 12 cubic centimeters. If they did not quite reach the 12 cubic centimeter mark on the Nessler tube, enough carbon bisulphide was added to complete the required volume. The color of the solution thus extracted from the brine was compared with that of solutions of known strength of potassium bromide that had received exactly the same treatment and at the same time the acidification by sulphuric acid was begun. All the bromine is not extracted by the amounts of carbon bisulphide recommended. Consequently if the content of bromine is large it is well to make one or two extra extractions with carbon bisulphide, transfer the extracts to a Nessler tube, and compare the color with that of the weaker standards.

CALCULATION OF RESULTS.

The results of each analysis of brine or bittern are expressed in two forms—(1) the amounts of the radicles determined in grams per liter and (2) the radicles in percentage of the anhydrous residue. The statements of the analyses in percentage composition of the anhydrous residues have been calculated from Turrentine's results by R. K. Bailey, to whom the writer is greatly indebted for this valuable assistance. As the computations were made with a slide rule the second place of decimals may be inaccurate by one or two units, but such an error is insignificant.

On page 277 will be found a table of factors for converting radicles to compounds, or conventional combinations. This can be done in several ways, and mainly for this reason it has been thought best to omit statements of conventional combinations. With the aid of the table, however, the conversion can be made if desired.

The figures of the analyses have been recalculated and extensively revised under the direction of Mr. Turrentine since the publication of Bulletin 94 of the Bureau of Soils, consequently the differences between the figures in the following tables and those in Bulletin 94 should be attributed to corrections and not to errors in transcription.

COMPOSITION OF ROCK SALT.

The samples of rock salt whose analyses are given in the following table were collected either by J. W. Turrentine or by the writer, except No. 10, which was forwarded by the company. In order that the sample might be as nearly representative as possible it was usually taken from a working face in the mine. A groove a few inches wide was cut from the top to the base of the working face, care being taken to remove small fragments so as not to give undue representation to any particular part of the bed. Most of the samples represent the entire thickness of the salt bed, as the entire thickness is usually worked. The fragments were then broken into uniform smaller fragments an inch or less in diameter and were thoroughly mixed and quartered, the latter operations being repeated until a sample of convenient size was obtained for shipment to the laboratory.

Analyses of rock salt from New York, Michigan, Kansas, and Louisiana.

Radicles in percentage of material soluble in water.

	1[a]	2	3	4	5	6	7	8	9	10
K	0.2	Trace.	Trace.	Trace.	Trace.	Trace.	0.1	Trace.	Trace.	Trace.
Na	36.0	38.9	38.0	39.0	38.8	38.4	38.6	38.3	38.3	39.1
Ca	1.96	.2	1.0	Trace.	Trace.	.8	.4	.8	.4	Trace.
Mg	.50	.1	.1	.2	.3	Trace.	.1	Trace.	.3	.1
Cl	59.94	59.6	59.7	59.3	59.8	60.0	60.0	60.0	60.2	59.9
SO_4	1.13	1.2	1.2	.5	1.0	.8	.8	.8	.6	.9
	99.73	100.0	100.0	99.0	99.9	100.0	100.0	99.9	99.8	100.0

[a] Expressed in percentage of dry sample.

1. Retsof Mining Co., Retsof, N. Y. Middle of rock-salt bed, 1911. J. A. Cullen, analyst.
2. Retsof Mining Co., Retsof, N. Y. Near floor in 8-foot working face of Room 24, 1911. R. F. Gardiner, analyst.
3. Sterling Salt Co., Halite, N. Y. Rock-salt dust beneath main crushers, 1911. R. F. Gardiner, analyst.
4. Sterling Salt Co., Halite, N. Y. From roof to floor in working face, west side of Room 1, northwest, 1911. R. F. Gardiner, analyst. J. W. Turrentine, collector.
5. Detroit Salt Co., Detroit, Mich. From roof to floor in working face, 1911. R. F. Gardiner, analyst.
6. Crystal Rock Salt Co., Kanopolis, Kans. From roof to floor in working face, 1911. R. F. Gardiner, analyst.
7. Royal Rock Salt Co., Kanopolis, Kans. From roof to floor in working face, 1911. R. F. Gardiner, analyst.
8. Bevis Rock Salt Co., Lyons, Kans. From top to bottom of 16-foot bed, 1911. R. F. Gardiner, analyst.
9. Bevis Rock Salt Co., Lyons, Kans. Fine salt screened from coarse, 1911. R. F. Gardiner, analyst.
10. Avery Rock Salt Co., Avery Island, La. From working face, 1911. R. F. Gardiner, analyst. Collected by company.

Though these analyses represent the water-soluble material they practically represent also the composition of the rock salt, as there was very little insoluble matter. A comparison of these analyses with those of salts in sea water (p. 217) will show how the salt purifies itself as it crystallizes from the complex sea water. The uniform and nearly complete exclusion of impurities is particularly noticeable. These results prove that the rock-salt beds now worked are negligible as sources of potassium salts.

COMPOSITION OF NATURAL SURFACE BRINES.

SEA WATER.

Sea water, whose composition has been the subject of elaborate investigation in many parts of the world, is mainly a solution of the chlorides and sulphates of sodium, magnesium, calcium, and potassium, but it contains also many other substances. It carries appreciable amounts of bromine, iodine, iron, silicon, carbonate, and phosphate, and the presence in it of fluorine, nitrogen, arsenic, boron, lithium, rubidium, caesium, barium, strontium, aluminum, manganese, nickel, cobalt, lead, silver, copper, zinc, gold, and radium has been demonstrated.[1]

Many of the more recent analyses of sea water from different parts of the world have been collated by Clarke,[2] whose tabulation of them is presented in the following table, the percentage composition of the anhydrous residues of the waters being given. The salinity or total content of mineral matter of each sample is given in the key following the table and is expressed in percentage or in grams per 100 grams.

Analyses of ocean salts.

	1	2	3	4	5	6	7	8
Cl	55.292	55.185	55.04	55.21	55.01	54.62	55.24	55.25
Br	.188	.179	.19	.19	.13	....	.17	....
SO_4	7.692	7.914	7.86	7.69	8.00	8.01	7.54	7.56
CO_3	.207	.213	.18	.09	.14	.27	.34	.37
Na	30.593	30.260	30.71	30.82	30.47	30.20	30.80	30.76
K	1.106	1.109	1.06	1.16	.96	2.10	1.10	1.14
Rb	....	....	....	....	.04	....	....	....
Ca	1.197	1.244	1.27	1.21	1.67	1.36	1.22	1.22
Mg	3.725	3.896	3.69	3.61	3.53	3.36	3.59	3.70
Fe, SiO_2, PO_4	....	....	....	....	.05	....	....	....
Fe, NH_4, NO_3	....	....	....	.02	....	....	....	....
$(FeAl)_2O_3$, SiO_2	....	....	....	....	....	.08	....	....
	100.000	100.000	100.00	100.00	100.00	100.00	100.00	100.00

1. Mean of 77 analyses of ocean water from many localities, collected by the *Challenger* expedition. W. Dittmar, analyst. *Challenger* Rept., Physics and chemistry, vol. 1, p. 203, 1884. Salinity, 3.301 to 3.737 per cent.
2. Atlantic water, mean of 22 samples collected on a voyage from the Cape of Good Hope to England. C. J. S. Makin, Chem. News, vol. 77, pp. 155, 171, 1898. Salinity, average, 3.631 per cent.
3. The Atlantic near Dieppe. Analysis by T. Schloesing, Compt. Rend., vol. 142, p. 320, 1906. Salinity, 32.420 grams per liter.
4. The Irish Sea. Analysis by T. E. Thorpe and E. H. Morton, Liebig's Annalen, vol. 158, p. 122, 1871. The small amounts of Fe_2O_3, NH_3, and N_2O_5 are here added together. A trace of lithium was also reported.
5. The Baltic Sea between Oeland and Gothland. Analysis by C. Schmidt, Acad. Sci. St.-Pétersbourg Bull., vol. 24, p. 231, 1878. In all Schmidt's analyses the bicarbonates given by him have been here reduced to normal salts. The quantities of Fe, PO_4, and SiO_2 found by Schmidt are so small that they have here been added together. Salinity of this sample, 0.7215 per cent.
6. The Atlantic at Bahia Blanca, coast of Argentina. Mean of two samples, taken at low and high tide. Analyses by F. Lahille, reported by E. H. Ducloux, Soc. cient. Argentina An., vol. 54, p. 62, 1902. Salinity, 3.365 per cent. Another pair of analyses is given of water taken at the mouth of Rio Negro.
7. The Gulf of Mexico off Loggerhead Key, Tortugas, near Florida. Analysis by George Steiger, laboratory of the U. S. Geological Survey, 1910. Salinity, 3.549 per cent.
8. Atlantic Ocean near Beaufort, North Carolina. Mean of five analyses, by A. S. Wheeler, of samples taken under varying conditions. Am. Chem. Soc. Jour., vol. 32, p. 646, 1910. Salinity, 3.179 to 3.607 per cent.

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[1] Forchhammer, G., Philos. Trans., vol. 155, pp. 203-262, 1865. Dittmar, W., *Challenger* Rept., Physics and chemistry, vol. 1, p. 1, 1884. Clarke, F. W., The data of geochemistry, 3d ed.: U. S. Geol. Survey Bull. 616, pp. 119-128, 1916.

[2] Op. cit., pp. 123-125.

Analyses of ocean salts—Continued.

	9	10	11	12	13	14	15	16
Cl	55.46	55.22	55.30	55.45	55.53	55.11	55.30	55.45
Br		.14	.14		.18	.19	.16	.17
SO$_4$	7.59	7.88	7.78	7.79	7.74	7.89	7.72	7.67
CO$_3$	.30	.10	.07	....	.19	.20	.19	.28
Na	30.53	30.65	30.85	30.41	30.37	30.64	30.51	....
K	1.12	.93	.89	1.17	1.09	1.09	1.12	....
Rb	....	.04	.04	....	....	....	....	....
Ca	1.21	1.21	1.16	1.18	1.26	1.23	1.19	1.22
Mg	3.79	3.75	3.69	3.82	3.64	3.65	3.81	....
Fe, SiO$_2$, PO$_4$	....	.08	.08	....	....	....	....	....
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	....

	17	18	19	20	21	22	23	24
Cl	55.12	55.59	55.60	55.96	55.46	55.43	55.41	54.78
Br	.18	.14	.13	.18	.13	.13	.13	.26
SO$_4$	7.47	7.67	7.65	7.49	7.91	7.76	7.79	7.60
CO$_3$	.46	.01	.02	.13	.04	.03	.05	.72
Na	30.46	31.21	30.81	30.31	30.23	30.67	30.89	30.57
K	1.16	.64	.97	1.06	.94	.97	.85	1.11
Rb	....	.03	.04	....	.03	.04	.03	....
Ca	1.41	1.05	.89	1.22	1.19	1.19	1.16	1.25
Mg	3.74	3.64	3.87	3.65	4.03	3.75	3.67	3.71
Fe, SiO$_2$, PO$_4$	....	.02	.02	....	.04	.03	.02	....
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

9. The north Atlantic between Norway, the Faroe Islands, and Iceland, and northward to Spitzbergen. Mean of 51 incomplete analyses by L. Schmelck, Den Norske Nordhavs-Expedition, pt. 9, p. 1, 1882. Soda and carbonic acid estimated by calculation, not directly determined. Salinity, 3.37 to 3.56 per cent.

10. The White Sea. Average of three analyses by C. Schmidt. Acad. Sci. St.-Pétersbourg Bull., vol. 24, p. 231, 1878. Salinity, 2.598 to 2.968 per cent.

11. The Arctic Ocean between the White Sea and Nova Zembla. Mean of two analyses by Schmidt, idem.

12. The Siberian Ocean. Water collected by the *Vega* expedition. Mean of four analyses by Forsberg, Vega Exped. Rept., vol. 2, p. 376, 1883. Salinity, 1.378 to 3.457 per cent.

13. Mediterranean Sea near Carthage. Analysis by T. Schloesing, Compt. Rend., vol. 142, p. 320, 1906. Salinity, 38.9744 grams per liter.

14. The Mediterranean, midsea, between Bizerta and Marseille. Salinity, 38.789 grams per liter. Analysis by Schloesing, idem.

15. The eastern Mediterranean, waters collected during the voyages of the Austrian steamer *Pola*. Analyst, K. Natterer, Monatsh. Chemie, vol. 13, pp. 873, 897, 1892; vol. 14, p. 624, 1893; vol. 15, p. 530, 1894. Three hundred samples of water were examined, some only for gases. The figures given here are the average from 42 analyses which were fairly complete. Salinity, 3.836 to 4.115 per cent.

16. The Sea of Marmora. Natterer, Monatsh. Chemie, vol. 16, p. 405, 1895; 44 partial analyses. Natterer gives the figures here utilized as averages of varying numbers of determinations. Mg, Na, and K not determined. Salinity, 2.310 to 4.061 per cent.

17. The Black Sea. Average of six analyses by S. Kolotoff, Russ. Phys. Chem. Soc. Jour., vol. 24, p. 82, 1893. Salinity, 1.826 to 2.223 per cent.

18. The Suez Canal at Ismailia. Analysis by C. Schmidt, Acad. Sci. St.-Pétersbourg Bull., vol. 24, p. 231, 1878. Salinity, 5.103 per cent. For other data on the Suez Canal, see L. Durand-Claye, Annales chimie et phys., 5th ser., vol. 3, p. 188, 1874. Very high salinities were noted. For a recent, incomplete analysis of Red Sea water, see J. B. Coppock, Chem. News, vol. 96, p. 212, 1907.

19. The Red Sea near the middle. Analysis by Schmidt, op. cit. Salinity, 3.976 per cent.

20. The Red Sea. Average of four analyses by Natterer, Monatsh. Chemie, vol. 20, p. 1, 1899; vol. 21, p. 1037, 1900. Water collected in the Suez Canal, the Timsah Lake, and the two Bitter Lakes. Many other partial analyses are given. The salinity of these particular samples ranged from 5.085 to 5.854 per cent.

21. The Straits of Malacca. Salinity, 2.7965 per cent.

22. The China Sea. Salinity, 3.208 per cent.

23. The Indian Ocean, mean of two analyses; salinity, 3.5534 and 3.6681 per cent. Analyses 21, 22, 23, by C. Schmidt, Mél. phys. chim., vol. 10, p. 594. Also Jahresber. Chemie, p. 1370, 1877. Schmidt's rubidium determinations need verification.

24. The "Mare Morto," an inclosed body of water on the island Lacromo in the Adriatic, having underground connection with the sea. Salinity, 3.1744 per cent. Analysis by W. Loebisch and L. Sipöcz, Min. Mitt., p. 171, 1876.

Other analyses of Atlantic water, taken off the coast of Brazil, with analyses of water from the mouths of the Amazon, are given by F. Katzer, in K. böhm. Gesell. Wiss. Sitzungsb., 1897, No. 17. These represent mixtures of sea and river water. For special determinations of bromine in sea water and its ratio to the chlorine see E. Berglund, Deutsch. chem. Gesell. Ber., vol. 18, p. 2888, 1885. An analysis of water from the Ionian Sea, by F. Wibel, is printed in Deutsch. chem. Gesell. Ber., vol. 6, p. 184, 1873. One by A. Vierthaler (Akad. Wiss. Wien Sitzungsb., vol. 56, p. 479, 1867), of Adriatic water taken near Spalato shows abnormally low sodium and high calcium, presumably due to admixtures of water from the land. See also W. Skey, New Zealand Colonial Mus. and Lab., 3d Ann. Rept., 1868, for seven analyses of sea water taken near that island; C. J. White, Roy. Soc. New South Wales Proc., vol. 41, p. 55, 1907, one analysis of water taken off Coogee; A. Burada, Ann. sci. Univ. Jassy, vol. 5, p. 251, 1909, one analysis of water from the Black Sea. On salinity of the Persian Gulf, Annalen der Hydrographie, vol. 7, p. 293, 1908. Two recent analyses of Adriatic water are reported by V. Gegenbauer, Min. pet. Mitt., vol. 29, p. 357, 1910.

The most striking feature brought out by these analyses is the remarkably uniform composition of the saline matter in spite of relatively large differences in concentration. Dittmar's results, given in column 1, may be taken as a standard of comparison, for they represent the largest number of refined complete analyses of samples covering the widest ranges of depth and geographic position. According to him the salinity of ocean water ranges from 3.301 to 3.737 per cent; the lower figure is the salinity of water from Indian Ocean south of 66° latitude, and the higher figure is that of the water from the middle of the north Atlantic near the Tropic of Cancer; the depth below the surface at which the samples were taken is not stated. According to Forchhammer[1] sea water contains an average of 3.4404 per cent (34.404 grams per kilogram) of salts, including 0.007 to 0.01 per cent of insoluble material left on treating with pure water the total solids obtained by evaporation. This concentration represents a possible content of about 2.7 per cent of sodium chloride. A saturated solution of sodium chloride, according to Gerlach,[2] contains 26.395 per cent of sodium chloride at 15° C. (59° F.). Thus it will be seen that concentrated salt solutions contain more than nine times as much sodium chloride as sea water.

The figures in the following table represent the average content of various salts in sea water calculated by Dittmar from his 77 complete analyses. This composition may be considered general for sea water. It should be remembered, however, that this combination of acidic and basic radicles to form salts is more or less arbitrary and is merely a convenient convention adopted for the purpose of indicating the possibilities of recovery of the salts by evaporation.

Conventional combinations representing the salts dissolved in sea water.

Sodium chloride (NaCl)	77. 758
Magnesium chloride ($MgCl_2$)	10. 878
Magnesium sulphate ($MgSO_4$)	4. 737
Calcium sulphate ($CaSO_4$)	3. 600
Potassium sulphate (K_2SO_4)	2. 465
Magnesium bromide ($MgBr_2$)	. 217
Calcium carbonate ($CaCO_3$)	. 345
	100. 000

In connection with the present interest in potash salts, it may be noted that the figure for potassium sulphate, 2.465 per cent, is equivalent to 2.110 per cent of potassium chloride and 1.106 per cent of potassium.

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[1] Forchhammer, G., *Challenger* Rept., Physics and chemistry, vol. 1, p. 2, 1884.
[2] Van Nostrand's Chem. Ann., p. 378, 1907.

WATER OF GREAT SALT LAKE.

The chief differences in the results of various chemists who have analyzed the water of Great Salt Lake are in the degree but not in the character of the salinity. It is to be expected that the concentration would change with greater or less dilution from local sources. Though the degree of salinity ranges from four to seven times that of ocean water the composition of the saline matter is much like that in ocean water. A sample from the lake, north of Lucin Cutoff, near Withee Junction, Utah, collected by the writer in 1912 had a salinity of 13.35 per cent according to a test by R. K. Bailey.

The following analyses tabulated by Clarke[1] show the composition of the water. Other analyses have been given by Gilbert.[2]

Analyses of water from Great Salt Lake.

	1	2	3	4	5	6	7	8	9
Cl	55.99	56.21	55.57	56.54	55.69	55.25	55.11	53.72	55.48
Br	Trace				Trace	Trace			
SO_4	6.57	6.89	6.86	5.97	6.52	6.73	6.66	5.95	6.68
CO_3		.07							.09
Li	Trace				.01	Trace			
Na	33.15	33.45	33.17	33.39	32.92	34.65	32.97	32.81	33.17
K	1.60	(?)	1.59	1.08	1.70	2.64	3.13	4.99	1.66
Ca	.17	.20	.21	.42	1.05	.16	.17	.31	.16
Mg	2.52	3.18	2.60	2.60	2.10	.57	1.96	2.22	2.76
$Fe_2O_3.Al_2O_3.SiO_2$					.01				
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Salinity, percentage	14.994	13.790	15.671	19.558	[a] 23.036	27.72	22.99	17.68	20.349

[a] More correctly, 230.355 grams per liter.

1. By O. D. Allen, analyst. U. S. Geol. Expl. 40th Par. Rept., vol. 2, p. 433, 1877. Water collected in 1869. A trace of boric acid is also reported in addition to the substances named in the table. Allen also gives analyses of a saline soil from a mud flat near Great Salt Lake. It contained 16.40 per cent of soluble matter much like that of the lake water.
2. By Charles Smart, analyst. Cited in Resources and attractions of the Territory of Utah, Omaha, 1879. Analyses made in 1877.
3. By E. von Cochenhausen, analyst for C. Ochsenius. Deutsch. geol. Gesell. Zeitschr., vol. 34, p. 359, 1882. Sample collected by Ochsenius, April 16, 1879. Ochsenius also gives an analysis of the salt manufactured from the water of Great Salt Lake.
4. By J. E. Talmage, analyst. Science, vol. 14, p. 455, 1889. Collected in 1889. An analysis of a sample taken in 1885 is also given.
5. By E. Waller, analyst. School of Mines Quart., vol. 14, p. 57, 1892. A trace of boric acid is also reported.
6. By W. Blum, analyst. Collected in 1904. Recalculated to 100 per cent. Reported by Talmage in Scottish Geog. Mag., vol. 20, p. 424, 1904. An earlier paper by Talmage on the lake is in the same journal, vol. 17, p. 617, 1901.
7. By W. C. Ebaugh and K. Williams, analysts. Chem. Zeitung, vol. 32, p. 409, 1908. Collected in October, 1907.
8. By W. Macfarlane, analyst. Science, vol. 32, p. 568, 1910. Collected in February, 1910. A number of other analyses, complete or incomplete, are cited in this paper by Ebaugh and Macfarlane.
9. By R. K. Bailey, analyst. U. S. Geological Survey laboratory. Sample collected by H. S. Gale, October 24, 1913.

Sodium is higher, but calcium and magnesium, especially calcium, are distinctly lower in the lake water than in sea water. (See pp. 217–218.) Carbonates are almost entirely absent from the lake water but are present to an appreciable extent in ocean water. Calcium carbonate is precipitated on the shore of the lake in the form of

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[1] Clarke, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 491, p. 144, 1911, and Bull. 616, p. 155, 1916.

[2] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, pp. 253–254, 1890

oolitic sand. Gilbert[1] states that the quantity of sodium chloride in the water of the lake is about 400,000,000 tons and that the amount of sodium sulphate is about 30,000,000 tons.

As the lake is shallow, its volume is greatly affected by small changes in its level. The total salinity (salt content) may be considered fairly constant, only the strength of the brines being affected by these changes in level. Observations were made in 1850, when the lake was at its lowest observed stage; in 1873, when the lake was at its highest stage; in 1869, when it was at an intermediate stage; and in 1885 and 1889. From a comparison of the extreme results it appears that the salinity was decreased 39 per cent by a rise of 10.5 feet, which represents on the assumed basis of no change in total saline content an increase of 73 per cent in the volume of water in the lake. The saline matter presumably has been derived chiefly from the fresh-water rivers flowing into it and from the brackish springs along its edges. Whether these springs derive their saline matter from extraneous sources or from beds originally deposited in the Bonneville basin is unknown. If the latter is true the springs could hardly be regarded as contributing an original quota of saline material. Gilbert[2] says that it must be regarded as an open question whether the existing lake and its characteristic brine date from the end of the Bonneville overflow (Pleistocene) or from a subsequent epoch of extreme aridity.

COMPOSITION OF NATURAL AND ARTIFICIAL UNDERGROUND BRINES.

BRINES AND SAMPLES.

Natural brines are those that are pumped from the ground in their natural state—that is, they are natural solutions of salt. Artificial brines, as the term is used in this paper, signifies brines that are formed by forcing fresh water into salt beds and thereby producing an artificial solution. The impurities of the water presumably enter into the brine. Important differences in chemical composition make it desirable to distinguish between the two types of commercial underground brine.

The brines whose analyses are given in the following tables arranged and discussed by States were sampled usually at the places where they flowed into the preliminary settling tanks. Composite samples were collected wherever possible, as it is believed that an analysis of united contributions from several wells is more nearly representative of the brine in a field than an analysis of brine from a single well.

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[1] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, p. 253, 1890.

[2] Idem, p. 258.

NEW YORK.

Analyses of artificial brines of New York.

Radicles in grams per liter.

	1	2	3	4	5	6	7	8	a9
K	0.3	....	0.8	0.5	11.8	12.0	2.0	0.4	0.2
Na	114.0	110.6	93.8	100.8	104.4	108.4	104.0	113.0	85.3
Ca	3.2	2.7	9.3	2.7	4.8	3.4	4.2	3.8	.4
Mg	.3	.3	1.0	.5	1.6	1.4	1.6	.2	.2
Cl	180.4	181.1	163.5	160.7	179.1	181.9	171.6	179.5	129.4
SO_4	2.3	2.4	.9	3.1	1.6	2.4	3.4	2.6	3.8
Br	....	....	....	....	1.1	1.1	.8	.7	.6
	300.5	297.1	269.3	268.3	304.4	310.6	287.6	300.2	219.9

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6	7	8	a9
K	0.10	....	0.29	0.18	3.87	3.87	0.69	0.13	0.09
Na	37.92	37.25	34.82	37.60	34.29	34.90	36.17	37.69	38.81
Ca	1.06	.91	3.45	1.00	1.58	1.09	1.46	1.26	.18
Mg	.10	.10	.37	.18	.52	.45	.56	.06	.09
Cl	60.06	60.94	60.74	59.90	58.86	58.57	59.66	59.76	58.83
SO_4	.76	.80	.33	1.14	.52	.77	1.18	.87	1.73
Br	....	....	....	....	.36	.35	.28	.23	.27
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[a] Natural brine (?).

1. Worcester Salt Co., Silver Springs, N. Y. From well No. 3, 1911. A. R. Merz, analyst.
2. Rock Glen Salt Co., Rock Glen, N. Y., 1911. A. R. Merz, analyst.
3. Star & Crescent Salt Co., Saltvale, N. Y., 1911. A. R. Merz, analyst.
4. Genesee Salt Co., Piffard, N. Y., 1911. A. R. Merz, analyst.
5. Watkins Salt Co., Watkins, N. Y., 1910. R. F. Gardiner, analyst. Collected by company.
6. International Salt Co., Watkins, N. Y., 1910. R. F. Gardiner, analyst. Collected by company.
7. Genesee Salt Co., Piffard, N. Y., 1910. R. F. Gardiner, analyst. Collected by company.
8. Remington Salt Co., Ithaca, N. Y., 1910. R. F. Gardiner, analyst. Collected by company.
9. Onondaga Pipe Line Co., Liverpool, N. Y., 1910. R. F. Gardiner, analyst. Collected by company.

The salinities and compositions of the brines represented by the analyses in the preceding table agree very well except that of sample 9, which probably represents the dilute natural brine from the glacial gravels and not an artificial brine. The abnormal content of potassium shown by samples 5 (Watkins Salt Co.) and 6 (International Salt Co.) is open to some doubt as to being truly representative of general conditions. On account of this doubt W. B. Hicks, of the United States Geological Survey, collected in 1914 several additional samples of these brines, the analyses of which are given further on. The analytical results obtained by W. B. Hicks and R. K. Bailey have been converted from grams per thousand into grams per liter, making use of the specific-gravity determinations. This was done to make the results comparable with the majority of the analyses in this report. The analyses showing the high potash content are given in the first column of the tables.

So far as saturation of the brine obtained at the Watkins Salt Co.'s plant goes, the results appear to be about the same as those obtained by the Bureau of Soils. The brine is nearly saturated. The analyses of the brine by Hicks indicate a much smaller content in potash than the analysis by Gardiner, and the smaller content is more in harmony with analyses of brines from other New York plants. Analyses Nos. 4 and 5 in the next table, which are of bitterns from vacuum pans, would naturally show higher concentration than analyses of the brines, but in the bitterns also the quantity of potash salts is low.

The analyses in the second following table, which are of samples collected at the plant of the International Salt Co., near Watkins, show, in general, similar low results for potash and in most respects are comparable with those obtained from the brines and bitterns of the Watkins Salt Co.

Merrill[1] has observed from study of many analyses of New York brines and salts that the samples from the top of a salt bed contain considerably more magnesium chloride than those from the bottom and that though the brine from a new well generally contains little magnesium chloride it contains more as the underground cavity increases in size or becomes connected with other cavities. He suggests that the overlying shales may be more highly charged with this soluble chloride than the salt beds—a condition that fits well into the theory of the deposition of this salt from an arm of the sea. If Merrill's hypothesis is true the existence of workable deposits of potassium salts over such beds is extremely doubtful.

Analyses of artificial brines of New York.

Radicles in grams per liter.[a]

	1		2		3		4		5		6	
	Grams.	Percentage.	Grams.	Percentage.	Grams.	Percentage.	Grams.	Percentage.	Grams.	Percentage.	Grains per thousand grams.	Percentage.
K	11.8	3.87	0.48	0.16	0.31	0.10	1.81	0.56	1.69	0.53	0.45	0.05
Na	104.4	34.29	117.01	38.00	119.62	37.74	103.61	32.12	102.20	31.86	349.64	38.49
Ca	4.8	1.58	3.10	1.01	3.59	1.17	17.17	5.33	17.27	5.38	8.54	.94
Mg	1.6	.52	.48	.16	.56	.18	2.54	.79	2.42	.75	1.45	.16
Cl	179.1	58.86	184.59	59.97	190.71	60.11	197.07	61.05	197.15	61.33	539.40	59.40
SO_4	1.6	.52	2.15	.70	2.22	.70	.48	.15	.48	.15	8.52	.96
Br	1.1	.36	......	......	......	......	......	......	......	......	......	......
	304.4	100.00	307.81	100.00	317.01	100.00	322.68	100.00	321.21	100.00	908.00	100.00

Samples from Watkins Salt Co., Watkins, N. Y.:
1. Artificial brine collected by company, 1910. R. F. Gardiner, analyst.
2. Artificial brine from wells Nos. 1 and 2, collected by W. B. Hicks, 1914. W. B. Hicks, analyst.
3. Artificial brine from well No. 3, collected by W. B. Hicks, 1914. R. K. Bailey, analyst.
4. Bittern resulting from 24-hour run collected from top portion direct from vacuum pan by W. B. Hicks, 1914. W. B. Hicks, analyst.
5. Bittern resulting from 24-hour run collected from bottom portion from the discharge pipe by W. B. Hicks, 1914. W. B. Hicks, analyst.
6. Salt from drainage bin, ready for driers, collected by W. B. Hicks, 1914. R. K. Bailey, analyst.

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[1] Merrill, F. J. H., Salt and gypsum industries of New York: New York State Mus. Bull. 11, p. 62, 1893.

Analyses of artificial brines of New York.

Radicles in grams per liter.[a]

	1	2	3	4	5	6	7	8	9	10
K	12	0.16	0.37	0.39	0.19	0.27	0.48	0.48	3.78	0.4
Na	108.4	128.27	122.05	111.43	121.42	110.66	114.31	113.64	80.03	378.6
Ca	3.4	3.35	4.00	3.02	3.42	.93	3.22	3.21	34.53	2.4
Mg	1.4	.73	.70	.43	.75	.12	.48	.48	6.22	.2
Cl	181.9	183.92	178.41	187.11	184.23	190.82	182.73	181.48	204.47	581.5
SO_4	2.4	2.39	2.94	2.34	2.22	6.30	2.03	2.14	1.22	3.3
Br	1.1	....	....	....	....	....	....	....	....	....
	310.6	318.82	308.47	304.72	312.23	309.1	303.25	301.43	330.25	[a] 966.4

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6	7	8	9	10
K	3.87	0.05	0.12	0.13	0.06	0.09	0.16	0.16	1.15	0.04
Na	34.90	40.24	39.66	36.57	38.89	35.80	37.71	37.69	24.23	39.17
Ca	1.09	1.06	1.30	.99	1.10	.30	1.06	1.07	10.46	.25
Mg	.45	.23	.23	.14	.24	.04	.16	.16	1.88	.02
Cl	58.57	57.67	57.97	61.40	59.00	61.69	60.24	60.21	61.91	60.18
SO_4	.77	.75	.72	.77	.71	[b] 2.08	.67	.71	.37	.34
Br	.35	....	....	....	....	....	....	....	....	....
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[a] Liter=1,000 grams.

[b] Probably too high.

Samples from International Salt Co., Watkins, N. Y. These samples except No. 1 were collected by W. B. Hicks, 1914.

1. Sample collected by company, 1910. R. F. Gardiner, analyst.
2. Artificial brine from well No. 1. R. K. Bailey, analyst.
3. Artificial brine from well No. 2. R. K. Bailey, analyst.
4. Artificial brine from well No. 3. R. K. Bailey, analyst.
5. Artificial brine from well No. 4. R. K. Bailey, analyst.
6. Artificial brine from well No. 5. R. K. Bailey, analyst.
7. Artificial brine from well No. 6. W. B. Hicks, analyst.
8. Artificial brine from well No. 7. W. B. Hicks, analyst.
9. Bittern taken from settling tank immediately after it had been drawn off from vacuum pan. W. B. Hicks, analyst.
10. Sample of salt taken from drainage bin. W. B. Hicks, analyst.

MICHIGAN.

Analyses of artificial brines of western Michigan.

Radicles in grams per liter.

	1	2	3	4	5	6	7	8	9
K	0.1	Trace.	0.8	0.1	0.2	0.5	0.1	0.2	0.1
Na	113.7	109.9	120.2	113.4	112.3	119.2	114.4	113.4	120.8
Ca	1.8	1.2	2.0	2.1	1.9	2.3	1.8	1.2	2.0
Mg	.4	1.4	.3	.4	.7	1.3	.8	.6	.4
Cl	176.9	173.6	188.0	176.9	175.9	191.4	178.6	178.0	188.2
SO_4	3.3	2.2	3.9	3.7	3.2	3.0	4.0	0.8	3.7
Br	....	Trace.	None.	....	....	Trace.	....	Trace.	Trace.
	296.2	288.3	315.2	296.6	294.2	317.7	299.7	294.2	315.2

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6	7	8	9
K	0.03	0.00	0.25	0.03	0.06	0.16	0.03	0.06	0.03
Na	38.37	38.13	38.12	38.29	38.20	37.52	38.17	38.58	38.34
Ca	.60	.41	.63	.71	.64	.72	.60	.41	.63
Mg	.13	.48	.09	.13	.22	.41	.27	.18	.13
Cl	59.63	60.22	59.68	59.60	59.79	60.25	59.68	60.50	59.70
SO_4	1.24	.76	1.23	1.24	1.09	.94	1.25	.27	1.17
Br	....	.00	.00	....	....	.00	....	.00	.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. Louis Sands Salt & Lumber Co., Manistee, Mich. From wells. A. R. Merz, analyst.
2. Louis Sands Salt & Lumber Co., Manistee, Mich. From well 2,013 feet deep. Collected by the company, 1910. R. F. Gardiner, analyst.
3. Louis Sands Salt & Lumber Co., Manistee, Mich. From well No. 2, 1910. J. A. Cullen, analyst.
4. R. G. Peters Salt & Lumber Co., East Lake, near Manistee, Mich. Composite from 6 wells, 1911; contains hydrogen sulphide. A. R. Merz, analyst.
5. Filer & Son, Filer City, near Manistee, Mich. From wells, 1911. A. R. Merz, analyst.
6. Filer & Son, Filer City, near Manistee, Mich. From hot settlers. Collected by J. W. Turrentine, 1910. J. A. Cullen, analyst.
7. State Lumber Co., Manistee, Mich. Composite from 2 wells at plant No. 2, 1911. A. R. Merz and R. F. Gardiner, analysts.
8. Stearns Salt & Lumber Co., Ludington, Mich. Composite from 4 wells, 1911. R. F. Gardiner, analyst.
9. Anchor Salt Co., Ludington, Mich. From settlers. Collected by company, 1910. J. A. Cullen, analyst.

The brines of the west shore of Michigan, like those of the east shore, are almost completely saturated. Their uniformity of composition suggests that they may be derived from a single bed. For a long time it was thought that there was but one bed of salt in this region,[1] but well No. 4 of the Anchor Salt Co. showed the presence of four beds, 20, 12, 7, and 5 feet, respectively, in thickness. The brines are exceptionally low in calcium and magnesium, and the percentage of sulphate is uniformly low.

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[1] Lane, A. C., Michigan Geol. Survey Ann. Rept., 1908, p. 59, 1909. Cook, C. W., Mineral resources of Michigan: Michigan Geol. and Biol. Survey Pub. 8, Geol. ser. 6, p. 319, 1911.

Analyses of natural brines of eastern Michigan.

Radicles in grams per liter.

	1	2	3	4	5	6	7	8	9	10	11
K	Trace.	0.4	1.4	0.8	1.0	Trace.	1.2	Trace.	Trace.	Trace.	5.29
Na	77.8	100.0	92.2	78.2	86.6	69.7	52.5	85.5	111.5	64.8	70.70
Ca	10.8	7.6	12.8	10.8	16.0	36.6	50.2	15.8	4.2	36.4	18.56
Mg	3.8	1.0	3.6	3.2	4.4	8.6	11.6	4.0	13.2	.8	4.93
Cl	145.4	155.1	155.4	145.9	172.8	197.6	205.4	163.0	205.4	165.6	156.68
SO_4	4.2	2.4	26.0	2.2	1.2	1.2	.6	.6	1.8	.6	Tracc.
Br	.4	1.7	2.0	.5	.4	2.2	Trace.	2.0	2.8	Trace.	4.23
Fe						.8	.8				.12
NH_4											
Sr											.59
SiO_2											Trace.
NH_4						.3					.59
Sr											Trace.
SiO_2											
	242.4	268.2	293.4	241.6	282.4	317.0	322.3	270.9	338.9	268.2	261.10

Radicles in percentage of anhydrous residue.

K	0.00	0.15	0.48	0.33	0.35	0.00	0.37	0.00	0.00	0.00	2.02
Na	32.13	37.27	31.42	32.36	30.63	21.99	16.27	31.55	32.90	24.18	27.08
Ca	4.45	2.83	4.36	4.47	5.67	11.54	15.57	5.83	1.24	13.57	7.11
Mg	1.57	.37	1.23	1.32	1.56	2.71	3.60	1.47	3.90	.30	1.89
Cl	59.96	57.86	52.97	60.40	61.23	62.35	63.75	60.19	60.60	61.73	60.01
SO_4	1.73	.89	8.86	.91	.42	.38	.19	.22	.53	.22	Tracc.
Br	.16	.63	.68	.21	.14	.69	.00	.74	.83	.00	1.62
Fe						.25	.25				.04
NH_4						.09					
Sr											.23
SiO_2											Trace.
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. Bliss, Van Auken Co., Saginaw, Mich. Composite from 3 wells, 1911. R. F. Gardiner, analyst.
2. Edward Germain, Saginaw, Mich. From well No. 1 (750 feet deep), 1910. R. F. Gardiner, analyst.
3. Mershon, Eddy, Parker & Co., Saginaw, Mich. Composite from 2 wells, 1911. R. F. Gardiner, analyst.
4. S. L. Eastman Flooring Co., Saginaw, Mich. Composite from 2 wells, 1911. R. F. Gardiner, analyst.
5. Saginaw Plate Glass Co., Saginaw, Mich. Composite from 10 wells, 1911. R. F. Gardiner, analyst.
6. Dow Chemical Co., Midland, Mich. Composite from 12 wells, 1911. R. F. Gardiner, analyst.
7. Dow Chemical Co., Mount Pleasant, Mich. Composite from 5 wells, 1911. R. F. Gardiner, analyst. (After removal of bromine.)
8. Saginaw Salt Co., St. Charles, Mich. From a well at Plant No. 1, 1911. R. F. Gardiner, analyst.
9. Saginaw Salt Co., St. Charles, Mich. Composite from 2 wells at Plant No. 2, 1911. R. F. Gardiner, analyst.
10. A. W. Wright, Alma, Mich. From depth of 2,863 feet, 1910. Collected by company. R. F. Gardiner, analyst.
11. Huron Milling Co., Harbor Beach, Mich. From a well approximately 2,000 feet deep. R. K. Bailey, analyst.

As the natural brines whose analyses are given in this table are from the Marshall sandstone of Michigan, with the possible exception of Nos. 10 and 11, it might be expected that there should be a certain consistency among the results. In a general way this is shown in the analyses of the first five samples, except No. 3, which is different in concentration and in content of sulphate. For natural brines the small amounts of sulphate are rather notable.

As the center of the geologic basin of the Lower Peninsula is approached there is a tendency toward increase in salinity. The heavier liquids tend to travel toward the lower levels. The bromides increase in the same direction, as do also the heavy iron salts, which precipitate as the basic ferric salts after the solutions have stood in the air for some time.

The Harbor Beach brine is of interest on account of its large content of potassium. Analyses of this brine have been published in the report of the Michigan Geological Survey,[1] and it was these published analyses indicating a very high potassium content and approximately complete saturation that first attracted attention. The results of the examination by the United States Geological Survey do not agree with those published. The degree of saturation obtained is lower, as is also the percentage of potassium chloride in the total salts. The brine can not be regarded as saturated if its specific gravity, which is 1.1745 at 17° C., its parts per thousand, and its content in calcium and magnesium are considered. The high content of bromine is of interest, especially if compared with that of brines which are now utilized for their bromine content in Michigan. As a source of bromine this brine should not be ignored.

Analyses of artificial brines of eastern Michigan and Canada.

Radicles in grams per liter.

	1	2	3	4	5	6	7	8	9
K	0.8	Trace.	1.4	2.4	Trace.	Trace.	Trace.	3.8	1.4
Na	132.6	120.6	78.2	123.3	121.3	114.5	119.2	119.6	110.1
Ca	2.8	.8	17.8	.8	.6	.6	1.4	1.4	6.4
Mg	.4	Trace.	12.8	Trace.	Trace.	1.0	.4	.9	3.0
Cl	205.4	183.8	182.1	189.3	185.2	179.0	185.0	191.4	190.2
SO_4	3.6	4.4	4.2	4.0	3.4	2.2	2.8	2.8	.6
Br	1.1	Trace.	1.7	.9	None.	....	Trace.	1.0	None.
	346.7	309.6	298.2	320.7	310.5	297.3	308.8	320.9	311.7

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6	7	8	9
K	0.23	0.00	0.47	0.74	0.00	0.00	0.00	1.18	0.45
Na	38.25	38.93	26.20	38.40	39.08	38.55	38.62	37.30	35.31
Ca	.81	.25	5.97	.24	.19	.20	.42	.43	2.06
Mg	.11	.00	4.29	.00	.00	.33	.12	.28	.96
Cl	59.25	59.40	61.09	59.10	59.64	60.18	59.94	59.63	61.03
SO_4	1.03	1.42	1.41	1.24	1.09	.74	.90	.87	.19
Br	.32	.00	.57	.28	.00	....	.00	.31	.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. Port Huron Salt Co., Port Huron, Mich. From a well about 1,900 feet deep, 1911. R. F. Gardiner, analyst.
2. Diamond Crystal Salt Co., St. Clair, Mich. From a single well, 1911. R. F. Gardiner, analyst.
3. Davidson, Wonsey Co., Marine City, Mich. From 2 wells, 1911. R. F. Gardiner, analyst.
4. Michigan Salt Works, Marine City, Mich. From company's single well, 1911. R. F. Gardiner, analyst.
5. Worcester Salt Co., Ecorse, near Detroit, Mich. From 2 wells. R. F. Gardiner, analyst.
6. Delray Salt Co., Delray, near Detroit, Mich. From well, 1911. R. F. Gardiner, analyst.
7. Michigan Alkali Co., Detroit, Mich. From well, 1911. R. F. Gardiner, analyst.
8. Mulkey Salt Co., Detroit, Mich. From 3 wells, 1911. R. F. Gardiner, analyst.
9. Western Canada Flour Mills Co., Goderich, Canada. From well No. 1, 1911. R. F. Gardiner, analyst.

The artificial brines pumped in the southeastern part of Michigan are generally similar in concentration, all being nearly saturated. Except in analyses Nos. 3 and 9, there is substantial agreement in sodium and chlorine. The content of sulphate also is fairly uniform except in No. 9. In view of the probability that the brines are

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[1] Michigan Geol. Survey Rept., vol. 5, pt. 2, p. 82, 1893.

pumped from different salt beds of the Monroe group and in view of the wide geographic range of the samples the uniformity in composition of the brines, which indicates uniformity in the composition of the original salt layers, is striking and indicates uniformity in the original physical geologic conditions of deposition. The high content of calcium and magnesium in analyses Nos. 3 and 9 is noteworthy. These samples resemble bitterns in composition, and they may be salt deposited in the last stages of evaporation in an interior basin or salt dissolved chiefly from the upper part of a salt bed or possibly from roof shales. The observations made in connection with the presence of magnesium salts in New York brines may apply here. (See p. 223.)

NORTHEASTERN OHIO.

Analyses of natural and artificial brines of northeastern Ohio.

Radicles in grams per liter.

	1	2	3	4	5	6	7	8	9	10	11
K	0.4	3.2	0.2	0.8	3.2	0.4	1.0	3.0	5.8	3.9	4.2
Na	123.0	68.0	117.2	126.8	62.7	122.1	128.2	122.0	48.0	43.4	62.0
Ca	1.0	29.0	.8	.4	30.8	.6	Trace.	.2	45.6	48.6	35.4
Mg	Trace.	6.4	Trace.	.9	6.4	Trace.	Trace.	Trace.	9.8	11.2	7.8
Cl	189.4	170.2	176.8	195.8	164.8	184.6	189.5	189.4	187.0	188.4	182.2
SO_4	2.8	8.6	6.8	4.6	Trace.	6.4	9.8	1.8	None.	.2	3.2
Br	Trace.	.2	None.	Trace.	2.0	None.	.7	Trace.	.4	....	Trace.
	316.6	285.6	301.8	329.3	269.9	314.1	329.2	316.4	296.6	295.7	294.8

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6	7	8	9	10	11
K	0.12	1.15	0.06	0.24	1.14	0.12	0.30	0.95	1.95	1.32	1.42
Na	38.88	24.50	38.90	38.51	23.22	38.93	38.98	38.57	16.20	14.69	21.05
Ca	.31	10.45	.24	.12	11.42	19	.00	.06	15.37	16.44	12.00
Mg	.00	2.30	.00	.27	2.37	.00	.00	.00	3.30	3.79	2.64
Cl	59.81	61.32	58.60	59.47	61.14	58.73	57.54	59.85	63.05	63.70	61.81
SO_4	.88	.21	2.20	1.39	.00	2.03	2.97	.57	.00	.06	1.08
Br	.00	.07	.00	.00	.71	.00	.21	.00	.13	....	.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. Colonial Salt Co., Kenmore, near Akron, Ohio. Artificial brine from well No. 6, 1911. R. F. Gardiner, analyst.
2. Colonial Salt Co., Akron, Ohio. Natural brine in strata above rock-salt horizon, 1911. R. F. Gardiner, analyst.
3. Columbia Chemical Co., Barberton, Ohio. Artificial brine forced to surface by hydraulic pressure, 1911. R. F. Gardiner, analyst.
4. Columbia Chemical Co., Barberton, Ohio. Artificial "cavity" brine, 1911. R. F. Gardiner, analyst.
5. Columbia Chemical Co., Barberton, Ohio. Natural brine in strata above salt horizon from which artificial brine is obtained, 1911. R. F. Gardiner, analyst.
6. Cleveland Salt Co., Cleveland, Ohio. Composite artificial brine from 2 wells, 1911. R. F. Gardiner, analyst.
7. Union Salt Co., Cleveland, Ohio. Artificial brine from 1 well, 1911. R. F. Gardiner, analyst.
8. Ohio Salt Co., Rittman, Ohio. Composite artificial brine from 2 wells, 1911. R. F. Gardiner, analyst.
9. Diamond Alkali Co., Fairport Harbor, Ohio. Natural brine in strata 300 feet above rock-salt horizon, 1911. R. F. Gardiner, analyst.
10. Same horizon as No. 9, but from another well half a mile distant, 1911. R. F. Gardiner, analyst.
11. Northeastern Oil & Gas Co., Austinburg, Ashtabula County, Ohio. Natural brine from well 2,000 feet deep, yielding about 5 barrels a day, collected by company, 1910. R. F. Gardiner, analyst.

The analysis of the artificial brines show close agreement in concentration, all the brines being nearly saturated, and also close agreement in content of sodium. The content of sulphate is variable, but it is usually somewhat higher than that of the artificial brines of New York. The almost complete absence of calcium and magnesium and the commonly low content of potassium are notable.

Comparison of the composition of natural with that of artificial brines is particularly facilitated by this table. The greater content of potassium, calcium, and magnesium of the natural brines is noteworthy. None of these brines contains much bromine or sulphate, and as a class they are neither so strong nor so pure solutions of salt as the artificial brines.

The geologic position of this natural-brine horizon in northern Ohio ranges from 350 to more than 400 feet above the highest salt beds from which artificial brines are pumped, a few records showing this distance as about 250 feet. This stratum of brine is sharply defined and is of wide extent. The brine is carefully cased off to prevent its getting into the artificial brines used in the manufacture of salt and alkali near Akron and Fairport Harbor, as it would injure the product.

The relatively high content of potassium of these natural brines is noteworthy. In fractional crystallization of the solution sodium chloride would separate first, carrying with it calcium sulphate. The calcium sulphate probably would not separate as an entity first because of its small amount and the relative abundance of the other salts.[1] This would leave the chlorides of potassium, calcium, and magnesium, and small amounts of iron. The removal of part of the lime and magnesia in order to bring the percentage of potassium up to that of a low-grade fertilizer presents a problem for the industrial chemist. These natural brines of Ohio deserve careful study for the purpose of ascertaining the potential value of the sodium-free residue as a fertilizer, and their position in a densely populated agricultural section makes the problem the more interesting.

The brine from the well at Austinburg (No. 11, p. 228) is not used for the production of salt, but it probably comes from the same horizon as other natural brines of northeastern Ohio. If this assumption is correct, this brine horizon extends 25 miles father east than it has been developed.

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[1] Van't Hoff, J. H., Physical chemistry in the service of the sciences: Chicago Univ. Decennial Pub., 2d ser., vol. 18, pp. 100-101, 1903.

SOUTHERN OHIO AND WEST VIRGINIA.

Analyses of natural brines of southern Ohio and West Virginia.

Radicles in grams per liter.

	1	2	3	4	5	6
K	0.2	0.2	0.4	0.2	0.3	0.3
Na	29.1	33.2	28.3	29.7	32.1	26.2
Ca	4.8	5.4	4.3	5.7	5.3	6.9
Mg	1.7	1.9	1.4	1.8	1.8	1.5
Cl	58.2	66.1	55.3	61.3	64.1	56.9
Br	.3	.3	.3	.3	.3	.4
	94.3	107.1	90.0	99.0	103.9	92.2

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6
K	0.23	0.21	0.42	0.22	0.27	0.30
Na	30.86	30.96	31.49	30.00	30.84	28.48
Ca	5.13	5.25	4.81	5.80	5.10	7.52
Ba	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Mg	1.79	1.73	1.53	1.83	1.76	1.65
Cl	61.69	61.56	61.46	61.81	61.71	61.66
SO_4	Trace.	None.	None.	None.	None.	None.
Br	.30	.29	.29	.34	.32	.39
	100.00	100.00	100.00	100.00	100.00	100.00

1. Pomeroy Chemical Co., Pomeroy, Ohio, 1918. R. K. Bailey, analyst; W. B. Hicks, collector. Total solids by determination, 8.86 per cent. Density at 18.6° C., 1.065. Little iron precipitate formed at bottom of vessel before analysis.
2. Pomeroy Salt Association, Pomeroy, Ohio, 1918. R. K. Bailey, analyst; W. B. Hicks, collector. Total solids by determination, 9.92 per cent. Density at 18.6° C., 1.079. Little iron precipitate formed at bottom of vessel before analysis.
3. Ohio River Salt Co., Mason, W. Va., 1918. R. K. Bailey, analyst; G. B. Richardson, collector. Total solids by determination, 8.49 per cent. Density at 21.5° C., 1.061. Little iron precipitate formed at bottom of vessel before analysis.
4. Liverpool Salt & Coal Co., Hartford, W. Va., 1918. R. K. Bailey, analyst; W. B. Hicks, collector. Total solids by determination, 9.27 per cent. Density at 18.6° C., 1.068. Little iron precipitate formed at bottom of vessel before analysis.
5. Mason Coal & Chemical Co., Hartford, W. Va., 1918. R. K. Bailey, analyst; W. B. Hicks, collector. Total solids by determination, 9.70 per cent. Density at 18.6° C., 1.071. Little iron formed in bottom of vessel before analysis.
6. J. Q. Dickinson & Co., Malden, W. Va., 1918. R. K. Bailey, analyst; G. B. Richardson, collector. Total solids by determination, 8.68 per cent. Density at 20.5° C., 1.062. Little iron precipitate formed at bottom of vessel before analysis.

The samples of natural brines of which analyses are given in the accompanying table were collected from the same geologic horizon along Ohio River in Ohio and West Virginia, except sample No. 6, which is from the interior of West Virginia, on Kanawha River.

A tendency toward greater concentration of calcium and magnesium to the southeast as the great trough formed by the coal-bearing rocks of the northern Appalachian field is approached might be expected, for it seems reasonable to suppose that the heavier liquid would move southeastward, and some such relation is indicated by these analyses.

The general presence of measurable amounts of bromine may be noted. These natural brines are sources of bromine.

The general similarity in composition of the brine from Malden, W. Va., to those collected along Ohio River is very apparent. The

Malden brine is utilized in the manufacture of salt, bromine, and calcium chloride. It contains a greater proportion of calcium than the brines along Ohio River and a greater proportion of magnesium than many of them. Though its proportionate content of bromine also is large, its total salinity is less than that of the brines along Ohio River.

Analyses of brine from oil wells in southern Ohio and West Virginia.[a]

Radicles in grams per liter.

	1	2	3	4	5	6	7	8	9	10	11
K	0.3	0.2	4.4	0.9	0.4	0.4	0.4	Trace.	0.2	2.7	1.2
Na	34.7	55.9	59.0	13.9	43.2	38.2	53.8	53.3	44.5	28.0	45.5
Ca	9.5	19.0	4.2	3.9	2.0	7.2	18.4	18.0	8.2	6.8	19.6
Mg	1.5	2.6	3.0	1.0	1.0	2.2	2.9	2.6	Trace.	.9	1.7
Cl	74.9	125.3	109.0	31.6	72.0	76.4	123.8	120.1	83.2	54.5	110.4
SO_4	Trace.	.2	2.0	.2	1.6	2.4	.2	2.2	Trace.	.5	.3
Br	.6	1.2	.2	.5	Trace.	Trace.	1.2	.3	None.	.8	1.0
	121.5	204.4	181.8	52.0	120.2	126.8	200.7	196.5	136.1	94.2	179.7

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6	7	8	9	10	11
K	0.25	0.09	2.42	1.73	0.33	0.31	0.19	0.00	0.15	2.86	0.62
Na	28.57	27.35	32.45	26.73	35.90	30.13	26.82	27.12	32.66	29.72	25.31
Ca	7.81	9.29	2.31	7.51	1.66	5.68	9.17	9.16	6.05	7.22	10.91
Mg	1.23	1.28	1.65	1.92	.83	1.73	1.45	1.33	.00	.95	.94
Cl	61.65	61.36	59.96	60.78	59.95	60.25	61.74	61.12	61.14	57.87	61.52
SO_4	.00	.09	1.10	.38	1.33	1.90	.09	1.12	.00	.53	.15
Br	.49	.54	.11	.95	.00	.00	.54	.15	.00	.85	.55
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[a] Samples collected by local representatives at the request of the United States Geological Survey.

1. South Penn Oil Co., Jefferson district, Pleasant County, W. Va. Brine from salt sand, 1910. J. A. Cullen, analyst.
2. South Penn Oil Co., Mannington district, Marion County, W. Va. Brine from Big Injun sand in well 2,092 feet deep, 1910. J. A. Cullen, analyst.
3. South Penn Oil Co., Mannington district, Marion County, W. Va. Brine from Big Injun sand at depth of 1,853 feet. R. F. Gardiner, analyst.
4. South Penn Oil Co., Union district, Wood County, W. Va. Brine from Cow Run sand, 1910. J. A. Cullen, analyst.
5. South Penn Oil Co., Union district, Wood County, W. Va. Brine from Big Injun sand, 1910. R. F. Gardiner, analyst.
6. South Penn Oil Co., Union district, Wood County, W. Va. Brine from Berea sand, 1910. R. F. Gardiner, analyst.
7. South Penn Oil Co., McElroy district, Tyler County, W. Va. Brine from Big Injun sand in oil well No. 1, 1,843 feet deep, on farm of the Conway heirs; yield, 20 barrels of brine and 10 barrels of oil a day, 1910. J. A. Cullen, analyst.
8. South Penn Oil Co., Ellsworth district, Tyler County, W. Va. Brine from well 1,859 feet deep, yielding 110 barrels of brine a day from Big Injun sand at a depth of 1,782 feet, 1910. R. F. Gardiner, analyst.
9. Pine Oil Co., Sistersville, Tyler County, W. Va. Natural brine from a well 1,250 feet deep, 1910. R. F. Gardiner, analyst.
10. South Penn Oil Co., Grant district, Ritchie County, W. Va. Brine from salt sand, 1910. J. A. Cullen, analyst.
11. South Penn Oil Co., Clay district, Harrison County, W. Va. Brine from 50-foot stratum of sand in well 2,094 feet deep, 1910. J. A. Cullen, analyst.

Analyses of brine from oil wells in southern Ohio and West Virginia—Continued.

Radicles in grams per liter.

	12	13	14	15	16	17	18	19	20	21
K	0.7	0.4	Trace.	0.2	Trace.	0.2	0.6	0.6	5.0	3.9
Na	55.1	28.5	51.3	58.6	52.4	32.8	34.6	39.5	139.5	58.1
Ca	19.8	9.0	14.4	7.0	Trace.	7.0	5.8	9.4	16.6	40.6
Mg	1.5	2.1	3.4	1.2	Trace.	1.2	.2	1.2	4.2	1.8
Cl	124.5	64.4	108.3	103.5	80.2	65.6	64.2	80.2	258.8	168.6
SO_4	.4	Trace.	6.6	3.4	.8	1.2	.4	.2	1.8	1.1
Br	1.2	.8	1.3	.1	Trace.	Trace.	Trace.	.2	.2	2.5
	203.2	105.2	185.3	174.0	133.4	108.0	105.8	131.3	426.1	276.6

Radicles in percentage of anhydrous residue.

K	0.34	0.38	0.00	0.11	0.00	0.18	0.56	0.45	1.17	1.41
Na	27.17	27.08	27.64	33.65	39.28	30.36	32.73	30.08	32.72	21.01
Ca	9.74	8.55	7.78	4.02	.00	6.48	5.49	7.15	3.89	14.67
Mg	.74	1.99	1.83	.66	.00	1.11	.18	.91	.98	.65
Cl	61.25	61.24	58.49	59.56	60.12	60.76	60.68	61.11	60.77	60.97
SO_4	.19	.00	3.56	1.95	.60	1.11	.36	.15	.42	.39
Br	.57	.76	.70	.05	.00	.00	.00	.15	.05	.90
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

12. South Penn Oil Co., Union district, Harrison County, W. Va. Brine from fourth saliferous sand in well 2,122 feet deep, 1910. J. A. Cullen, analyst.
13. South Penn Oil Co., Grant district, Wetzel County, W. Va. Brine at 2,770 feet, 1910. J. A. Cullen, analyst.
14. South Penn Oil Co., Grant district, Doddridge County, W. Va. Brine from Gordon sand at depth of 3,047 feet, 1910. R. F. Gardiner, analyst.
15. South Penn Oil Co., Freemans Creek district, Lewis County, W. Va. Brine from well No. 2, 2,247 feet deep on farm of T. M. Bode, 1910. R. F. Gardiner, analyst.
16. Geo. T. Berlin. Brine from well 1,167 feet deep at Bethel, Monroe County, Ohio; yield, 3 barrels a day, 1910. R. F. Gardiner, analyst.
17. Geo. T. Berlin. Brine from well, 1,228 feet deep at Bethel, Monroe County, Ohio; yield, 5 barrels a day, 1910. R. F. Gardiner, analyst.
18. G. A. Gifford. Brine from well 1,600 feet deep at Center, Monroe County, Ohio; yield, 15 barrels a day, 1910. R. F. Gardiner, analyst.
19. G. A. Gifford. Brine from well 1,560 feet deep at Green, Monroe County, Ohio; yield, 18 barrels a day. This sample is from the Newcastle pool, the greatest salt-water pool in eastern Ohio, 1910. R. F. Gardiner, analyst.
20. Southern Oil Co., Junction City, Perry County, Ohio. Brine from well 2,700 feet deep; yield, 48 barrels a day, 1910. R. F. Gardiner, analyst.
21. Southern Oil Co., Vinton County, Ohio. Brine from a well 2,100 feet deep; yield, 150 barrels a day, 1910. J. A. Cullen, analyst.

Most of the brines tested from oil wells in southern Ohio and West Virginia are rather dilute compared with brines used for making salt, though some of them contain unusually high proportions of potassium, calcium, and magnesium. Analyses Nos. 3, 10, 20, and 21 represent natural brines carrying more than 2.5 grams per liter of potassium. The relative proportions of calcium and magnesium in the brines represented by analyses Nos. 2, 7, 8, 11, 12, 14, 20, and 21 are great enough to give the solutions the characters of bitterns. As a group the brines of this section contain little sulphate.

The marked differences in the concentration and composition of all the brines suggests that they come from different horizons or at least from different vertical positions in the saline deposits. The brines from Monroe County, Ohio (see Nos. 16–19), just across Ohio River from Wetzel, Tyler, Doddridge, and Marion counties, W. Va., are much alike in composition and resemble the natural brines around

Mason and Pomeroy (see Nos. 1–6, p. 230). The brines from Junction City and Vinton County (Nos. 20 and 21) are distinctly different, being more like bitterns.

PENNSYLVANIA.

Analyses of natural brines of Pennsylvania.

Radicles in grams per liter.

	1	2	3	4	5	6
K	0.7	Trace.	0.2	0.9	0.6	Trace.
Na	26.0	27.3	2.1	28.6	38.3	27.0
Ca	7.0	6.9	Trace.	10.7	6.0	4.0
Mg	1.1	1.3	Trace.	2.0	.6	.6
Cl	56.2	57.9	3.4	68.3	70.0	50.4
SO_4	Trace.	Trace.	Trace.	1.4	2.4	Trace.
Br	.8	.5	None.	1.0	Trace.	Trace.
	91.8	93.9	5.7	112.9	117.9	82.0

Radicles in percentage of anhydrous residue.

K	0.76	0.00	3.51	0.80	0.51	0.00
Na	28.32	29.10	36.85	25.33	32.49	32.92
Ca	7.62	7.34	.00	9.48	5.09	4.87
Mg	1.19	1.38	.00	1.76	.51	.73
Cl	61.24	61.65	59.64	60.51	59.37	61.48
SO_4	.00	.00	.00	1.24	2.03	.00
Br	.87	.53	.00	.88	.00	.00
	100.00	100.00	100.00	100.00	100.00	100.00

1. John A. Beck Salt Co., Pittsburgh, Pa. Composite from 4 wells, 1911. J. A. Cullen, analyst.
2. John A. Beck Salt Co., Pittsburgh, Pa. From well 1,600 feet deep. Collected by the company, 1910. J. A. Cullen, analyst.
3. N. V. V. Franchot, Eldred, McKean County, Pa. From oil well 1,100 feet deep, 1910. R. F. Gardiner, analyst.
4. Southern Oil Co., Pittsburgh, Pa. From oil well 1,187 feet deep, Highland, Clarion County, Pa. Collected by Clarence Fennen, Clarion, Pa., 1910. J. A. Cullen, analyst.
5. Southern Oil Co., Pittsburgh, Pa. From oil well 1,727 feet deep, Butler, Butler County, Pa.; yield, 2 barrels a day. Collected by the company, 1910. R. F. Gardiner, analyst.
6. From well 1,591 feet deep, producing 8 barrels a day. Collected by H. H. Hemphill, Penn Township, Butler County, Pa., 1910. R. F. Gardiner, analyst.

The two analyses of brine from wells of the John A. Beck Salt Co. (Nos. 1 and 2) check closely. The brine was used for the manufacture of salt, bromine, and calcium chloride, and the large proportion of the last salt and of magnesium chloride indicated by the conventional combinations should be noted. The Beck plant is no longer in existence, and salt is not now manufactured in Pittsburgh. The other analyses in this table represent brines from oil wells not now used as sources of salt.

KANSAS.

Analyses of artificial brines of Kansas.

Radicles in grams per liter.

	1	2	3	4	5	6	7	8	9
K	0.4	0.8	0.1	Trace.	0.5	0.5	0.1	Trace.	0.2
Na	132.0	133.4	120.9	100.3	116.7	116.2	.5	100.3	116.6
Ca	Trace.	2.2	2.0	Trace.	2.0	1.6	.5	3.2	1.2
Mg	.4	.8	.2	1.2	.7	3.0	.3	.8	.8
Cl	199.0	184.8	188.0	154.4	183.2	186.6	2.3	162.2	181.7
SO_4	7.4	37.8	3.9	4.6	4.1	6.8	.3	Trace.	4.2
Br	Trace.	Trace.	None.	None.	Trace.	Trace.	None.	Trace.	None.
	339.2	359.8	315.1	260.5	307.2	314.7	4.0	266.5	304.7

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6	7	8	9
K	0.11	0.22	0.03	0.00	0.16	0.15	2.50	0.00	0.07
Na	38.90	37.07	38.37	38.50	38.02	36.96	12.50	37.66	38.27
Ca	.00	.61	.63	.00	.65	.51	12.50	1.31	.39
Mg	.11	.22	.06	.46	.23	.95	7.50	.30	.26
Cl	58.70	51.37	59.68	59.28	59.61	59.27	57.50	60.83	59.63
SO_4	2.18	10.51	1.23	1.76	1.33	2.16	7.50	.00	1.38
Br	.00	.00	.00	.00	.00	.00	.00	.00	.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. Barton Salt Co., Hutchinson, Kans. Composite from 3 wells, 1910. R. F. Gardiner, analyst.
2. Carey Salt Co., Hutchinson, Kans. Composite from 4 wells, 1911. R. F. Gardiner, analyst.
3. Western Salt Works, Hutchinson, Kans. Composite from 3 wells, 1910. J. A. Cullen, analyst.
4. Union Ice & Salt Co., Hutchinson, Kans. From a depth of 700 feet, running very light. Collected by the company, 1910. R. F. Gardiner, analyst.
5. Hutchinson Salt Co., Hutchinson, Kans. Composite from 8 or 9 wells at Joy Morton works, 1911. J. A. Cullen, analyst.
6. Orient Salt Co., Anthony, Kans. From company's well.
7. Natural water from a flowing well 130 feet deep, drilled for gas near Ellsworth, Kans.
8. Ellsworth Salt Co., Ellsworth, Kans. Composite from 5 wells, 1910. R. F. Gardiner, analyst.
9. Sterling Salt Co., Sterling, Kans. From 1 well, 1911. J. A. Cullen, analyst.

These analyses show the composition of artificial brines used in the manufacture of salt. Nearly all are almost completely saturated, and most of them contain a large proportion of salt. They are low in potassium, calcium, and magnesium, and contain only traces of bromine.

No. 7 represents a comparatively fresh water. The sulphate in No. 2 is surprisingly high, and the figure is probably erroneous.

LOUISIANA.

Analyses of natural brines of Louisiana.

Radicles in grams per liter.

	1	2	3
K	0.4	0.8	0.6
Na	2.3	4.4	47.6
Ca	.2	.4	Trace.
Mg	Trace.	Trace.	Trace.
Cl	2.0	6.4	72.4
SO_4	3.2	2.2	1.6
Br	Trace.	None.	Trace.
	8.1	14.2	122.2

Radicles in percentage of anhydrous residue.

	1	2	3
K	4.94	5.63	0.49
Na	28.39	31.02	39.02
Ca	2.47	2.82	.00
Mg	.00	.00	.00
Cl	24.70	45.02	59.18
SO_4	39.50	15.51	1.31
Br	.00	.00	.00
	100.00	100.00	100.00

1. New Mansfield, De Soto Parish, La. From well 830 feet deep, yielding 4,000,000 cubic feet a day of brine at a pressure of 380 pounds. Collected by S. S. Hunter, Shreveport, La., 1910. R. F. Gardiner, analyst.
2. Caddo oil field, La. From oil well. Collected by S. S. Hunter, Shreveport, La., 1910. R. F. Gardiner, analyst.
3. Evangeline oil field, Evangeline, La. From oil well, 1910. R. F. Gardiner, analyst.

These natural brines, which come from oil or gas wells in Louisiana, are too dilute for practical use as sources of saline material.

TEXAS.

Analyses of natural and artificial brines of Texas.

Radicles in grams per liter.

	1	2	[a]3	4	5	6	7	8
K	0.3	0.2	0.1	2.4	Trace.	0.6	3.4	3.2
Na	118.2	114.4	102.1	98.9	4.0	47.6	62.7	20.0
Ca	2.1	1.8	1.5	10.4	.2	13.4	5.2	3.4
Mg	.7	1.0	Trace.	.8	.4	2.0	Trace.	1.4
Cl	188.7	179.4	157.1	172.2	6.0	102.6	104.4	42.8
SO_4	Trace.	3.6	3.4	3.8	2.2	1.1	6.0	1.2
Br	Trace.	Trace.	....	Trace.	Trace.	.8	Trace.	None.
	310.0	300.4	264.2	288.5	12.8	168.1	181.7	72.0

Radicles in percentage of anhydrous residue.

	1	2	[a]3	4	5	6	7	8
K	0.09	0.07	0.04	0.83	0.00	0.35	1.87	4.45
Na	38.15	38.06	38.71	34.25	31.26	28.32	34.51	27.79
Ca	.67	.60	.53	3.61	1.56	7.97	2.86	4.72
Mg	.22	.33	.00	.28	3.12	1.19	.00	1.94
Cl	60.87	59.74	59.44	59.71	46.88	61.08	57.46	59.42
SO_4	.00	1.20	1.28	1.32	17.18	.65	3.30	1.68
Br	.00	.00	....	.00	.00	.44	.00	.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[a] Grams per kilogram.

1. Grand Saline Salt Co., Grand Saline, Tex. Artificial brine from well 418 feet deep, ready for evaporators. Collected by the company, 1910. J. A. Cullen, analyst.
2. Grand Saline Salt Co., Grand Saline, Tex. Artificial brine directly from well No. 1, depth 418 feet. Collected by the company, 1910. R. F. Gardiner, analyst.
3. B. W. Carrington, Grand Saline, Tex. Artificial brine from well at plant No. 2. R. K. Bailey, analyst.
4. Edward Bros., Midland, Crane County, Tex.; Salt Lake, Juan Cordova Survey. Collected by Edward Bros., 1910. R. F. Gardiner, analyst.
5. Brine from well in sec. 15, block 2, Crane County, Tex. Collected by Edward Bros., Midland, Tex., 1910. R. F. Gardiner, analyst.
6. Producers Oil Co., Houston, Tex. Natural brine from oil well 1,800 feet deep, Wichita County, Tex.; yield, half a barrel a day. Collected by Frank Cullison, Electra, Tex., 1910. J. A. Cullen, analyst.
7. Producers Oil Co., Houston, Tex. Natural brine from well 1,198 feet deep, Herman lease, Hardin County, Tex.; yield, 75 barrels a day. Collected by E. F. Woodward, Humble, Tex., 1910. R. F. Gardiner, analyst.
8. Producers Oil Co., Houston, Tex. Brine from well 1,350 feet deep, Sour Lake, Tex.; yield, 50 barrels of brine a day. Collected 1910. R. F. Gardiner, analyst.

Nos. 1–4 represent brines used in the manufacture of salt. These are normal brines except No. 4, which is somewhat low in sodium chloride. No. 6 represents a dilute brine approaching a bittern in composition, as indicated by its rather large content of chlorides of calcium and magnesium. The high relative proportion of potassium shown by No. 8 indicates a weak natural brine resembling a bittern so far as character and relative proportions of dissolved constituents are concerned.

OKLAHOMA.

Analyses of natural brines.

Radicles in grams per liter.

	1	2	3	4	5	6	7	8	9
K	0.2	1.2	0.2	0.4	0.6	0.2	1.0	0.6	0.6
Na	94.9	112.8	58.9	112.1	115.1	38.2	14.0	19.9	40.9
Ca	2.6	3.0	2.1	7.6	2.7	3.6	1.3	5.0	3.6
Mg	1.5	2.2	1.1	1.2	1.9	.8	.6	1.6	1.4
Cl	153.5	185.0	95.2	185.8	185.2	67.1	25.4	43.4	71.4
SO_4	4.0	3.8	3.9	3.8	3.3	.7	.9	1.6	3.4
Br	Trace.	Trace.	Trace.	.4	Trace.	.6	Trace.	Trace.	Trace.
	256.7	308.0	161.4	311.3	308.8	111.2	43.2	72.1	121.3

Radicles in percentage of anhydrous residue.

K	0.08	0.39	0.12	0.13	0.19	0.18	2.31	0.83	0.49
Na	36.94	36.61	36.46	36.03	37.28	34.36	32.42	27.60	33.72
Ca	1.02	.97	1.30	2.44	.86	3.23	3.01	6.93	2.98
Mg	.59	.71	.68	.39	.61	.72	1.39	2.22	1.15
Cl	59.81	60.09	59.03	59.66	60.00	60.34	58.79	60.20	58.86
SO_4	1.56	1.23	2.41	1.22	1.06	.63	2.08	2.22	2.80
Br	.00	.00	.00	.13	.00	.54	.00	.00	.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Radicles in grams per liter.

	10	11	12	13	14	15	16	17
K	0.9	0.2	0.7	1.1	0.9	0.5	0.8	0.3
Na	45.0	2.5	46.7	47.2	51.4	66.0	46.2	41.6
Ca	8.0	1.1	7.9	9.0	13.8	9.7	6.1	7.1
Mg	1.7	.2	1.7	1.3	.6	.7	2.2	2.4
Cl	89.3	6.4	92.8	93.2	105.9	120.7	89.4	82.5
SO_4	.8	.1	1.0	.4	Trace.	.7	Trace.	.7
Br	.6	None.	.4	.5	.5	.4	Trace.	.3
	146.3	10.5	151.2	152.7	173.1	198.7	144.7	134.9

Radicles in percentage of anhydrous residue.

K	0.61	1.90	0.46	0.72	0.52	0.25	0.55	0.22
Na	30.77	23.82	30.89	30.89	29.70	33.27	31.96	30.84
Ca	5.46	10.47	5.22	5.89	7.97	4.88	4.21	5.26
Mg	1.16	1.90	1.12	.85	.34	.35	1.52	1.78
Cl	61.05	60.96	61.39	61.07	61.18	60.70	61.76	61.16
SO_4	.54	.95	.66	.26	.00	.35	.00	.52
Br	.41	.00	.26	.32	.29	.20	.00	.22
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. A. Henquenet, Ferguson, Blaine County, Okla. From well 5 feet deep, 1910. J. A. Cullen, analyst.
2. D. A. Thomas, Salton, Harmon County, Okla. From spring No. 1, 1910. J. A. Cullen, analyst.
3. D. A. Thomas, Salton, Harmon County, Okla. From spring No. 2, 1910. J. A. Cullen, analyst.
4. W. H. Chaney, Salton, Harmon County, Okla. From spring, 1910. R. F. Gardiner, analyst.
5. W. H. Chaney, Salton, Harmon County, Okla. From spring, 1910. J. A. Cullen, analyst.
6. Prairie Oil & Gas Co., Muskogee County, Okla. From well 1,569 feet deep, producing 50 barrels of brine a day, 1910. J. A. Cullen, analyst.
7. Prairie Oil & Gas Co., Nowata County, Okla. From well 430 feet deep, producing 4 barrels a day, 1910. J. A. Cullen, analyst.
8. Prairie Oil & Gas Co., Nowata County, Okla. From well 1,674 feet deep, producing 800 barrels a day, 1910. R. F. Gardiner, analyst.
9. Prairie Oil & Gas Co., Nowata County, Okla. From well 1,240 feet deep, in NE. ¼ NE. ¼ sec. 14, T. 27 N., R. 14 E.; yield, 100 barrels a day, 1910. R. F. Gardiner, analyst.
10. Prairie Oil & Gas Co., Bryan, Okmulgee County, Okla. From well 1,674 feet deep, producing 80 barrels a day, 1910. J. A. Cullen, analyst.
11. Prairie Oil & Gas Co., Hamilton, Okmulgee County, Okla. From well 2,222 feet deep, producing 3 barrels a day, 1910. J. A. Cullen, analyst.
12. Prairie Oil & Gas Co., Morris, Okmulgee County, Okla. From well 1,587 feet deep, producing 25 barrels a day, 1910. J. A. Cullen, analyst.
13. Prairie Oil & Gas Co., Schulten, Okmulgee County, Okla. From well 2,007 feet deep, producing 40 barrels a day, 1910. J. A. Cullen, analyst.
14. Prairie Oil & Gas Co., Hominy, Osage County, Okla. From well 2,375 feet deep, producing 500 barrels a day, 1910. J. A. Cullen, analyst.
15. Prairie Oil & Gas Co., Osage County, Okla. From well 1,565 feet deep, producing 15 barrels a day; sample sent from Bartlesville, Okla., 1910. J. A. Cullen, analyst.
16. Prairie Oil & Gas Co., Cleveland, Pawnee County, Okla. From oil well 1,750 feet deep, producing 50 barrels a day, 1910. J. A. Cullen, analyst.
17. Prairie Oil & Gas Co., Tulsa County, Okla. From well 1,557 feet deep, in NE. ¼ SE. ¼ sec. 18, T. 17 N., R. 12 E.; yield, 6 barrels a day, 1910. J. A. Cullen, analyst.

Analyses of natural brines—Continued.

Radicles in grams per liter.

	18	19	20	21	22	23	24	25	26
K	Trace.	1.0	1.0	Trace.	0.5	0.6	Trace.	1.0	1.0
Na	37.3	38.4	43.3	40.0	32.1	34.4	23.9	122.9	117.7
Ca	13.2	8.2	6.9	7.8	4.5	4.8	2.2	2.3	1.0
Mg	1.0	2.0	1.7	1.4	2.2	2.4	.2	1.3	1.6
Cl	82.8	80.7	84.7	79.4	63.9	68.8	40.0	195.9	183.0
SO_4	1.0	Trace.	Trace.	Trace.	.1	.5	1.6	4.4	8.0
Br	Trace.	.4	.4	Trace.	.6	.5	Trace.	Trace.	....
	135.3	130.7	138.0	128.6	103.9	112.0	67.9	327.8	312.3

Radicles in percentage of anhydrous residue.

	18	19	20	21	22	23	24	25	26
K	0.00	0.76	0.72	0.00	0.48	0.53	0.00	0.31	0.32
Na	27.59	29.41	31.41	31.08	30.92	30.67	35.20	37.47	37.68
Ca	9.75	6.27	5.00	6.06	4.33	4.27	3.24	.70	.32
Mg	.74	1.52	1.23	1.09	2.12	2.14	.29	.39	.51
Cl	61.18	61.75	61.36	61.77	61.53	61.41	58.92	59.79	58.61
SO_4	.74	.00	.00	.00	.09	.49	2.35	1.34	2.56
Br	.00	.30	.28	.00	.53	.49	.00	.00	....
	100.00	100.01	100.00	100.00	100.00	100.00	100.00	100.00	100.00

18. Prairie Oil & Gas Co., Tulsa County, Okla. From well 1,148 feet deep, in T. 21 N.; yield, 7 barrels a day, 1910. R. F. Gardiner, analyst.

19. Prairie Oil & Gas Co., Tulsa County, Okla. From oil well No. 2, 1,178 feet deep, producing 500 barrels a day, 1910. J. A. Cullen, analyst.

20. Prairie Oil & Gas Co., Dawson, Tulsa County, Okla. From well 1,150 feet deep, producing 10 barrels a day, 1910. J. A. Cullen, analyst.

21. Producers' Oil Co., Tulsa County, Okla. From well 1,200 feet deep, producing 200 barrels a day, 1910. R. F. Gardiner, analyst.

22. Prairie Oil & Gas Co., Washington County, Okla. From well 925 feet deep, producing 240 barrels a day, 1910. J. A. Cullen, analyst.

23. Prairie Oil & Gas Co., Washington County, Okla. From well 1,305 feet deep, producing 25 barrels a day, 1910. J. A. Cullen, analyst.

24. Prairie Oil & Gas Co., Jefferson, Washington County, Okla. From well 1,224 feet deep, producing 30 barrels a day, 1910. R. F. Gardiner, analyst.

25. From spring, Woodward County, Okla. Collected by P. L. Clifton, Pomeroy, Ohio, 1910. J. A. Cullen, analyst.

26. From spring in sec. 33, T. 27 N., R. 19 W., north of Woodward, Woodward County, Okla. Collected by P. L. Clifton, 1910. R. F. Gardiner, analyst.

Most of the samples from Oklahoma were collected by drillers and represent natural brines from wells drilled for oil or gas. Nearly all are rather dilute, but Nos. 25 and 26, which are from the same locality, and Nos. 2, 4, and 5, which are likewise from the same locality, are strong natural brines from springs and are purer solutions of sodium chloride than the brines from the oil and gas wells.

The rather large amount of calcium chloride and magnesium chloride and the small amounts of sulphate in the natural brines are noteworthy. A few of the analyses indicate a tendency toward concentration of potassium salts, though they do not warrant further investigation of these brines as sources of potash. Small amounts of bromine are generally present in the brines.

MISCELLANEOUS.

Analyses of natural brines of Illinois, Kentucky, Tennessee, Virginia, and Utah.

Radicles in grams per liter.

	1	2	3	4	[a] 5
K	Trace.	0.1	0.6	1.5	0.4
Na	16.5	15.5	2.4	114.6	102.1
Ca	.8	1.2	Trace.	2.3	.1
Mg	1.6	1.8	Trace.	.3	Trace.
Cl	31.2	28.2	2.0	180.6	156.8
SO_4	.2	4.2	2.2	3.7	3.2
Br	Trace.	None.	None.	None.	....
	50.3	51.0	7.2	303.0	262.6

Radicles in percentage of anhydrous residue.

	1	2	3	4	5
K	0.00	0.19	8.33	0.49	0.13
Na	32.82	30.40	33.32	37.80	38.89
Ca	1.58	2.35	.00	.76	.05
Mg	3.16	3.52	.00	.10	.00
Cl	62.05	55.31	27.79	59.63	59.71
SO_4	.39	8.23	30.56	1.22	1.22
Br	.00	.00	.00	.00	....
	100.00	100.00	100.00	100.00	100.00

[a] Grams per kilogram.

1. From Shlaffly oil well, 1,052 feet deep, yielding 75 barrels a day, in southwest corner of SE. ¼ SE. ¼ sec. 3, T. 2 N., R. 3 W., Clinton County, Ill. Collected by E. W. Shaw, 1911. R. F. Gardiner, analyst.
2. From well 300 feet deep in Griffin, Wayne County, Ky. Collected by New Domain Oil & Gas Co., Lexington, Ky., 1910. R. F. Gardiner, analyst.
3. From Douglas well No. 1 in Spring Valley oil field, Overton County, Tenn., about 1 mile south of Netherland. The well flowed several thousand barrels of oil from a depth of less than 55 feet, and the oil was followed by this water, which has been flowing since 1866. Collected by M. J. Munn, 1910. R. F. Gardiner, analyst.
4. Mathieson Alkali Works, Saltville, Smyth County, Va. Brine from a depth of approximately 1,000 feet, 1910. J. A. Cullen, analyst.
5. Brine from salt springs in Salt Creek Canyon, east of Nephi, Juab County, Utah. Collected by Jackson Bros., 1912. R. K. Bailey, analyst.

Tests of miscellaneous natural substances from Nevada, Utah, Wyoming, and California.

	Total water-soluble salts, dried and ignited (percentage of original sample).	Potassium in percentage of ignited residue.		
		Equivalent as potassium (K).	Equivalent as potassium oxide (K_2O).	Equivalent as potassium chloride (KCl).
1	79.89	0.49	0.59	0.93
2	9.34	4.92	5.92	9.38
3	92.93	.72	.87	1.38
4	6.74	3.18	3.83	6.07
5	21.55	.85	1.02	1.61
6	54.19	.34	.41	.65
7	65.84	2.59	3.12	4.94

1. Saline incrustation on surface of desert near Withee Junction, west of Ogden, Utah. Collected in 1912. R. K. Bailey, analyst.
2. Yellow deposit at outlet of bathing tank, Hot Springs, north of Brigham, Utah. G. F. Loughlin, collector, 1912. R. K. Bailey, analyst.
3. Salt from seepage on flat below spring inclosure near a hot spring on Oregon Short Line, 10 miles north of Ogden, Utah. G. F. Loughlin, collector, 1912. R. K. Bailey, analyst.
4. Green clay half a mile east of Salt Springs, near entrance to Death Valley, Cal. Unsurveyed land. This clay, exposed 7 or 8 feet thick where the road crosses an arroyo, is supposed to contain nitrates. Collected in 1912. R. K. Bailey, analyst.
5. Natural soda on bank of Green River, near toll gate, 1 mile north of Green River, Wyo. Collected in 1912. R. K. Bailey, analyst.
6. Natural soda near base of river cliff, about 1 mile southeast of Green River, Wyo. Collected in 1912. R. K. Bailey, analyst.
7. Saline material collected at Steamboat Springs, Nev. Collected in 1912. R. K. Bailey, analyst.

COMPOSITION OF BITTERNS.

NEW YORK.

Analyses of bitterns from artificial brines of New York.

Radicles in grams per liter.

	1	2	3	4	5	6	7
K	Trace.	Trace.	1.0	0.2	0.6	0.2	0.6
Na	117.0	120.0	109.1	114.9	111.4	73.2	112.0
Ca	4.8	4.0	10.3	5.4	8.2	5.3	.8
Mg	2.2	.8	1.6	.8	.6	.7	.8
Cl	187.9	190.6	191.1	185.4	185.6	122.8	173.4
SO_4	3.6	4.6	.6	2.4	2.0	1.1	1.2
Br	1.1	.9	....	.8	2.0	....	.6
	316.6	320.9	313.7	309.9	310.4	203.3	289.4

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6	7
K	0.00	0.00	0.32	0.06	0.19	0.09	0.21
Na	36.98	37.39	34.80	37.21	35.90	36.01	38.72
Ca	1.52	1.25	3.28	1.74	2.64	2.64	.27
Mg	.69	.25	.51	.25	.19	.34	.27
Cl	59.37	59.40	60.90	59.72	59.80	60.38	59.91
SO_4	1.10	1.43	.19	.77	.64	.54	.41
Br	.34	.28	....	.25	.64	....	.21
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Radicles in grams per liter.

	8	9	10	11	12	13	14
K	1.7	2.8	1.9	9.4	1.8	1.3	2.2
Na	110.1	100.3	106.7	56.8	93.7	114.2	108.9
Ca	11.4	19.9	13.5	20.2	25.2	6.4	7.6
Mg	1.0	1.8	1.5	1.6	2.6	1.9	1.9
Cl	193.1	197.2	193.5	135.0	197.5	192.8	187.5
SO_4	.7	.5	.8	2.2	.4	1.2	1.3
	318.0	322.5	317.9	225.2	321.2	317.8	309.4

Radicles in percentage of anhydrous residue.

	8	9	10	11	12	13	14
K	0.53	0.87	0.60	4.17	0.56	0.41	0.71
Na	34.61	31.01	33.52	25.23	29.18	35.95	35.21
Ca	3.59	6.17	4.25	8.97	7.85	2.01	2.45
Mg	.34	.56	.47	.71	.81	.60	.61
Cl	60.71	61.24	60.91	59.94	61.48	60.66	60.60
SO_4	.22	.15	.25	.98	.12	.37	.42
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. International Salt Co., Myers, N. Y. After 22 hours' evaporation. Collected by J. W. Turrentine, 1911. R. F. Gardiner, analyst.
2. International Salt Co., Myers, N. Y. Collected by J. W. Turrentine, 1911. R. F. Gardiner, analyst.
3. Remington Salt Co., Ithaca, N. Y. From evaporators, representing a concentration of 350 tons of original brine to 25 tons. Collected by J. W. Turrentine, 1911. A. R. Merz, analyst.
4. Remington Salt Co., Ithaca, N. Y. From centrifuges at 9 a. m., first hour of centrifuging. Collected by J. W. Turrentine, 1911. R. F. Gardiner, analyst.
5. Remington Salt Co., Ithaca, N. Y. From centrifuges at end of 7 hours' centrifuging. Collected by J. W. Turrentine, 1911. R. F. Gardiner, analyst.
6. Le Roy Salt Co., Le Roy, N. Y. Waste bittern from the plant, 1911. A. R. Merz, analyst.
7. Solvay Process Co., Syracuse, N. Y. From brine from 50-foot salt bed 1910. R. F. Gardiner, analyst.
8. Worcester Salt Co., Silver Springs, N. Y. From vacuum pan, 1911. A. R. Merz, analyst.
9. Worcester Salt Co., Silver Springs, N. Y. From grainer No. 6, 1911. A. R. Merz, analyst.
10. Rock Glen Salt Co., Rock Glen, N. Y. After 10 days' evaporation in open pans, 1911. A. R. Merz, analyst.
11. Rock Glen Salt Co., Rock Glen, N. Y. After 6 weeks' evaporation in grainer, taken at time of run-off, 1910. R. F. Gardiner, analyst.
12. Star & Crescent Salt Co., Saltvale, N. Y. From open pans, representing concentration of 85,000 gallons of original brine to approximately 2,250 gallons, taken at time of run-off, 1911. A. R. Merz, analyst.
13. Genesee Salt Co., Piffard, N. Y. From open pans after 36 hours' evaporation, representing concentration of 30,000 gallons to 15,000 gallons, 1911. A. R. Merz, analyst.
14. Genesee Salt Co., Piffard, N. Y. From grainer after 2 weeks' evaporation, 1911. A. R. Merz, analyst.

MICHIGAN.

Analyses of bitterns from artificial brines of western Michigan.

Radicles in grams per liter.

	1	2	3	4	5	6
K	2.0	0.5	0.2	6.0	0.7	....
Na	89.7	115.1	119.1	107.6	111.1	121.4
Ca	5.2	3.9	2.4	8.4	3.5	2.8
Mg	15.4	3.0	1.6	3.4	4.6	.3
Cl	191.8	191.4	189.8	191.8	189.8	190.4
SO_4	3.2	2.3	3.4	5.0	2.3	2.4
Br	Trace.	....	....	None.	....	....
	307.3	316.2	316.5	322.2	312.0	317.3

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6
K	0.65	0.16	0.06	1.86	0.22	....
Na	29.19	36.40	37.61	33.40	35.66	38.26
Ca	1.69	1.23	.76	2.61	1.12	.88
Mg	5.02	.95	.51	1.05	1.47	.09
Cl	62.41	60.54	59.99	59.53	60.80	60.01
SO_4	1.04	.72	1.07	1.55	.73	.76
Br	.00	....	....	.00	....	....
	100.00	100.00	100.00	100.00	100.00	100.00

1. Filer & Son, Filer City, near Manistee, Mich. Drippings from salt, 1911. R. F. Gardiner, analyst.
2. R. G. Peters Salt & Lumber Co., East Lake, Manistee, Mich. From grainer after 19 days' evaporation, 1911. A. R. Merz, analyst.
3. Buckley-Douglas Lumber Co. (formerly State Lumber Co.), Manistee, Mich. From grainer after 4 weeks' evaporation, 1911. A. R. Merz, analyst.
4. Buckley-Douglas Lumber Co., Manistee, Mich. From grainer after 17 days' evaporation, 1911. R. F. Gardiner, analyst.
5. Louis Sands Salt & Lumber Co., Manistee, Mich. From grainer after 3 weeks' evaporation, 1911. A. R. Merz, analyst.
6. Stearns Salt & Lumber Co., Ludington, Mich. From grainer, 1911. A. R. Merz, analyst.

Certain of the bitterns of western Michigan are slightly less concentrated than the brines from which they are derived. (See analyses above.) This difference is not greater, however, than would be accounted for by the usual variations in strength of both brines and bitterns. Generally the relative proportions of sodium and sulphate are less in the bitterns than in the brines and the relative proportions of calcium and magnesium are greater, because of the precipitation of crystals of sodium chloride and calcium sulphate and the gradual concentration of the alkaline-earth chlorides with which the solution is not completely saturated. Several of the bitterns have resulted from the concentration of very large amounts of brine; the constitution of the bitterns, therefore, indicates the marked paucity of deliquescent chlorides and salts of potassium in the brines of western Michigan.

Analyses of bitterns from artificial brines of eastern Michigan and Canada.

Radicles in grams per liter.

	1	2	3	4	5	6	7	8	9
K	Trace.	0.1	Trace.	0.4	Trace.	Trace.	2.0	1.6	1.4
Na	119.9	120.3	121.1	115.9	117.1	121.4	104.6	118.4	115.7
Ca	1.8	2.0	1.9	2.2	3.4	.6	13.8	1.2	4.6
Mg	Trace.	.2	.2	1.4	.6	Trace.	2.7	Trace.	2.4
Cl	184.2	186.8	187.5	184.8	188.0	185.5	194.6	179.6	191.6
SO_4	4.8	3.8	3.4	3.6	2.0	1.8	.6	4.6	3.2
Br	Trace.	....	....	None.	.8	2.5	....	7.8	None.
	310.7	313.2	314.1	308.3	311.9	311.8	318.3	313.2	318.9

Radicles in percentage of anhydrous residue.

K	0.00	0.03	0.00	0.13	0.00	0.00	0.63	0.51	0.43
Na	38.57	38.43	38.57	37.63	37.54	38.93	32.86	37.79	36.32
Ca	.58	.65	.61	.71	1.09	.19	4.34	.38	1.44
Mg	.00	.06	.06	.45	.19	.00	.85	.00	.75
Cl	59.31	59.65	59.68	59.91	60.29	59.50	61.14	57.36	60.06
SO_4	1.54	1.18	1.08	1.17	.64	.58	.18	1.47	1.00
Br	.00	....	....	.00	.25	.80	....	2.49	.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. Port Huron Salt Co., Port Huron, Mich. From grainer after 2 weeks' evaporation, 1911. R. F. Gardiner, analyst.
2. Delray Salt Co., Delray, near Detroit, Mich. Drippings from salt being conveyed from vacuum pans, 1911. A. R. Merz, analyst.
3. Delray Salt Co., Delray, near Detroit, Mich. From grainer after 12 days' evaporation, 1911. A. R. Merz, analyst.
4. Pennsylvania Salt Co., Wyandotte, Mich. From dripping vats, 1910. R. F. Gardiner, analyst.
5. Diamond Crystal Salt Co., St. Clair, Mich. From grainer after 23 days' evaporation, 1911. R. F. Gardiner, analyst.
6. Davidson, Wonsey Co., Marine City, Mich. Drippings from vacuum-pan salt, 1911. R. F. Gardiner, analyst.
7. Michigan Salt Works, Marine City, Mich. From grainer after 6 weeks' evaporation, 1911. A. R. Merz, analyst.
8. Mulkey Salt Co., Detroit, Mich. After 30 to 35 days' evaporation, 1911. R. F. Gardiner, analyst.
9. Western Canada Flour Mills Co., Goderich, Canada. From grainer after 5 weeks' evaporation, 1911. R. F. Gardiner, analyst.

The analyses in the accompanying table indicate that the bitterns from artificial brines of eastern Michigan are similar in character to the brines from which they are derived. (See analyses, pp. 226–227.) Indeed some of the brines are more strongly concentrated than the resultant bitterns. The content of alkaline-earth metals in the bitterns is not large, and the contents of sodium and chlorine are not markedly different from those of the original brines. The relative content of sulphate is ordinarily less in the bitterns because of its tendency to precipitate in combination with calcium as the solution is heated. The content of bromine in bittern No. 8 is abnormally large compared with that of the other samples. The fact that the Mulkey Salt Co. pumps from the 950-foot level in the upper bed of salt, the top of which lies about 900 feet below the surface, may explain the bittern-like nature of the brine but does not explain its low content of magnesium.

Analyses of bitterns from natural brines of eastern Michigan.

Radicles in grams per liter.

	1	2	3	4	5	6	7	8	9	10
K	1.3	1.6	4.2	2.6	10.2	8.2	Trace.	5.4	1.2	Trace.
Na	66.1	75.2	64.7	76.1	.0	1.8	6.2	8.2	52.5	60.9
Ca	40.6	32.4	36.4	32.8	192.6	174.0	82.0	87.2	50.2	.6
Mg	11.5	9.6	11.0	9.6	35.2	40.4	25.4	16.3	11.6	.4
Cl	207.7	200.8	204.1	195.8	452.2	433.3	223.6	219.2	205.4	91.5
SO_4	.4	Trace.	.8	1.4	None.	3.0	3.4	1.8	.6	3.6
Br	....	4.4	3.3	2.2	Trace.	.5	.4	Trace.	Trace.	4.3
	327.6	324.0	324.5	320.5	690.2	661.2	341.0	338.1	321.5	161.3

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6	7	8	9	10
K	0.40	0.50	1.29	0.81	1.48	1.24	0.00	1.60	0.37	0.00
Na	20.20	23.21	19.93	23.74	.00	.27	1.82	2.40	16.33	37.79
Ca	12.39	10.00	11.22	10.21	27.91	26.33	24.04	25.72	15.60	.37
Mg	3.51	2.97	3.39	3.00	5.10	6.11	7.45	4.97	3.63	.24
Cl	63.38	61.97	62.90	61.12	65.51	65.53	65.58	64.78	63.89	56.69
SO_4	.12	.00	.25	.44	.00	.45	1.00	.53	.18	2.24
Br	....	1.35	1.02	.68	.00	.07	.11	.00	.00	2.67
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. Hine & Co., Bay City, Mich. From grainer after 5 days' evaporation, 1911. A. R. Merz, analyst.
2. Bliss-Van Auken Co., Saginaw, Mich. From grainer after 5 days' evaporation, 1911. R. F. Gardiner, analyst.
3. Edward Germain, Saginaw, Mich. From grainer after 14 days' evaporation, 1911. R. F. Gardiner, analyst.
4. Mershon-Eddy-Parker Co., Saginaw, Mich. From grainer after 4 days' evaporation, 1911. R. F. Gardiner, analyst.
5. Saginaw Chemical Works, Saginaw, Mich. Bittern concentrated to 8.5 per cent of the volume of the original brine before the final evaporation for the preparation of calcium chloride. When the hot sample had cooled a crystalline solid separated, which contained 1.1 per cent potassium, equivalent to 2.3 per cent potassium chloride. Collected by J. W. Turrentine, 1911. R. F. Gardiner, analyst.
6. Saginaw Plate Glass Co., Saginaw, Mich. From grainer, concentrated to 45° Baumé, 1910. R. F. Gardiner, analyst.
7. Saginaw Plate Glass Co., Saginaw, Mich. From a grainer just before going to the chemical plant; concentrated to 30-31° Baumé, 1910. R. F. Gardiner, analyst.
8. W. J. Mason, Saginaw, Mich. "Mother water." Collected by Mr. Mason, 1910. R. F. Gardiner, analyst.
9. Dow Chemical Co., Mount Pleasant, Mich. After removal of bromide; it contains iron. Collected in 1911. R. F. Gardiner, analyst.
10. Saginaw Salt Co., St. Charles, Mich. From grainer after 4 days' evaporation, 1911. R. F. Gardiner, analyst.

For comparing the composition of bitterns the statements of composition in percentage are the most useful, because the degree of salinity of the bitterns is so divergent, partly because of the varying periods of time during which they have accumulated but chiefly because of the varying amounts of original brine which they represent. Analysis No. 10 obviously represents a diluted sample, for the bittern is less strongly concentrated than the brines from which it is supposed to have been formed. All the sulphate and sodium have been removed from No. 5 by its high degree of concentration; the high proportion of potassium in this bittern is noteworthy, but in the others the quantity of potassium is small and variable.

NORTHEASTERN OHIO.

Analyses of bitterns from artificial brines of northeastern Ohio.

Radicles in grams per liter.

	1	2	3	4	5	6
K	2.8	1.2	Trace.	0.7	1.8	2.8
Na	108.4	100.1	103.9	103.7	97.6	104.8
Ca	12.8	16.3	4.2	16.5	12.0	13.5
Mg	1.6	3.7	3.0	1.3	2.4	2.2
Cl	193.0	194.5	174.2	192.3	187.8	192.3
SO_4	5.0	.7	2.4	1.1	1.8	3.3
Br	Trace.	Trace.	Trace.	Trace.	Trace.	.5
	323.6	316.5	287.7	315.6	303.4	319.4

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6
K	0.86	0.38	0.00	0.22	0.59	0.87
Na	33.53	31.64	36.08	32.88	32.20	32.83
Ca	3.95	5.15	1.46	5.23	3.96	4.23
Mg	.49	1.17	1.04	.41	.79	.69
Cl	59.62	61.44	60.59	60.91	61.87	60.20
SO_4	1.55	.22	.83	.35	.59	1.03
Br	.00	.00	.00	.00	.00	.15
	100.00	100.00	100.00	100.00	100.00	100.00

1. Colonial Salt Co., Kenmore, near Akron, Ohio. Bittern from grainer after 5½ months' evaporation, 1911. R. F. Gardiner, analyst.
2. Union Salt Co., Cleveland, Ohio. Bittern from grainer after 5 days' evaporation, 1911. A. R. Merz, analyst.
3. Cleveland Salt Co., Cleveland, Ohio. Bittern after 30 days' evaporation.
4. Ohio Salt Co., Rittman, Ohio. Bittern after 35 days' evaporation, 1911. A. R. Merz, analyst.
5. Ohio Salt Co., Rittman, Ohio. Bittern from boot of vacuum pan, 1911. A. R. Merz and R. F. Gardiner, analysts.
6. Ohio Salt Co., Rittman, Ohio. Saline solution from boot of vacuum pan, 1911. J. A. Cullen, analyst.

These bitterns from brines of northeastern Ohio are comparable in concentration with the brines from which they were made. The chief differences between the composition of the brines and that of the bitterns are the larger amounts of calcium, magnesium, and potassium and the smaller amounts of sodium in the bitterns. The content of sulphate is generally less in the bitterns, probably because of its precipitation during evaporation.

SOUTHERN OHIO AND WEST VIRGINIA.

Analyses of bitterns from natural brines of southern Ohio and West Virginia.

Radicles in grams per liter.

	1	2	3	4	5	6
K	2.7	1.6	3.1	1.6	3.7	3.5
Na	1.1	.7	6.9	1.6	4.1	4.6
Ca	142.9	148.1	112.0	151.5	123.0	131.7
Mg	40.1	53.5	31.3	43.2	35.5	28.8
Cl	371.7	422.1	299.1	395.4	327.3	321.9
Br	8.8	12.5	6.9	9.6	7.7	7.1
	567.3	638.5	459.3	602.9	501.3	497.6

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6
K	0.49	0.25	0.67	0.27	0.75	0.70
Na	.20	.12	1.52	.27	.82	91
Ca	25.19	23.19	24.38	25.12	24.53	26.47
Ba	Trace or none.	Trace or none.	Present, not determined.	Trace or none	Trace.	Trace or none.
Mg	7.07	8.37	6.83	7.17	7.08	5.80
Cl	65.50	66.11	65.10	65.58	65.28	64.70
S_4O	None.	None.	None.	None.	None.	None.
Br	1.55	1.96	1.50	1.59	1.54	1.42
	100.00	100.00	100.00	100.00	100.00	100.00

1. Pomeroy Salt Association, Pomeroy, Ohio, 1918. R. K. Bailey, analyst; G. B. Richardson, collector. Total solids by determination, 40.64 per cent. Density at 24° C., 1.396. Considerable precipitated salt in bottom of bottle with some iron.
2. Pomeroy Chemical Co., Pomeroy, Ohio, 1918. R. K. Bailey, analyst; G. B. Richardson, collector. Total solids by determination, 44.37 per cent. Density at 24° C., 1.439. Considerable salt and iron precipitated on bottom of vessel.
3. Liverpool Salt & Coal Co., Hartford, W. Va., 1918. R. K. Bailey, analyst; G. B. Richardson, collector. Total solids by determination, 34.59 per cent. Density at 24° C., 1.328. Considerable salt and iron precipitated at bottom of vessel.
4. Mason Coal & Chemical Co., Hartford, W. Va., 1918. R. K. Bailey, analyst; G. B. Richardson, collector. Total solids by determination, 42.46 per cent. Density at 24.0° C., 1.420. Considerable salt and some iron precipitated at bottom of vessel.
5. Ohio River Salt Co., Mason, W. Va., 1918. R. K. Bailey, analyst; G. B. Richardson, collector. Total solids by determination, 36.94 per cent. Density at 21.5° C., 1.357. Considerable salt and some iron precipitated at bottom of vessel.
6. J. Q. Dickinson & Co., Malden, W. Va., 1918. R. K. Bailey, analyst; W. B. Hicks, collector. Total solids by determination, 36.75 per cent. Density at 18.6° C., 1.354. Trace of iron precipitate found in bottom of vessel.

The high concentration and the low percentage of sodium chloride in the bitterns from the natural brines along Ohio and Kanawha rivers should be noted. The analyses of these bitterns should be compared with a subsequent one of calcium chloride, obtained by further concentration. (See analysis, p. 248.) These bitterns are sources of bromine, and attention is directed to this element.

KANSAS.

Analyses of bitterns from artificial brines of Kansas.

Radicles in grams per liter.

	1	2	3	4	5
K	1.0	0.4	Trace.	0.2	1.4
Na	90.4	117.8	118.2	101.1	116.6
Ca	1.4	2.3	.8	.4	2.5
Mg	15.8	1.6	2.4	11.6	1.6
Cl	182.5	188.5	186.2	182.0	189.4
SO_4	3.4	3.4	5.4	11.2	3.4
Br	.9	Trace.	Trace.	Trace.	Trace.
	295.4	314.0	313.0	306.5	314.9

Radicles in percentage of anhydrous residue.

	1	2	3	4	5
K	0.34	0.12	0.00	0.06	0.44
Na	30.61	37.48	37.74	33.02	37.03
Ca	.47	.73	.26	.13	.79
Mg	5.36	.51	.77	3.78	.51
Cl	61.77	60.08	59.50	59.35	60.15
SO_4	1.15	1.08	1.73	3.66	1.08
Br	.30	.00	.00	.00	.00
	100.00	100.00	100.00	100.00	100.00

1. Western Salt Works, Hutchinson Salt Co., Hutchinson, Kans. From open pan after 25 days' evaporation, 1911. R. F. Gardiner, analyst.
2. Barton Salt Co., Hutchinson Kans. After 24 days' evaporation, 1911. J. A. Cullen, analyst.
3. Sterling Salt Co., Sterling, Kans. From grainer after 30 days' evaporation, 1911. R. F. Gardiner, analyst.
4. Orient Salt Co., Anthony, Kans. From grainer after 8 days' evaporation, 1911. R. F. Gardiner, analyst.
5. Ellsworth Salt Co., Ellsworth, Kans. From grainer, 1911. J. A. Cullen, analyst.

The bitterns of Kansas thus far examined are similar in concentration to the artificial brines from which they are derived. They differ from the brines in their content of calcium and magnesium, but part of the content of alkaline earths possibly comes from the water used in dissolving the salt. The content of sulphate is notably lower than that of the brines. The content of potassium salts is too small to be of importance. Analyses 1 and 4 indicate the presence of surprisingly large amounts of magnesium in two of the bitterns.

TEXAS AND UTAH.

Analyses of bitterns from brines of Texas and Utah.

Radicles in grams per liter.

	1	2
K	0.4	8.4
Na	101.3	79.5
Ca	1.5	Trace.
Mg	Trace.	13.8
Cl	158.3	146.8
SO_4	2.5	34.0
Br	....	....
	264.0	282.5

Radicles in percentage of anhydrous residue.

	1	2
K	0.15	2.97
Na	38.37	28.15
Ca	.57	.00
Mg	.00	4.90
Cl	59.96	51.95
SO_4	.95	12.03
Br	....	....
	100.00	100.00

1. B. W. Carrington, Grand Saline, Tex. From grainer after 6(?) weeks' evaporation, 1912. R. K. Bailey, analyst.
2. Inland Crystal Salt Co., Saltair, Utah. Residual bittern after salt had been making 4 weeks in harvesting pond; ordinarily evaporation would be allowed to progress 2 weeks longer. Collected in 1912. R. K. Bailey, analyst.

SEA WATER.

Analyses of bitterns from sea water.

[Samples collected by E. E. Free, 1912. R. F. Gardiner, analyst.]

Radicles in grams per liter.

	1	2	3	4	5	6	7	[a] 8
K	8.2	13.4	13.2	14.6	21.5	35.0	11.8	0.7
Na	80.0	75.8	38.8	27.7	9.1	93.6	60.1	61.0
Ca	1.2	2.2	.6	.5	1.0	.2	1.1	Trace.
Mg	24.0	23.4	50.6	62.7	79.4	8.6	43.9	24.8
Cl	179.2	176.6	179.4	183.3	220.1	180.4	190.8	148.5
SO_4	30.0	31.4	53.6	74.2	62.0	29.0	55.8	34.1
Br	3.0	3.0	3.0	3.0	2.0	2.0	2.8	....
	325.6	325.8	339.2	366.0	395.1	348.8	366.3	269.1

[a] Grams per kilogram.

Radicles in percentage of anhydrous residue.

	1	2	3	4	5	6	7	8
K	2.51	4.11	3.89	3.99	5.44	10.03	3.22	0.25
Na	24.57	23.27	11.45	7.57	2.30	26.83	16.41	22.68
Ca	.37	.68	.18	.14	.26	.06	.30	.00
Mg	7.38	7.18	14.92	17.13	20.09	2.47	11.98	9.21
Cl	55.03	54.20	52.88	50.07	55.71	51.72	52.10	55.19
SO_4	9.22	9.64	15.80	20.28	15.69	8.32	15.23	12.67
Br	.92	.92	.88	.82	.51	.57	.76	....
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. Leslie Salt Refining Works, San Mateo, Cal. Representative sample taken near northwest corner of mother-liquor pond.
2. Leslie Salt Refining Works, San Mateo, Cal. From southeast corner of mother-liquor pond.
3. Leslie Salt Refining Works, San Mateo, Cal. From salt-making pond, in which salt had been forming during the summer.
4. Oliver Salt Works, Mount Eden, Cal. From slop pond, representing 5 years' accumulation.
5. Oliver Salt Works, Mount Eden, Cal. Mother liquor that had been subjected to special treatment.
6. California Salt Co., Alvarado, Cal. From slop pond, representing 3 years' accumulation, though considerable quantities had been abstracted for use in forcing, and small quantities of other waste liquors had been added.
7. Pioneer Salt Co., San Francisco, Cal. One year's accumulation.
8. Long Beach Salt Co., Long Beach, Cal. Abnormally concentrated bittern from an outlying tank, 1912. R. K. Bailey, analyst.

The analyses of the bitterns resulting from extraction of salt from sea water on the California coast are remarkable for the indicated amounts of magnesium salts, both the chloride and the sulphate, and also for the rather large amount of potassium. Calcium is present in very small amount, probably in the form of sulphate. Bromine is relatively small in amount. The relatively large contents of potassium make it probable that these bitterns might be evaporated and utilized in the manufacture of low-grade fertilizer material, such as manure salts, hartsalz, and kainite.

COMPOSITION OF CALCIUM CHLORIDE.

The following analyses show the composition of the calcium chloride obtained from the brines of Michigan, Ohio, West Virginia, and Pennsylvania.

Analyses of calcium chloride obtained from brines of Michigan, Ohio, West Virginia, and Pennsylvania.

Radicles in percentage of total weight.

	1	2	3	4	5	6	7
K	0.7	0.8	Trace.	Trace.	0.3	0.2	Trace.
Na	.6	2.4	3.7	Trace.	.0	.1	None.
Ca	19.5	19.6	18.5	24.6	18.9	18.4	30.4
Mg	4.9	5.1	5.3	6.3	4.6	3.4	1.8
Cl	50.4	53.9	53.9	62.0	43.9	42.6	59.0
SO_4	None.	None.	None.	1.6	None.	None.	Trace.
CO_3					.6	.3	
Br		None.	Trace.	None.	1.1	None.	None.
	76.1	81.8	81.4	94.5	69.4	65.0	91.2

1. Eureka Calcium Works, Pomeroy, Ohio, 1911. R. F. Gardiner, analyst.
2. Liverpool Salt & Coal Co., Hartford, W. Va., 1911. R. F. Gardiner, analyst.
3. Hartford City Salt Co., Hartford, W. Va., 1911. R. F. Gardiner, analyst.
4. J. Q. Dickinson & Co., Malden, W. Va., 1911. J. A. Cullen, analyst.
5. Saginaw Chemical Works, Saginaw, Mich. Traces of barium and strontium. Collected in 1911. R. F. Gardiner, analyst.
6. Van Schaack Calcium Works, Mount Pleasant, Mich., 1911. R. F. Gardiner, analyst.
7. Pittsburgh Calcium Chloride Works, Pittsburgh, Pa., 1911. R. F. Gardiner, analyst.

COMPOSITION OF MISCELLANEOUS SUBSTANCES.

The composition of miscellaneous substances obtained in the manufacture of salt from brines of New York, Michigan, and Ohio is shown by the following analyses:

Analyses of miscellaneous substances obtained in the manufacture of salt from brines of New York, Michigan, and Ohio.

Radicles in percentage of total weight.

	1	2	3	4	[a] 5
K	Trace.	Trace.	0.1	Trace.	1.4
Na	26.0	31.9	19.1	13.4	51.1
Ca	8.6	.1	14.2	2.0	10.8
Mg	Trace.	3.4	.1	3.2	3.4
Cl	40.4	45.0	51.2	31.8	107.8
SO_4	20.0	19.6	5.0	2.4	1.4
Br	None.	....	None.	None.	Trace.
	95.0	100.0	89.7	52.8	175.9

[a] Results expressed in grams per liter.

1. Worcester Salt Co., Silver Spring, N. Y. Dust from salt driers, said to contain an accumulation of gypsum, 1911. R. F. Gardiner, analyst.
2. Different sample of No. 1.
3. Bliss-Van Auken Co., Saginaw, Mich. Sludge from grainer floor, removed during clean up, 1911. R. F. Gardiner, analyst.
4. Port Huron Salt Co., Port Huron, Mich. Sludge from settling tanks, 1911. R. F. Gardiner, analyst.
5. Slagel Salt Co., Mason, W. Va. Sediment from settler, 1911. R. F. Gardiner, analyst.

POTASH FROM COMMERCIAL BRINES AND BITTERNS.

The artificial brines and the bitterns derived from the main salt fields of the eastern United States appear to be valueless as sources of even low-grade salts of potassium.

The natural brines of Ohio, New York, and Michigan seem, however, to offer attractive fields for future investigation by industrial chemists. The brines found 250 to 400 feet above the top of the salt beds at some points in Ohio might be evaporated to make a low grade of manure salts, hartsalz, or kainite. Similar use might be made of the bitterns produced from sea water on the California coast. Detailed investigation of the chemical engineering features of such recovery may develop economic possibilities.

POTASH SALTS.

SCOPE OF INVESTIGATIONS.

The United States Geological Survey has concentrated its investigations of the possibilities of finding commercial deposits of soluble potash salts in the United States along the following lines: (1) Exploration by deep drilling for deposits in Nevada, Texas, and other western States; (2) examination of occurrences of certain rocks and minerals that are rich in potash; (3) investigation of the salt deposits, brines, and bitterns in the United States; (4) general geologic study of the "Red Beds" in the Southwest to determine the most favorable locations for future drilling operations. In addition to these general studies special investigations have been undertaken in areas where potash salts have been reported.

The papers listed below comprise those of most importance published to date on the series of studies just outlined.

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PRODUCTION OF SALT IN THE UNITED STATES.

By A. T. COONS.

RELIABILITY OF STATISTICS.

The figures given below as representing the production of salt in the United States for the years 1880 to 1917 are compiled from the records of the division of mineral resources of the United States Geological Survey and have been published in the annual volumes of Mineral Resources. The figures for 1880 are those collected by the Tenth Census and are for the census year June 1, 1879, to May 31, 1880. The statement for 1881 was largely estimated, and the returns for 1882 were derived from official reports made by the State salt inspectors and from estimates made by persons closely connected with the salt business. For the years 1883 and 1884 the figures were obtained more and more from the producers by correspondence, and from 1885 to the present time the figures have been compiled directly from reports of producers and contain practically no estimates. The unit of measurement of salt varies for different localities, the salt reported being measured in bushels of 56 pounds, in barrels of 280 pounds, and in tons of 2,000 pounds. As the earliest figures were all reduced to the barrel and published in that way, this measurement has been adhered to, although at present the measurement by tons is probably more common, all of the rock salt and a large part of the manufactured material being now sold by that standard. Many of the values given for the barreled salt prior to 1893 included the value of the barrels. This was obviously not the true value of the salt, and from 1893 to the present time the value has been that of the bulk salt itself as sold by the producer f. o. b. at point of shipment.

TOTAL PRODUCTION.

The following table gives the statistics of the salt produced and sold in the United States from 1880 to 1917:

Salt produced and sold in the United States, 1880–1917.

Year.	Salt manufactured (evaporated).		Salt in brine (sold or used by chemical works).		Rock salt.		Total.		Average price per barrel.
	Quantity (barrels, 280 pounds).	Value.	Quantity (barrels, 280 pounds).	Value.	Quantity (barrels, 280 pounds).	Value.	Quantity (barrels, 280 pounds).	Value.	
1880	....	....	....	....	[a] 62,400	$56,160	5,961,060	$4,829,566	$0.81
1881	....	....	....	....	....	....	6,200,000	4,200,000	.68
1882	....	....	....	....	[a] 82,500	....	6,412,373	4,320,140	.67
1883	....	....	....	....	[a] 265,215	141,125	6,192,231	4,251,042	.69
1884	....	....	....	....	[a] 223,964	125,677	6,514,937	4,197,734	.64
1885	....	....	....	....	[a] 299,271	139,991	7,038,653	4,825,345	.69
1886	....	....	....	....	[b] 402,964	....	7,707,081	4,736,585	.61
1887	....	....	....	....	[b] 772,314	....	8,003,962	4,093,846	.51
1888	....	....	....	....	[b] 933,600	....	8,055,881	4,374,203	.54
1889	....	....	....	....	[b] 1,237,179	....	8,005,565	4,195,412	.52
1890	....	....	....	....	[b] 1,390,278	....	8,876,991	4,752,286	.54
1891	....	....	....	....	[b] 1,138,928	....	9,987,945	4,716,121	.47
1892	....	....	....	....	[b] 1,134,843	....	11,698,890	5,654,915	.48
1893	7,902,776	....	[c] 2,110,287	....	1,884,145	....	11,897,208	4,154,668	.35
1894	9,344,935	....	[d] 1,356,876	....	2,266,606	....	12,968,417	4,739,285	.37
1895	9,695,665	....	[d] 1,884,221	....	2,089,763	....	13,669,649	4,423,084	.32
1896	9,535,754	....	[c] 2,531,086	....	1,783,886	....	13,850,726	4,040,839	.29
1897	10,709,252	....	[c] 3,614,491	....	1,649,459	....	15,973,202	4,920,020	.31
1898	12,351,809	....	[c] 3,077,024	....	2,183,801	....	17,612,634	6,212,554	.35
1899	13,680,720	....	[c] 3,483,858	....	2,544,036	....	19,708,614	6,867,467	.35
1900	12,324,246	....	[d] 5,571,063	....	2,974,033	....	20,869,342	6,944,603	.33
1901	12,325,197	....	[d] 5,003,526	....	3,237,938	....	20,566,661	6,617,449	.32
1902	12,058,514	....	[d] 8,900,881	....	2,889,836	....	23,849,231	5,668,636	.24
1903	12,674,151	....	[d] 3,118,417	....	3,175,521	....	18,968,089	5,286,988	.28
1904	13,653,911	....	4,006,950	$200,348	4,369,141	....	22,030,002	6,021,222	.27
1905	13,362,426	....	7,869,931	393,497	4,733,765	....	25,966,122	6,095,922	.23
1906	13,725,174	$5,024,239	9,573,680	478,684	4,873,526	1,155,427	28,172,380	6,658,350	.24
1907	14,672,329	5,800,168	9,222,471	461,124	5,809,328	1,347,031	29,704,128	7,608,323	.26
1908	14,791,635	5,868,026	8,869,216	443,638	5,161,211	1,241,968	28,822,062	7,553,632	.26
1909	15,398,118	6,617,324	8,770,807	438,540	5,938,721	1,287,967	30,107,646	8,343,831	.28
1910	13,950,492	5,817,770	9,389,226	469,461	6,965,938	1,613,113	30,305,656	7,900,344	.26
1911	14,924,350	6,266,451	10,027,411	501,225	6,232,207	1,578,016	31,183,968	8,345,692	.27
1912	14,824,428	7,134,627	11,408,623	570,316	7,091,757	1,697,829	33,324,808	9,402,772	.28
1913	15,223,063	7,575,558	11,588,444	579,014	7,587,791	1,968,567	34,399,298	10,123,139	.29
1914	15,422,097	7,583,000	11,805,414	589,519	7,577,172	2,024,898	34,804,683	10,197,417	.29
1915	16,884,456	8,845,827	13,222,848	601,965	8,324,192	2,229,894	38,431,496	11,747,686	.31
1916	17,534,543	10,148,836	18,140,836	831,841	9,773,950	2,665,270	45,449,329	13,645,947	.30
1917	17,732,600	14,959,261	20,647,057	1,083,586	11,464,464	3,897,595	49,844,121	19,940,442	.40

[a] Louisiana.
[b] Louisiana and New York.
[c] Includes a small quantity of solar salt.
[d] Includes a small quantity of manufactured salt.

With the exception of fluctuations in the years 1883, 1889, 1901, 1903, and 1908, caused by trade conditions, there has been a steady increase in both quantity and value of the salt produced in the United States since figures of production have been available. During the last 10 years the total quantity has increased 65 per cent, while the value has increased 162 per cent, with an increase in average price of 14 cents. The large increase in value has been due in part to the gradual adoption of various processes of making high grades of salt for table, dairy, and manufacturing use, the increased use of rock salt, and since 1914 to the increase in prices necessary to offset the increased cost of fuel, labor, and supplies caused by the war. The values and average

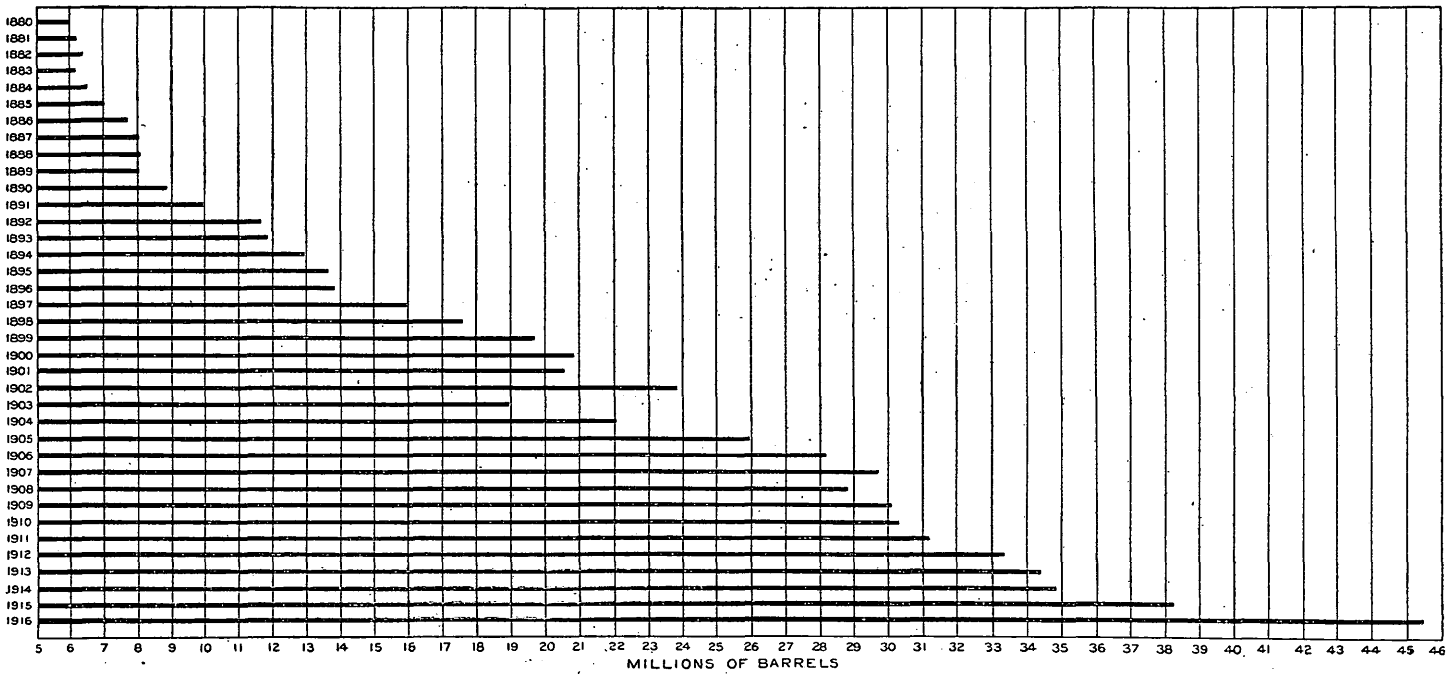

FIGURE 15.—Diagram showing total production of salt in the United States, by years, 1880-1916.

prices given in the above table are influenced by the increase in quantity of salt produced and used by alkali and chemical manufacturers. The salt content of the brines used by these firms has necessarily a low value, as the producers do not calculate the value of this salt until after its conversion into other chemicals. During the last 10 years the salt in these brines has increased 123 per cent.

Rock-salt production has increased 97 per cent during this period, a gain which is accounted for by the increased demand for chemicals and the readiness with which the production by mining can be expanded in comparison with the evaporation of brine.

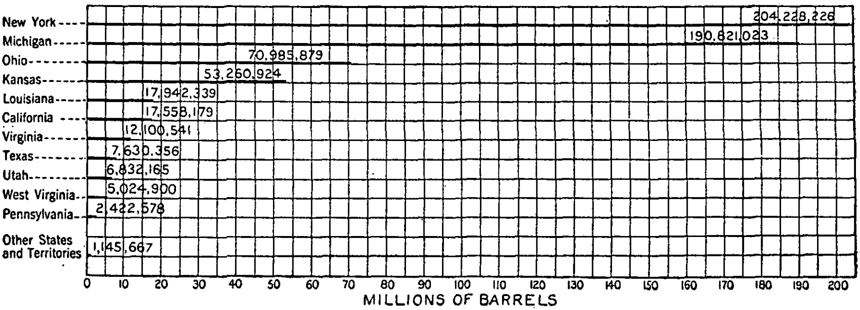

FIGURE 16.—Diagram showing total production of salt in the United States, by States, 1894-1916.

The production of evaporated salt increased 20 per cent during the 10 years, and in 1917 showed an increase of but 1.1 per cent over 1916, compared with increases of 13.8 per cent and 17.3 per cent, respectively, for salt contained in brines and in rock salt.

The increase in the production of salt in the United States from 1880 to 1916 is shown diagrammatically in figures 15 and 16.

PRODUCTION BY GRADES.

The collection of statistics by grades of manufactured salt was not attempted until 1893. Though the various grades are not known by the same trade names in all the States, the following table is presented as representing the method of grading the salt sold in the United States:

Salt produced and sold in the United States, 1893–1917, by grades.

Year.	Table and dairy.		Common fine.		Common coarse.		Packers.		Solar.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Barrels.		*Barrels.*		*Barrels.*		*Barrels.*		*Barrels.*	
1893	1,791,577		5,478,054		444,498		96,657		2,110,287	
1894	2,839,140		5,281,754		438,074		103,041		587,305	
1895	2,173,123		6,099,480		280,284		118,801		983,870	
1896	2,230,409		6,598,733		300,365		163,035		2,531,086	
1897	2,555,278		6,868,798		516,143		609,378		3,614,491	
1898	2,198,339		8,583,128		873,671		379,635		3,077,024	
1899	1,866,165		6,883,352		4,562,217		182,930		3,483,858	
1900	2,312,130		6,773,217		1,921,321		145,305		1,086,916	
1901	2,177,447		7,159,953		1,630,560		84,636		1,200,141	
1902	2,027,798		6,692,587		1,571,137		466,987		1,172,484	
1903	2,441,908		6,351,855		1,829,460		270,170		1,743,101	
1904	2,508,408		6,819,109		2,604,981		96,130		1,189,393	
1905	2,380,808		6,818,690		2,724,769		327,192		903,143	
1906	2,923,044	$1,624,961	6,483,937	$2,060,257	2,550,209	$781,596	452,490	$153,007	1,080,591	$339,795
1907	3,537,157	2,067,154	7,684,638	2,599,080	2,055,054	611,769	422,324	173,856	802,929	312,846
1908	3,202,016	2,109,785	7,388,903	2,455,980	2,550,333	799,138	373,284	147,225	1,156,034	319,185
1909	3,042,824	2,240,128	7,745,204	2,736,917	2,843,393	929,111	385,802	169,744	1,283,548	508,098
1910	3,514,748	2,249,827	6,153,296	2,158,386	2,602,737	799,405	327,304	147,434	1,223,371	418,495
1911	3,773,798	2,528,671	6,267,850	2,048,527	2,970,492	1,041,619	408,928	162,945	1,343,046	444,324
1912	3,961,450	3,164,638	6,021,052	2,109,076	2,753,375	1,096,643	751,551	296,238	1,105,935	408,939
1913	3,881,387	3,223,836	6,521,058	2,423,012	3,464,978	1,414,760	(a)	(a)	1,161,649	446,342
1914	4,121,574	3,221,007	6,237,860	2,383,588	3,789,163	1,453.484	1,080,199	451,206		
1915	4,341,063	3,720,020	7,013,065	2,762,450	3,834,101	1,724,503	1,161,208	508,402		
1916	4,675,723	4,326,531	7,485,943	3,314,795	4,057,034	1,958,094	835,092	539,079		
1917	4,914,443	5,908,788	7,489,800	5,311,668	3,525,107	2,659,013	1,138,293	524,987		

[a] A small output reported directly as packers is included under "Common coarse."

Salt produced and sold in the United States, 1893–1917, by grades—Continued.

Year.	Rock.		Milling.		In brine.		Other grades.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Barrels.		*Barrels.*		*Barrels.*		*Barrels.*		*Barrels.*	
1893	1,884,145		5,141				6,413		11,816,772	$4,154,668
1894	2,266,606		95,621				1,356,876		12,968,417	4,739,285
1895	2,089,763		40,107				1,884,221		13,669,649	4,423,084
1896	1,783,886		133,271				109,941		13,850,726	4,040,839
1897	1,649,459						159,655		15,973,202	4,920,020
1898	2,183,801		156,579				160,457		17,612,634	6,212,554
1899	2,544,036		96,178				89,878		19,708,614	6,867,467
1900	2,974,033		85,357		(a)		5,571,063		20,869,342	6,944,603
1901	3,237,938		72,460		(a)		5,003,526		20,566,661	6,617,449
1902	2,889,836		127,521		(a)		8,900,881		23,849,231	5,668,636
1903	3,175,521		37,657		(a)		3,118,417		18,968,089	5,286,988
1904	4,369,141		349,421		4,006,950		86,469		22,030,002	6,021,222
1905	4,733,765				7,869,931		207,824		25,966,122	6,095,922
1906	4,873,520	$1,155,427			9,573,680	$478,683	234,903	$64,624	28,172,380	6,658,350
1907	5,809,328	1,347,031			9,222,471	461,124	110,227	35,463	29,704,128	7,439,551
1908	5,161,211	1,241,968			8,869,216	443,638	121,065	36,713	28,822,062	7,553,632
1909	5,938,721	1,287,967			8,770,807	438,540	94,347	33,326	30,157,646	8,343,831
1910	6,965,938	1,613,113			9,389,226	469,461	129,036	44,223	30,305,656	7,900,344
1911	6,232,210	1,578,016			10,027,411	501,225	160,233	40,365	31,183,968	8,345,692
1912	7,091,759	1,697,829			11,408,623	570,316	231,063	59,093	33,324,808	9,402,772
1913	7,587,791	1,968,567			11,588,444	579,014	193,991	67,608	34,399,298	10,123,139
1914	7,577,172	2,024,898	193,301	73,715	11,805,414	589,519	34,804,683	10,197,417		
1915	8,324,192	2,299,894	335,019	130,452	13,222,848	601,965	38,231,496	11,747,686		
1916	9,773,950	2,665,270	480,751	210,337	18,140,836	831,841	45,449,329	13,645,947		
1917	11,464,464	3,897,595	664,957	554,805	20,647,057	1,083,586	49,844,121	19,940,442		

[a] Included in "Other grades."

In this classification table and dairy salt includes table, butter, cheese, pretzel, casing, "paste," and similar special brands, generally artificially dried. Packers', common fine, and common coarse include salt used in curing fish, packing meat, preparing pickles, curing hides, and for packing purposes in general, and also salt known as "medium No. 1" and "ground alum." Coarse solar, as the name suggests, includes coarse salt manufactured by solar evaporation. Rock salt includes all salt mined and shipped, whether ground, lumped, or screened. Other grades include all second-grade or No. 2 salt, such as agricultural and refuse salt, including sweepings. Salt in brine includes the salt content of all salt liquor used in the manufacture of soda ash and other chemicals or sold without being evaporated to dryness.

PRODUCTION BY STATES.

The statistics of the production of salt by States are rather unsatisfactory for the first few years because of the difficulty experienced in getting into touch with the producers themselves and the necessity of depending on dealers, railroads, and State inspectors for information. Nevertheless the following comparative tables are presented, the records for the earlier years being the most complete obtainable.

Salt produced and sold in the United States, 1880-1917, by States.

State.	1880[a]		1881		1882	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Quantity (barrels).	Value.
California	176,949	$121,650	[b] 192,857	....	214,200	$150,000
Kansas	2,600	5,700	....	....	(c)	(c)
Kentucky	16,600	21,950	....	....	....	....
Louisiana	62,400	56,160	....	....	182,500	(c)
Massachusetts	1,915	3,800	....	....	....	....
Michigan	2,485,177	2,271,913	[d] 2,750,299	....	[d] 3,037,317	2,126,122
Nevada	35,482	92,640	[e] 17,857	[e] $45,000	[b] 15,000	37,800
New York	1,749,641	1,107,760	[d] 1,583,447	....	[d] 1,668,036	834,018
Ohio	530,060	363,791	....	....	[b] 400,000	300,000
Pennsylvania	170,290	177,415	....	....	....	....
Texas	10,120	29,700	....	....	....	....
Utah	96,760	60,280	[b] 100,000	[b] 70,000	[b] 92,820	65,000
Virginia	85,179	127,678	....	....	(c)	(c)
West Virginia	535,887	380,369	....	....	[b] 400,000	300,000
Wyoming	1,000	8,760	....	....	....	....
Other States and Territories	....	....	[b] 1,555,540	....	[b] 402,500	507,200
	5,961,060	4,829,566	6,200,000	4,200,000	6,412,373	4,320,140

[a] Figures for census year ending May 31, 1880.
[b] Estimated.
[c] Included in "Other States and Territories."
[d] Report of State salt inspector.
[e] Churchill County only.

Salt produced and sold in the United States, 1880-1917, by States—Continued.

State.	1883		1884		1885	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Quantity (barrels).	Value.
California	214,286	$150,000	178,571	$120,000	221,428	$160,000
Illinois	(a)	(a)	(a)	(a)	(a)	(a)
Indiana	(a)	(a)	(a)	(a)	(a)	(a)
Kansas	(a)	(a)	(a)	(a)	(a)	(a)
Kentucky	(a)	(a)	(a)	(a)	(a)	(a)
Louisiana	265,215	141,125	223,964	125,677	299,271	139,911
Michigan	2,894,672	2,344,684	3,161,806	2,392,536	3,297,403	2,967,663
Nevada	21,429	15,000	17,857	12,500	28,593	20,000
New York	1,619,486	680,638	1,788,454	705,978	2,304,787	874,258
Ohio	350,000	231,000	320,000	201,600	306,847	199,450
Tennessee	(a)	(a)	(a)	(a)	(a)	(a)
Utah	107,143	100,000	114,285	80,000	107,140	75,000
Virginia	(a)	(a)	(a)	(a)	(a)	(a)
West Virginia	320,000	211,000	310,000	195,000	223,184	145,070
Wyoming	....	....	(a)	(a)	(a)	(a)
Other States and Territories	400,000	377,595	400,000	364,443	250,000	243,993
	6,192,231	4,251,042	6,514,937	4,197,734	7,038,653	4,825,345

State.	1886		1887		1888	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Quantity (barrels).	Value.
California	214,285	$150,000	200,000	$140,000	220,000	$92,400
Illinois	(a)	(a)	(a)	(a)	(a)	(a)
Indiana	(a)	(a)	(a)	(a)	(a)	(a)
Kansas	(a)	(a)	(a)	(a)	155,000	189,000
Kentucky	(a)	(a)	(a)	(a)	(a)	(a)
Louisiana	299,691	108,372	341,093	118,735	394,385	134,652
Michigan	3,677,257	2,426,989	3,944,309	2,291,842	3,866,228	2,261,743
Nevada	30,000	21,000	....	....	(a)	(a)
New York	2,431,563	1,243,721	2,353,560	936,894	2,318,483	1,130,409
Ohio	400,000	260,000	365,000	219,000	380,000	247,000
Tennessee	(a)	(a)	(a)	(a)	(a)	(a)
Utah	164,285	100,000	325,000	102,375	151,785	32,000
Virginia	(a)	(a)	(a)	(a)	(a)	(a)
West Virginia	250,000	162,500	225,000	135,000	220,000	143,000
Wyoming	(a)	(a)	....	....	....	....
Other States and Territories	240,000	264,003	250,000	150,000	350,000	143,999
	7,707,081	4,736,585	8,003,962	4,093,846	8,055,881	4,374,203

State.	1889		1890		1891	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Quantity (barrels).	Value.
California	150,000	$63,000	62,363	$57,085	200,949	$90,303
Illinois	(a)	(a)	(a)	(a)	39,670	34,909
Indiana	(a)	(a)	(a)	(a)	....	....
Kansas	450,000	202,500	882,666	397,199	855,536	304,775
Kentucky	(a)	(a)	(a)	(a)	....	....
Louisiana	325,629	152,000	273,553	132,000	173,714	102,375
Michigan	3,856,929	2,088,909	3,837,632	2,302,579	3,966,784	2,037,289
Nevada	....	....	(a)	(a)	60,799	39,898
New York	2,273,007	1,136,503	2,532,036	1,266,018	2,839,544	1,340,036
Ohio	250,000	162,500	231,303	136,617	(a)	(a)
Tennessee	(a)	(a)	(a)	(a)	(a)	(a)
Utah	200,000	60,000	427,500	126,100	969,000	265,350
Virginia	(a)	(a)	(a)	(a)	70,442	70,425
West Virginia	200,000	130,000	229,938	134,688	(a)	(a)
Other States and Territories	300,000	200,000	300,000	200,000	811,507	430,761
	8,005,565	4,195,412	8,776,991	4,752,286	9,987,945	4,716,121

[a] Included in "Other States and Territories."

Salt produced and sold in the United States, 1880–1917, by States—Continued.

State.	1892		1893		1894	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Quantity (barrels).	Value.
California	235,774	$104,938	292,858	$137,962	332,246	$172,678
Illinois	60,000	48,000	59,161	30,168	50,000	27,500
Kansas	1,480,100	773,989	1,277,180	471,543	1,382,409	529,392
Louisiana	200,000	100,000	191,430	97,200	186,050	86,134
Michigan	3,829,478	2,046,963	3,057,898	888,837	3,341,425	1,243,619
Nevada	22,929	22,806	6,559	4,481	3,670	4,030
New York	3,472,073	1,662,816	5,662,074	1,870,084	6,270,588	1,999,146
Ohio	[a] 899,244	[a] 394,720	543,963	209,393	528,996	187,432
Pennsylvania	25,571	10,741	280,343	136,436	203,236	83,750
Texas	121,250	99,500	126,000	110,267	142,857	101,000
Utah	1,292,471	340,442	189,006	130,075	268,186	209,077
Virginia	60,000	50,000	....	....	64,222	43,580
West Virginia	(b)	(b)	210,736	68,222	194,532	51,947
	11,698,890	5,654,915	11,897,208	4,154,668	12,968,417	4,739,285

State.	1895		1896		1897	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Quantity (barrels).	Value.
California	318,935	$158,683	430,121	$198,963	470,893	$162,654
Illinois	67,119	31,548	(c)	(c)	(c)	(c)
Kansas	1,341,617	483,701	1,408,607	397,296	1,538,327	488,022
Louisiana	159,771	78,169	(c)	(c)	(c)	(c)
Michigan	3,343,395	1,048,251	3,164,238	718,408	3,993,225	1,253,403
Nevada	7,000	5,600	(c)	(c)	(c)	(c)
New York	6,832,331	1,943,398	6,069,040	1,896,681	6,805,854	1,948,759
Ohio	781,033	326,520	1,662,358	432,877	1,575,414	421,757
Oklahoma	....	....	....	....	(c)	(c)
Pennsylvania	157,243	67,411	198,596	56,717	164,287	45,107
Texas	125,000	55,000	(c)	(c)	(c)	(c)
Utah	294,485	121,762	279,800	96,550	405,179	196,056
Virginia	65,000	40,000	(c)	(c)	(c)	(c)
West Virginia	176,720	63,041	176,921	50,717	441,893	160,129
Other States and Territories	....	....	461,045	192,630	578,130	244,133
	13,669,649	4,423,084	13,850,726	4,040,839	15,973,202	4,920,020

State.	1898		1899		1900	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Quantity (barrels).	Value.
California	653,009	$185,848	642,563	$281,741	621,857	$216,291
Idaho	....	....	(c)	(c)	(c)	(c)
Illinois	(c)	(c)	(c)	(c)	(c)	(c)
Kansas	1,882,329	616,591	1,645,350	546,291	2,233,878	1,076,945
Kentucky	....	....	(c)	(c)	(c)	(c)
Louisiana	(c)	(c)	(c)	(c)	(c)	(c)
Massachusetts	....	....	(c)	(c)	(c)	(c)
Michigan	5,263,564	1,628,081	7,117,382	2,205,924	7,210,621	2,033,731
Nevada	(c)	(c)	7,671	10,084	(c)	(c)
New York	6,791,798	2,369,323	7,489,105	2,540,426	7,897,071	2,171,418
Ohio	1,682,247	826,868	1,460,516	575,864	1,425,283	696,326
Oklahoma	(c)	(c)	5,248	4,704	5,861	6,136
Pennsylvania	154,287	46,000	(c)	(c)	(c)	(c)
Texas	254,284	119,700	312,436	204,330	(c)	(c)
Utah	266,250	103,778	236,135	115,100	249,128	151,662
Virginia	(c)	(c)	(c)	(c)	(c)	(c)
West Virginia	247,668	88,462	221,534	107,987	243,873	118,407
Wyoming	....	....	(c)	(c)	....	....
Other States and Territories	417,198	227,903	570,674	275,016	981,770	473,687
	17,612,634	6,212,554	19,708,614	6,867,467	20,869,342	6,944,603

[a] Includes West Virginia.
[b] Included in Ohio.
[c] Included in "Other States and Territories."

Salt produced and sold in the United States, 1880-1917, by States—Continued.

State	1901		1902		1903	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Quantity (barrels).	Value.
California	601,659	$133,656	682,660	$253,085	629,701	$198,630
Idaho	(a)	(a)	(a)	(a)	(a)	(a)
Illinois	(a)	(a)	(a)	(a)	....	....
Kansas	2,087,791	614,365	2,158,486	514,401	1,555,934	564,232
Kentucky	(a)	(a)	(a)	(a)	....	....
Louisiana	(a)	(a)	(a)	(a)	568,936	178,342
Massachusetts	(a)	(a)	(a)	(a)	(a)	(a)
Michigan	7,729,641	2,437,677	8,131,781	1,535,823	4,297,542	1,119,984
Nevada	(a)	(a)	(a)	(a)	(a)	(a)
New York	7,286,320	2,089,834	8,523,389	1,938,539	8,170,648	2,007,807
Ohio	1,153,535	455,924	2,109,987	593,504	2,798,899	795,897
Oklahoma	7,506	5,986	(a)	(a)	(a)	(a)
Oregon	....	....	(a)	(a)	....	....
Pennsylvania	(a)	(a)	(a)	(a)	(a)	(a)
Texas	(a)	(a)	347,906	143,683	314,000	117,647
Utah	334,484	326,016	417,501	270,626	212,955	181,710
Virginia	(a)	(a)	(a)	(a)	(a)	(a)
West Virginia	231,722	94,732	208,592	97,721	244,236	35,797
Other States and Territories	1,134,003	459,259	1,268,929	321,254	175,238	86,942
	20,566,661	6,617,449	23,849,231	5,668,636	18,968,089	5,286,988

State.	1904		1905		1906	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Quantity (barrels).	Value.
California	821,557	$205,435	664,099	$188,330	806,788	$291,528
Idaho	(a)	(a)	(a)	(a)	1,574	1,867
Kansas	2,161,819	717,101	2,098,585	576,139	2,198,837	681,022
Louisiana	1,095,850	320,000	1,055,186	303,507	1,179,528	268,005
Massachusetts	(a)	(a)	(a)	(a)	(a)	(a)
Michigan	5,425,904	1,579,206	9,492,173	1,851,332	9,936,802	2,018,760
Nevada	(a)	(a)	(a)	(a)	11,249	6,420
New Mexico	....	....	(a)	(a)	(a)	(a)
New York	8,600,656	2,101,568	8,359,121	2,167,931	8,978,630	2,098,686
Ohio	2,455,829	478,523	2,526,558	565,946	3,236,785	789,237
Oklahoma	(a)	(a)	(a)	(a)	9,893	4,965
Pennsylvania	(a)	(a)	(a)	(a)	(a)	(a)
Texas	376,695	149,246	444,832	142,993	360,733	170,559
Utah	253,829	321,301	177,342	135,465	262,212	169,635
Virginia	(a)	(a)	(a)	(a)	(a)	(a)
West Virginia	575,000	66,470	202,151	74,063	200,055	57,584
Other States and Territories	262,863	82,372	946,075	90,216	989,294	100,082
	22,030,002	6,021,222	25,966,122	6,095,922	28,172,380	6,658,350

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[a] Included in “Other States and Territories.”

Salt produced and sold in the United States, 1880–1917, by States—Continued.

State.	1907		1908		1909	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Quantity (barrels).	Value.
California	626,693	$302,940	899,028	$374,828	886,564	$558,889
Hawaii	....	....	....	....	a 7,796	a 5,292
Idaho	1,600	2,040	1,114	1,413	793	1,118
Kansas	2,667,459	962,334	2,588,814	882,984	2,769,849	782,676
Louisiana	1,157,621	226,892	(b)	(b)	(b)	(b)
Massachusetts	(c)	(c)	....	....	....	....
Michigan	10,786,630	2,231,129	10,194,279	2,458,303	9,966,744	2,732,556
Nevada	6,457	3,654	9,714	4,785	16,107	19,847
New Mexico	(c)	(c)	(c)	(c)	(c)	(c)
New York	9,642,178	2,335,150	d10,023,872	d 2,386,471	d10,914,255	d 2,646,736
Ohio	3,851,243	979,078	3,427,478	864,710	3,684,775	993,700
Oklahoma	800	910	(c)	(c)	(c)	(c)
Pennsylvania	(c)	(c)	(c)	(c)	(c)	(c)
Porto Rico	....	....	....	....	a 166,790	a 26,810
Texas	356,086	226,540	442,571	255,652	409,315	260,286
Utah	345,557	199,779	242,678	169,833	246,935	147,318
Virginia	(c)	(c)	(c)	(c)	(c)	(c)
West Virginia	156,147	76,527	145,157	70,481	150,492	76,463
Other States and Territories	105,657	61,350	847,357	84,172	887,231	92,140
	29,704,128	7,608,323	28,822,062	7,553,632	30,107,646	8,343,831

State.	1910		1911		1912	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Quantity (barrels).	Value.
California	937,514	$519,667	1,086,163	$555,359	1,090,000	$620,196
Hawaii	11,450	9,570	8,463	11,850	8,286	9,180
Idaho	885	1,127	314	532	(c)	(c)
Kansas	2,811,448	947,369	2,159,859	806,027	2,573,626	844,292
Louisiana	(b)	(b)	(b)	(b)	(c)	(c)
Michigan	9,452,022	2,231,262	10,320,074	2,633,155	10,946,739	2,974,429
Nevada	17,535	10,600	12,856	16,952	12,536	15,752
New Mexico	(c)	(c)	(c)	(c)	(c)	(c)
New York	d11,642,520	d 2,585,739	d11,234,928	d 2,538,151	10,527,221	2,615,334
Ohio	3,673,850	951,963	4,302,507	1,100,453	5,269,179	1,364,136
Oklahoma	2,564	881	500	431	(c)	(c)
Pennsylvania	(c)	(c)	(c)	(c)	(c)	(c)
Porto Rico	(c)	(c)	(c)	(c)	(c)	(c)
Texas	382,164	272,568	385,200	299,537	373,064	290,328
Utah	249,850	185,869	272,420	171,268	283,293	154,734
Virginia	(c)	(c)	(c)	(c)	(c)	(c)
West Virginia	155,625	62,955	183,379	78,805	139,121	66,023
Other States and Territories	968,229	120,774	1,217,305	133,172	2,101,743	448,368
	30,305,656	7,900,344	31,183,968	8,345,692	33,324,808	9,402,772

a Statistics not obtained before 1909.
b Included in New York.
c Included in "Other States and Territories."
d Includes Louisiana.

Salt produced and sold in the United States, 1880–1917, by States—Continued.

State.	1913		1914		1915	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.	Quantity (barrels).	Value.
California	1,082,993	$759,485	1,100,443	$782,921	1,048,457	$694,070
Hawaii	6,071	5,950	....	....	(a)	(a)
Idaho	(a)	(a)	300	520	(a)	(a)
Kansas	2,698,079	860,404	2,967,864	924,550	3,765,164	1,035,879
Louisiana	(a)	(a)	(a)	(a)	(a)	(a)
Michigan	11,528,800	3,293,032	11,670,976	3,299,005	12,588,788	4,304,731
Nevada	8,971	7,947	4,336	2,448	6,929	3,950
New Mexico	(a)	(a)	(a)	(a)	(a)	(a)
New York	10,780,514	2,865,187	10,389,314	3,824,733	11,217,471	2,976,405
Ohio	5,310,135	1,318,156	5,482,836	1,320,554	5,880,243	1,462,192
Oklahoma	(a)	(a)	(a)	(a)	(a)	(a)
Pennsylvania	(a)	(a)	(a)	(a)	....	....
Porto Rico	(a)	(a)	(a)	(a)	(a)	(a)
Texas	355,529	278,008	334,979	251,493	444,978	345,944
Utah	330,443	191,686	375,457	231,512	394,850	266,334
Virginia	(a)	(a)	(a)	(a)	(a)	(a)
West Virginia	113,921	63,803	145,429	78,036	232,239	115,143
Other States and Territories	2,183,842	479,481	2,332,649	481,646	2,652,377	543,038
	34,399,298	10,123,139	34,804,683	10,197,417	38,231,496	11,747,686

State.	1916		1917	
	Quantity (barrels).	Value.	Quantity (barrels).	Value.
California	1,124,236	$656,975	1,536,814	$933,429
Hawaii	(a)	(a)	(a)	(a)
Idaho	314	511	114	216
Kansas	4,564,793	1,302,359	5,335,543	2,027,466
Louisiana	(a)	(a)	(a)	(a)
Michigan	14,918,278	4,612,567	16,078,136	6,877,202
Nevada	(a)	(a)	(a)	(a)
New Mexico	(a)	(a)	(a)	(a)
New York	14,087,750	3,698,798	15,457,636	5,371,713
Ohio	6,706,193	2,038,749	7,345,307	2,839,575
Oklahoma	(a)	(a)	(a)	(a)
Pennsylvania	....	....	(a)	(a)
Porto Rico	(a)	(a)	(a)	(a)
Texas	541,157	467,119	608,436	564,029
Utah	433,236	289,457	565,678	352,145
Virginia	(a)	(a)	(a)	(a)
West Virginia	238,493	122,669	177,457	191,044
Other States and Territories	2,834,879	496,743	2,750,000	1,783,623
	45,449,329	13,645,947	49,844,121	19,940,442

[a] Included in "Other States and Territories."

RANK OF STATES.

The following table presents general information of interest to the salt trade. It gives for the three years 1915–1917 the number of operating plants, the average price per short ton, and the relative rank of the individual States as to both quantity and value of the salt produced.

Number of plants producing salt, rank of States, and average price per short ton, 1915–1917.

State.	1915				1916				1917			
	Number of operating plants.	Rank of State by—		Average price per ton.	Number of operating plants.	Rank of State by—		Average price per ton.	Number of operating plants.	Rank of State by—		Average price per ton.
		Total quantity.	Total value.			Total quantity.	Total value.			Total quantity.	Total value.	
California	[a] 25	7	5	[b] $3.98 [c] 4.73	[a] 26	7	5	[b] $2.99 [c] 4.20	[a] 26	5	5	[b] $4.21 [c] 4.34
Hawaii	[c] 1	12	11	[c] 8.00	[c] 1	12	12	[c] 7.00	[c] 1	13	12	[c] 15.00
Idaho	[c] 1	16	16	[c] 10.00	[a] 3	15	16	[b] 10.00 [c] 15.00	[a] 4	17	17	[b] 10.00 [c] 15.60
Kansas	[a] 10	4	4	[b] 1.34 [c] 2.55	[a] 10	4	4	[b] 1.35 [c] 2.61	[a] 10	4	4	[b] 1.66 [c] 3.63
Louisiana	[b] 2	5	6	[b] 2.52	[b] 2	5	7	[b] 2.28	[b] 2	6	6	[b] 3.37
Michigan	[a] 27	1	1	[b] 2.02 [c] 2.43	[a] 27	1	1	[b] 2.60 [c] 2.18	[a] 24	1	1	[b] 2.92 [c] 3.06
Nevada	[c] 3	14	14	4.07	[c] 2	13	14	[c] 4.35	[a] 2	14	14	[b] 3.00 [c] 3.18
New Mexico	[c] 1	13	13	[c] 2.76	[c] 1	12	13	[c] 2.00	[c] 2	12	13	[c] 2.41
New York	[a] 26	2	2	[b] 1.95 [c] 1.86	[a] 25	2	2	[b] 1.98 [c] 1.81	[a] 23	2	2	[b] 2.41 [c] 2.52
Ohio	[c] 10	3	3	[c] 1.78	[c] 10	3	3	[c] 2.17	[c] 9	3	3	[c] 2.77
Oklahoma	[c] 2	15	15	[c] 6.91	[c] 2	14	15	[c] 6.22	[c] 2	16	15	[c] 6.61
Pennsylvania	......	......	......	......	......	......	......	......	[c] 1	15	16	[c] 3.00
Porto Rico	[c] 2	11	10	[c] 2.57	[c] 2	11	10	[c] 2.62	[c] 2	11	10	[c] 4.24
Texas	[c] 5	8	7	[c] 5.55	[c] 5	8	6	[c] 5.46	[c] 5	8	7	[c] 6.62
Utah	[a] 7	9	8	[b] 2.29 [c] 5.04	[a] 7	9	8	[b] 2.24 [c] 4.99	[a] 7	9	8	[b] 2.54 [c] 4.60
Virginia	[c] 1	6	12	......	[c] 1	6	11	......	[c] 1	7	11	......
West Virginia	[c] 4	10	9	[c] 3.54	[c] 4	10	9	[c] 3.67	[c] 4	10	9	[c] 7.69
Total brine and rock salt	127	......	......	[b] 1.97 [c] 2.26	128	......	......	[b] 1.95 [c] 2.62	125	......	......	[b] 2.43 [c] 2.99
Total United States	......	......	......	2.19	......	......	......	2.14	......	......	......	2.86

[a] Includes both rock and brine salt. [b] Rock salt. [c] Brine salt.

For the Census of 1880, 268 salt plants reported operations. There were 161 plants in 1897, 136 in 1911, and only 129 in 1913.

PRODUCTION ON THE ONONDAGA SALT SPRINGS RESERVATION, N. Y.

The longest record of production of salt in any district in the United States is that of the Onondaga Salt Springs Reservation, N. Y., and the quantity of salt produced in this reservation from 1797 to 1917 is shown in the following table. The figures from 1905 to 1917 are not those of salt inspected but of salt sold and have been compiled from reports made by the Onondaga Coarse Salt Association, as the State sold the springs in 1908. A quantity of brine used from 1888 to 1896 in chemical works at Syracuse is included in the production of this district, although outside of the reservation. These figures do not, of course, represent the total production of salt in the State of New York during recent years.

Salt produced on the Onondaga Salt Springs Reservation, N. Y., 1797–1917, as reported by the State superintendent of salt inspection, in bushels of 56 pounds.

Year.	Solar salt.	Fine salt.	Total.	Year.	Solar salt.	Fine salt.	Total.
1797	....	25,474	25,474	1859	1,345,022	5,549,250	6,894,277
1798	....	59,928	59,928	1860	1,462,565	4,130,682	5,593,242
1799	....	42,704	42,704	1861	1,884,697	5,315,694	7,200,391
1800	....	50,000	50,000	1862	1,983,022	7,070,852	9,053,874
1801	....	62,000	62,000	1863	1,437,656	6,504,727	7,942,383
1802	....	75,000	75,000	1864	1,971,122	5,407,712	7,378,834
1803	....	90,000	90,000	1865	1,886,760	4,499,170	6,385,930
1804	....	100,000	100,000	1866	1,978,183	5,180,320	7,158,503
1805	....	154,071	154,071	1867	2,271,892	5,323,673	7,595,565
1806	....	122,577	122,577	1868	2,027,490	6,639,126	8,666,616
1807	....	175,448	175,448	1869	1,857,942	6,804,295	8,662,237
1808	....	319,618	319,618	1870	2,487,691	6,260,422	8,748,113
1809	....	128,282	128,282	1871	2,464,464	5,910,492	8,374,956
1810	....	450,000	450,000	1872	1,882,604	6,048,321	7,930,925
1811	....	200,000	200,000	1873	1,691,359	5,768,998	7,460,357
1812	....	221,011	221,011	1874	1,667,368	4,361,932	6,029,300
1813	....	226,000	226,000	1875	2,655,955	4,523,491	7,179,446
1814	....	295,000	295,000	1876	2,308,679	3,083,998	5,392,677
1815	....	322,058	322,058	1877	2,525,335	3,902,648	6,427,983
1816	....	348,665	348,665	1878	2,788,754	4,387,443	7,176,197
1817	....	408,665	408,665	1879	2,957,744	5,364,418	8,322,162
1818	....	406,540	406,540	1880	2,516,485	5,482,265	7,998,750
1819	....	548,374	548,374	1881	3,011,461	4,905,775	7,917,236
1820	....	458,329	458,329	1882	3,032,447	5,307,733	8,340,180
1821	....	526,049	526,049	1883	2,444,374	5,053,057	7,497,431
1822	....	481,562	481,562	1884	2,353,860	4,588,410	6,942,270
1823	....	726,988	726,988	1885	2,439,332	4,494,967	6,934,299
1824	....	816,634	816,634	1886	2,772,348	3,329,409	6,101,757
1825	....	757,203	757,203	1887	3,118,974	2,576,823	5,695,797
1826	....	811,023	811,023	1888	3,115,314	2,542,053	5,657,367
1827	....	983,410	983,410	1889	2,916,922	2,448,117	5,365,039
1828	....	1,160,888	1,160,888	1890	2,726,471	2,201,651	4,928,122
1829	....	1,129,280	1,129,280	1891	2,113,727	1,735,186	3,848,913
1830	....	1,435,446	1,435,446	1892	3,122,789	1,282,885	4,405,674
1831	....	1,514,037	1,514,037	1893	2,332,052	733,854	3,065,906
1832	....	1,652,985	1,652,985	1894	2,355,394	871,860	3,227,254
1833	....	1,838,646	1,838,646	1895	2,608,289	605,835	3,214,125
1834	....	1,943,252	1,943,252	1896	2,464,422	342,179	2,806,601
1835	....	1,209,867	1,209,867	1897	2,500,691	341,503	2,842,195
1836	....	1,912,858	1,912,858	1898	2,044,924	428,456	2,473,381
1837	....	2,167,287	2,167,287	1899	2,089,982	412,591	2,502,572
1838	....	2,575,033	2,575,033	1900	2,422,804	337,948	2,760,751
1839	....	2,864,718	2,864,718	1901	2,235,251	374,842	2,610,093
1840	....	2,622,305	2,622,305	1902	1,491,579	186,176	1,677,755
1841	220,247	3,120,520	3,340,767	1903	1,837,424	95,801	1,933,225
1842	163,021	2,128,882	2,291,903	1904	1,608,299	135,090	1,743,389
1843	318,105	2,809,395	3,127,500	1905	2,456,424	....	2,456,424
1844	332,418	3,671,134	4,003,552	1906	2,554,055	135,240	2,689,295
1845	353,455	3,408,903	3,762,358	1907	2,079,893	69,821	2,149,714
1846	331,705	3,507,146	3,838,851	1908	2,603,036	....	2,603,036
1847	262,879	3,688,476	3,951,355	1909	2,568,485	....	2,568,485
1848	342,497	4,394,629	4,737,126	1910	2,341,750	....	2,341,750
1849	377,735	4,705,834	5,083,569	1911	2,177,071	....	2,177,071
1850	374,732	3,894,187	4,268,919	1912	1,484,071	....	1,484,071
1851	378,967	4,235,150	4,614,117	1913	2,184,773	....	2,184,773
1852	633,595	4,288,938	4,922,533	1914	1,297,250	....	1,297,250
1853	577,947	4,826,577	5,404,524	1915	1,777,821	....	1,777,821
1854	734,474	5,068,873	5,803,347	1916	1,248,643	....	1,248,643
1855	498,124	5,584,761	6,082,885	1917	672,429	....	672,429
1856	709,391	5,257,419	5,966,810				
1857	481,280	3,830,846	4,312,126		139,262,746	271,416,742	410,679,488
1858	1,514,554	5,518,665	7,033,219				

The total of 410,679,488 bushels of salt, equivalent to 82,135,894 barrels, or 11,499,025 short tons, produced from the springs of this reservation during the 121 years for which records are available is of especial interest, as this is the only district in New York where the natural brine is produced, the other districts producing either rock salt or brine made by dissolving salt with water forced into the deposits of rock salt. The total output for these 121 years is more than one and four-fifths times the present yearly production of salt in the entire country. While the State controlled these springs, the expense of building and repairing the tanks from which the brine was delivered to the lessee was borne by the State, and for every bushel of salt made the State received at first (1797), 4 cents in lieu of rent. In 1805, 3 cents a bushel was paid; in 1812, 12½ cents; in 1834, 6 cents; and in 1846, 1 cent, the last rate being continued for the remaining years. The output of the springs was made into fine salt for 43 years, from 1797 to 1840, when solar salt also began to be marketed. The producing of fine salt was gradually discontinued, until now the product is practically all solar salt.

EARLY PRODUCTION IN MICHIGAN.

Salt was first made in Michigan in 1860. The production from 1860 to 1868, inclusive, according to a report made by the first inspector, appointed in 1869, was as follows:

Salt produced in Michigan, 1860–1868, in barrels of 280 pounds.

Year.	Production.	Year.	Production.
1860	4,000	1865	477,200
1861	125,000	1866	407,997
1862	243,000	1867	474,721
1863	466,000	1868	555,690
1864	529,073		

The production as reported by the State inspector from 1869 to 1889, inclusive, was as follows:

Salt produced in Michigan, 1869–1889, in barrels of 280 pounds.

Year.	Production.	Year.	Production.
1869	561,288	1880	2,685,588
1870	621,352	1881	2,750,299
1871	728,175	1882	3,037,317
1872	724,481	1883	2,894,672
1873	823,346	1884	3,161,806
1874	1,026,979	1885	3,297,403
1875	1,081,865	1886	3,677,257
1876	1,462,729	1887	3,944,309
1877	1,660,997	1888	3,866,228
1878	1,885,884	1889	3,846,979
1879	2,058,040		

The figures used by the United States Geological Survey for compiling the statistics of production since 1889 have been reported by the producers in Michigan. The annual State totals thus obtained differ from those of the Michigan salt inspector because the Survey collects data for the quantity sold whereas the State inspector reports the quantity of salt made and inspected; the Survey also includes in its figures the salt content of the brine pumped and used by chemical manufacturers in the State, whereas the State inspector does not.

EARLY PRODUCTION IN WEST VIRGINIA.

Dr. J. P. Hale, of Charleston, W. Va., gives the following figures of production of salt in the State from 1797 to 1882, inclusive.

Salt produced in West Virginia, 1797–1882, in bushels of 56 pounds.

1797	(1)	1838	1,811,076	1855	1,493,548
1798–1807	No record.	1839	1,593,217	1856	1,264,049
1808	(2)	1840	1,419,205	1857	1,266,749
1809–1813	No record.	1841	1,443,645	1858–1863	No record.
1814	600,000	1842	1,919,389	1864	1,300,991
1815–1826	No record.	1843	2,197,887	1865	861,973
1827	787,000	1844	1,874,919	1866	1,275,017
1828	863,542	1845	2,578,499	1867	1,321,066
1829	989,758	1846	3,224,786	1868	1,528,282
1830	906,132	1847	2,690,087	1869	1,822,430
1831	956,814	1848	2,876,010	1870	1,721,963
1832	1,029,207	1849	2,951,492	1871–1874	No record.
1833	1,288,873	1850	3,142,100	1875	967,465
1834	1,702,956	1851	2,862,676	1876–1879	No record.
1835	1,960,583	1852	2,741,570	1880	2,679,435
1836	1,762,410	1853	2,729,910	1881	No record.
1837	1,880,415	1854	2,233,863	1882	2,000,000

EXPORTS.

The following figures, compiled from reports of the Bureau of Foreign and Domestic Commerce, Department of Commerce, show the exports of salt from the United States from 1790 to 1917. The export trade has fluctuated greatly, but it has increased about 400 per cent in quantity and about 355 per cent in value during the last ten years, the figures for 1917 being the greatest ever recorded in the history of the export trade.

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[1] Daily production, 150 pounds.

[2] Daily production, 25 bushels.

Salt of domestic production exported from the United States, 1790–1917.

Year ending—	Quantity.	Value.	Year ending—	Quantity.	Value.
Sept. 30—	*Bushels.*		June 30 –	*Bushels.*	
1790	31,935	$8,236	1873	73,323	$43,777
1791	4,208	1,052	1874	31,657	15,701
1830	47,488	22,978	1875	47.094	16,273
1831	45,847	26,848	1876	51,014	18,378
1832	45,072	27,914	1877	65,771	20,133
1833	25,069	18,211	1878	72,427	24,968
1834	89,064	54,007	1879	43,710	13,612
1835	126,230	46,483	1880	22,179	6,613
1836	49,917	31,943	1881	45,455	14,752
1837	99,133	58,472	1882	42,085	18,265
1838	114,155	67,707	1883	54,147	17,321
1839	264,337	64,272	1884	70,014	26,007
1840	92,145	42,246	Dec. 31—	*Pounds.*	
1841	215,084	62,765	1885	4,101,587	26,488
1842	110,400	39,064	1886	4,828,863	29,580
June 30—			1887	4,685,080	27,177
1843 *a*	40,678	10,262	1888	5,359,237	32,986
1844	157,529	47,755	1889	5,378,450	31,405
1845	131,500	45,151	1890	4,927,022	30,079
1846	117,627	30,520	1891	4,448,846	23,771
1847	202,244	42,333	1892	5,208,935	28,399
1848	219,145	73,274	1893	5,792,207	38,375
1849	312,063	82,972	1894	10,853,759	46,780
1850	319,175	75,103	1895	7,203,024	30,939
1851	344,061	61,424	1896	10,711,314	43,202
1852	1,467,676	89,316	1897	11,593,321	52,320
1853	515,857	119,729	1898	17,280,193	63,624
1854	548,185	159,026	1899	25,200,191	86,465
1855	536,073	156,879	1900	15,021,861	65,410
1856	698,458	311,495	1901	18,865,247	86,414
1857	576,151	190,699	1902	10,188,771	55,432
1858	533,100	162,650	1903	25,499,630	95,570
1859	717,257	212,710	1904	27,928,088	113,625
1860	475,445	129,717	1905	68,475,356	239,223
1861	537,401	144,046	1906	67,976,581	274,627
1862	397,506	228,109	1907	61,603,422	232,895
1863	584,901	277,838	1908	53,253,739	202,338
1864	635,519	296,088	1909	80,306,820	269,273
1865	589,537	358,109	1910	98,026,369	320,926
1866	70,644	300,980	1911	97,745,833	335,285
1867	605,825	304,030	1912	124,819,713	418,525
1868	624,970	289,936	1913	140,578,092	515,194
1869	442,947	190,076	1914	164,589,012	586,055
1870	298,142	119,582	1915	160,948,389	613,850
1871	120,156	47,151	1916	168,129,201	567,441
1872	42,603	19,978	1917	227,985,222	1,000,773

a Nine months.

IMPORTS.

Import figures for salt have been collected since 1867 by the Bureau of Foreign and Domestic Commerce, Department of Commerce. The following table compiled from reports of this bureau shows the quantity and value of salt imported and entered for consumption in the United States from 1867 to 1917, according to the condition and use of the salt.

Salt imported and entered for consumption in the United States, 1867–1913.

Year ending—	In bags, barrels, and other packages.		In bulk.		For curing fish.		Not elsewhere specified.		Total quantity.	Total value.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.		
June 30—	*Pounds.*		*Pounds.*		*Pounds.*		*Pounds.*		*Pounds.*	
1867	254,470,862	$696,570	229,304,323	$336,302					483,775,185	$1,032,872
1868	308,446,080	915,546	219,975,096	365,458					528,421,176	1,281,004
1869	297,382,750	895,272	256,765,240	351,168					554,147,990	1,246,440
1870	288,479,187	797,194	349,776,433	507,874	68,597,023	$87,048			706,852,643	1,392,116
1871	283,993,799	800,454	274,730,573	355,318	64,671,139	66,008			623,395,511	1,221,780
1872	258,232,807	788,893	257,637,230	312,569	57,830,929	60,155			573,700,966	1,161,617
1873	239,494,117	1,254,818	388,012,132	525,585	86,756,628	86,193			714,262,877	1,866,596
1874	358,375,496	1,452,161	427,294,209	649,838	105,613,913	126,896			891,283,618	2,228,895
1875	318,673,091	1,200,541	401,270,315	549,111	110,294,440	119,607			830,237,846	1,869,259
1876	331,266,140	1,153,480	379,478,218	462,106	118,760,638	126,276			829,504,996	1,741,862
1877	359,005,742	1,059,941	444,044,370	532,831	132,433,972	140,787			935,484,084	1,733,559
1878	352,109,963	1,062,995	414,813,516	483,909	100,794,611	96,898			867,718,090	1,643,802
1879	375,286,472	1,150,018	434,760,132	532,706	94,060,114	95,841			904,106,718	1,778,565
1880	400,970,531	1,180,082	449,743,872	548,425	109,024,446	119,667			959,738,849	1,848,174
1881	412,442,291	1,242,543	529,361,041	658,068	133,395,065	144,347			1,075,198,397	2,044,958
1882	329,969,300	1,086,932	399,100,228	474,200	134,777,569	147,058			863,847,097	1,708,190
1883	312,911,360	1,035,946	412,938,686	451,001	142,065,557	154,671			867,915,603	1,641,618
1884	340,759,010	1,093,628	441,613,517	433,827	126,605,276	122,463			908,977,803	1,649,918
1885	351,276,969	1,030,029	412,322,341	386,858	140,067,018	121,429			903,666,328	1,538,316
December 31—										
1886	319,232,750	966,993	366,621,223	371,000	103,360,362	94,721			789,214,335	1,432,714
1887	275,774,571	850,069	343,216,331	328,201	105,577,947	107,089			724,568,849	1,285,359
1888	238,921,421	620,425	272,650,231	246,022	113,459,083	111,120			625,030,735	977,567
1889	180,906,293	627,134	234,499,635	249,232	97,960,624	100,123			513,366,552	976,489
1890	172,611,041	575,260	243,756,044	252,848	98,279,719	96,648			514,646,804	924,756
1891	150,033,182	492,144	220,309,985	224,569	103,990,324	89,196			474,333,491	805,909
1892	150,799,014	488,108	201,366,103	196,371	105,192,086	90,327			457,357,203	774,806
1893	98,037,648	358,575	146,945,390	63,404	103,536,135	87,749			348,519,173	509,728
1894	60,793,685	206,229	101,525,281	86,718	93,723,885	79,482	178,112,857	$263,707	434,155,708	636,136
1895	601,086	1,723	1,874,644	1,874	8,668,490	12,195	548,007,449	739,122	559,151,669	754,914
1896	350,620	814	1,627,030	1,640	8,351,913	11,814	510,082,259	687,890	520,411,822	702,158
1897	36,801,048	114,072	50,775,105	46,412	32,961,953	33,962	297,511,108	370,592	418,049,214	565,038
1898	114,573,146	361,366	178,458,117	165,784	78,028,189	61,503			371,059,452	588,653
1899	119,720,721	372,921	158,263,237	133,862	100,118,609	72,899			378,102,567	579,682
1900	113,194,092	368,802	198,697,810	193,873	87,925,922	71,632			399,817,824	634,307
1901	117,140,959	413,896	171,067,229	165,803	115,257,757	96,625			403,465,945	676,324
1902	118,480,793	422,304	151,169,362	138,552	99,878,031	86,698			369,528,186	647,554
1903	72,838,011	259,029	147,635,246	134,714	107,487,450	102,205			327,960,707	495,948
1904	69,657,850	209,509	143,903,175	135,408	118,718,456	122,837			332,279,481	467,754
1905	73,252,959	247,853	155,091,301	153,904	93,972,951	90,422			322,317,211	492,189

1906	74,228,878	257,593	159,674,675	149,944	115,359,107	101,326	....	....	349,262,660	508,862
1907	74,762,435	242,377	115,826,979	108,166	107,008,980	100,739	....	....	297,598,394	451,282
1908	66,409,270	219,272	153,031,808	120,979	99,844,560	104,439	....	....	319,285,638	444,690
1909	65,581,839	220,503	135,735,445	132,884	97,722,473	84,440	....	....	299,039.757	437,827
1910	53,143,200	178,000	118,796,400	104,822	102,265,982	88,100	....	....	274,205,582	370,922
1911	61,648,200	181,405	108,055,700	95,801	114,475,300	97,824	....	....	284,179,200	375,030
1912	57,453,400	179,199	133,080,800	112,749	89,091,700	78,700	....	....	279,625,900	370,648
1913	70,433,300	209,752	185,743,900	160,400	a 53,353,300	51,593	....	....	309,530,500	421,745
1914	65,614,400	212,349	195,994,500	168,154	....	....	....	....	261,608,900	380,803
1915	57,449,100	196,593	187,203,600	169,859	....	....	....	....	244,652,700	366,452
1916	48,804,300	200,290	195,353,500	142,298	....	....	....	....	244,157,800	342,588
1917	26,943,300	139,339	102,901,000	140,796	....	....	....	....	129,844,300	280,135

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[a] This class was not carried separately after Oct. 3, 1913.

TARIFF REGULATIONS ON SALT.

As the tariff acts of different years have had considerable influence on the importations of salt, a brief statement of the various Acts of Congress regulating imports of salt has been compiled.[1]

Act of July 4, 1789: Six cents per bushel on all salt imported.

Act of August 10, 1790: Twelve cents per bushel on all salt imported.

Act of July 8, 1797: That from and after the thirtieth day of September next, there shall be levied, collected, and paid upon all salt imported into the United States, in ships or vessels of the United States, in addition to the duty of twelve cents now payable by law, eight cents per bushel, and on all salt which, after the said thirtieth day of September, shall be imported into the United States, in ships or vessels not of the United States, the like additional duty of eight cents, and ten per centum thereon; further, that all drawbacks and allowances now authorized by law, in relation to the existing duty on salt imported into the United States, shall apply to the additional duty laid by this act, and that in addition thereto, there shall be allowed and paid upon provisions salted within the United States, except upon dried fish, upon the exportation thereof to any foreign port or place as follows, viz: On pickled fish at the rate of twelve cents per barrel, and on other provisions at the rate of ten cents per barrel; and from and after the first day of January next there shall be an addition of thirty-three and a third per centum to the allowances now respectively granted to ships or vessels employed in the bank or other cod fisheries, and the terms provided by an act entitled "An act concerning certain fisheries of the United States and for the regulation and government of the fishermen employed therein," and during the continuance of the said act; and further, that this act shall continue in force for two years, and from thence until the end of the next session of Congress, and no longer.

Act of May 2, 1792: From June 30, the bushel shall contain fifty-six pounds.

Act of May 7, 1800: That an act passed on the eighth day of July, one thousand seven hundred and ninety-seven, entitled "An act laying an additional duty on salt imported into the United States, and for other purposes," shall be, and the same is hereby, continued in force for and during the term of ten years from the third day of March, one thousand eight hundred, and from thence to the end of the next session of Congress thereafter and no longer. Repealed March 3, 1807.

Act of July 29, 1813: That from and after the first day of January next (1814), a duty of twenty cents per bushel shall be laid, imposed, and collected, upon all salt imported from any foreign port or place into the United States. In calculating the said duty, every fifty-six pounds of salt shall be computed as equal to one bushel.

Act of April 27, 1816: Twenty cents per bushel on all salt imported.

Act of May 29, 1830: Fifteen cents from December 31, 1830, to December 31, 1831; after that, ten cents.

Act of July 14, 1832: Ten cents per bushel on all salt imported.

Act of August 30, 1842: Eight cents per bushel on all salt imported.

Act of March 2, 1861: Salt imported in bulk, four cents per bushel; in bags, sacks, barrels, or other packages, six cents per bushel.

Act of August 15, 1861: Salt imported in bulk, twelve cents per one hundred pounds; in bags, sacks, barrels, or other packages, eighteen cents per one hundred pounds.

Act of July 14, 1862: Salt imported in bulk, six cents per one hundred pounds; in bags, sacks, barrels, or other packages, six cents per one hundred pounds.

Act of June 30, 1864: Salt imported in bulk, eighteen cents per one hundred pounds; in bags, sacks, barrels, or other packages, twenty-four cents per one hundred pounds.

Act of July 28, 1866: Vessels licensed to engage in fisheries may take on board imported salt in bond to be used in curing fish, under such regulations as the Secretary

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[1] Tariff Acts, 1789-1909, 61st Cong., 2d sess., H. Doc. 671.

of the Treasury shall prescribe, and upon proof that said salt has been used in curing fish, the duties on same shall be remitted.

Act of June 6, 1872: Salt imported in bulk, eight cents per one hundred pounds; in bags, sacks, barrels, or other packages, twelve cents per one hundred pounds.

Act of March 3, 1883: Salt in bags, sacks, barrels, or other packages, twelve cents per one hundred pounds; in bulk, eight cents per one hundred pounds, Provided that exporters of meats, whether packed or smoked, which have been cured in the United States with imported salt, shall, upon satisfactory proof, under such regulations as the Secretary of the Treasury shall prescribe, that such meats have been cured with imported salt; have refunded to them from the Treasury, the duties paid on the salt so used in curing such exported meats, in amounts not less than one hundred dollars, and Provided further, that imported salt in bond may be used in curing fish taken by vessels licensed to engage in the fisheries, and in curing fish on the shores of the navigable waters of the United States, under such regulations as the Secretary of the Treasury shall prescribe, and upon proof that the salt has been used for either of the purposes stated in this proviso, the duties on the same shall be remitted.

Act of October 1, 1890: Salt imported in bags, sacks, barrels, or other packages, twelve cents per one hundred pounds; in bulk, eight cents per one hundred pounds; Provided that imported salt in bond may be used in curing fish taken by vessels licensed to engage in the fisheries, and in curing fish on the shores of the navigable waters of the United States, under such regulations as the Secretary of the Treasury shall prescribe, and upon proof that the salt has been used for either of the purposes stated in this proviso, the duties on the same shall be remitted, and Provided further, that exporters of meats, whether packed or smoked, which have been cured in the United States with imported salt, shall upon satisfactory proof, under such regulations as the Secretary of the Treasury shall prescribe, that such meats have been cured with imported salt, have refunded to them from the Treasury the duties paid on the salt so used in curing such exported meats, in amounts not less than one hundred dollars.

Act of August 27, 1894: On the free list: Salt in bulk and salt in bags, sacks, barrels, or other packages, but the coverings shall pay the same rate of duty as if imported separately: Provided, That if salt is imported from any country whether independent or dependency which imposes a duty upon salt exported from the United States, then there shall be levied, paid, and collected upon such salt the rate of duty existing prior to the passage of this Act.

Act of July 24, 1897: Salt in bags, sacks, barrels, or other packages, twelve cents per one hundred pounds; in bulk, eight cents per one hundred pounds: Provided, that imported salt in bond may be used in curing fish taken by vessels licensed to engage in the fisheries, and in curing fish on the shores of the navigable waters of the United States, under such regulations as the Secretary of the Treasury shall prescribe, and upon proof that the salt has been used for either of the purposes stated in this proviso, the duties of the same shall be remitted: Provided further, that exporters of meats, whether packed or smoked, which have been cured in the United States with imported salt, shall, upon satisfactory proof, under such regulations as the Secretary of the Treasury shall prescribe, that such meats have been cured with imported salt, have refunded to them from the Treasury the duties paid on the salt so used in curing such exported meats, in amounts not less than one hundred dollars.

Act of August 5, 1909: Salt in bags, sacks, barrels, or other packages, eleven cents per one hundred pounds; in bulk, seven cents per one hundred pounds: Provided, that imported salt in bond may be used in curing fish taken by vessels licensed to engaged in the fisheries, and in curing fish on the shores of the navigable waters of the United States under such regulations as the Secretary of the Treasury shall prescribe, and upon proof that the salt has been used for either of the purposes stated in this proviso the duties on the same shall be remitted: Provided further, that exporters of meats, whether packed or smoked, which have been cured in the United States with imported salt, shall, upon satisfactory proof, under such regulations as the Secretary of the Treasury shall prescribe, that such meats have been cured with imported salt, have refunded to them from the Treasury the duties paid on the salt so used in curing such exported meats, in amounts not less than one hundred dollars.

Act of October 3, 1913: Salt placed on the free list.

DOMESTIC CONSUMPTION.

The consumption of salt in the United States from 1880 to 1917 is given in the following table. The annual domestic consumption increased very rapidly from about 10,000,000 barrels in 1890 to more than 20,000,000 barrels in 1899, and it has continued to increase till it has exceeded 49,000,000 barrels. The quantity of salt imported annually dropped markedly between 1885 and 1893, and after marked increases up to 1897 has irregularly decreased to less than 500,000 barrels in 1917. The exports rose from a little more than 4,000 barrels in 1880 to 20,000 barrels in 1893, and then jumped to slightly more than 63,000 barrels in 1896 and to more than 800,000 barrels in 1917. The steady increase in domestic production has rendered the market for foreign salt in the United States less and less important. The percentage of imports to total consumption decreased steadily from 38.3 per cent in 1881 to 9.49 per cent in 1893 and was less than 1 per cent in 1917. The United States, therefore, now supplies more than 99 per cent of the salt it consumes during the year. This country is not dependent on any foreign country for any portion of its salt supply, as the capacity of its active mines and manufacturing plants is greatly in excess of the present output.

Salt consumed in the United States, 1880-1917, in barrels of 280 pounds.

Source.	1880	1881	1882	1883	1884	1885	1886	1887
Domestic production	5,961,060	[a] 6,200,000	6,412,373	6,192,231	6,514,937	7,038,653	7,707,081	8,003,962
Imports	3,427,639	3,839,994	3,085,168	3,099,698	3,246,349	3,227,380	2,818,623	2,587,745
	8,388,699	10,039,994	9,497,541	9,291,929	9,761,286	10,266,033	10,525,704	10,591,707
Exports	4,436	9,091	8,417	10,829	14,003	14,649	17,246	16,732
Domestic consumption	9,384,263	10,030,903	9,489,124	9,281,100	9,747,283	10,251,384	10,508,458	10,574,975
Increase or decrease from preceding year	....	+646,640	−341,779	−208,024	+466,183	+504,101	+257,074	+66,517
Percentage of imports to total consumption	36.5	38.3	32.5	33.4	33.3	31.5	26.8	24.5

[a] Estimated.

Salt consumed in the United States, 1880-1917, in barrels of 280 pounds—Continued.

Source.	1888	1889	1890	1891
Domestic production	8,055,881	8,055,565	8,876,991	9,987,945
Imports	2,232,253	1,833,452	1,838,024	1,694,048
	10,288,134	9,889,017	10,715,015	11,681,993
Exports	19,140	19,209	17,597	15,889
Domestic consumption	10,268,994	9,869,808	10,697,418	11,666,104
Increase or decrease from preceding year	−305,981	−399,186	+827,610	+968,686
Percentage of imports to total consumption	21.7	18.5	17.2	14.5

Source.	1892	1893	1894	1895
Domestic production	11,698,890	11,897,208	12,968,417	13,669,649
Imports	1,633,419	1,244,711	1,550,555	1,996,970
	13,332,309	13,141,919	14,518,972	15,666,619
Exports	18,603	20,686	38,763	36,855
Domestic consumption	13,313,706	13,121,233	14,480,209	15,629,764
Increase or decrease from preceding year	+1,647,602	−192,473	+1,358,976	+1,149,555
Percentage of imports to total consumption	12.3	9.49	10.71	12.78

Source.	1896	1897	1898	1899
Domestic production	13,850,726	15,973,202	17,612,634	19,708,614
Imports	1,858,614	1,493,033	1,325,212	1,350,366
	15,709,340	17,466,235	18,937,846	21,058,980
Exports	63,391	54,195	61,715	90,000
Domestic consumption	15,645,949	17,412,040	18,876,131	20,968,980
Increase or decrease from preceding year	+16,185	+1,766,091	+1,464,091	+2,092,849
Percentage of imports to total consumption	11.88	8.57	7.02	6.4

Source.	1900	1901	1902	1903	1904	1905
Domestic production	20,869,342	20,566,661	23,849,231	18,968,089	22,030,002	25,966,122
Imports	1,427,921	1,440,950	1,319,744	1,185,578	1,186,712	1,151,133
	22,297,263	22,007,611	25,168,975	20,153,667	23,216,714	27,117,255
Exports	53,650	67,376	36,386	91,070	99,743	244,555
Domestic consumption	22,243,613	21,940,235	25,132,589	20,062,597	23,116,971	26,872,700
Increase or decrease from preceding year	+1,274,633	−303,378	+3,192,354	−5,069,992	+3,054,374	+3,755,729
Percentage of imports to total consumption	6.4	6.6	5.3	5.9	5.1	4.3

Source.	1906	1907	1908	1909	1910	1911
Domestic production	28,172,380	29,704,128	28,822,062	30,107,646	30,305,656	31,183,968
Imports	1,247,367	1,062,851	1,140.306	1,067,999	979,305	1,014,926
	29,419,747	30,766,979	29,962,368	31,175,645	31,284,961	32,198,894
Exports	242,774	220,012	190,192	286,810	350,094	349,092
Domestic consumption	29,176,973	30,546,967	29,772,176	30,888,835	30,934,867	31,849,802
Increase or decrease from preceding year	+2,304,273	+1,369,994	−774,791	+1,116,659	+46,032	+914,935
Percentage of imports to total consumption	4.3	3.4	3.8	3.4	3.2	3.2

Salt consumed in the United States, 1880–1917, in barrels of 280 pounds—Continued.

Source.	1912	1913	1914	1915	1916	1917
Domestic production	33,324,808	34,399,298	34,804,683	38,231,496	45,449,329	49,844,121
Imports	998,664	1,105,466	934,319	873,760	871,992	463,730
	34,323,472	35,504,764	35,739,002	39,105,256	46,321,321	50,307,851
Exports	445,785	502,065	587,818	574,816	600,461	814,233
Domestic consumption	33,877,687	35,002,699	35,151,184	38,531,440	45,720,860	49,493,618
Increase or decrease from preceding year	+2,027,885	+1,125,012	+148,485	+3,380,256	+7,189,420	+3,772,758
Percentage of imports to total consumption	2.9	3.2	2.7	2.3	1.9	.9

USEFUL TABLES AND FACTORS.

Conversion table for salt solutions.

[Computed by F. E. Englehardt.[a]]

Salimeter degrees.	Baumé degrees.	Specific gravity.	Percentage of salt (sodium chloride).	Weight of 1 gallon of brine in avoirdupois pounds (of 7,000 grains each).	Pounds of salt in 1 U. S. gallon (231 cubic inches) of brine.	Gallons of brine containing 1 bushel (56 pounds) of salt.	Pounds of water to be evaporated to produce 1 bushel of salt.	Pounds of coal required to produce 1 bushel of salt (1 pound of coal evaporating 6 pounds of water).	Bushels of salt that can be made with 1 ton (2,000 pounds) of coal.
1	0.26	1.002	0.265	8.347	0.022	2,531.40	21,076.00	3,512.67	0.569
2	.52	1.003	.530	8.356	.044	1,264.40	10,510.00	1,751.67	1.141
3	.78	1.005	.795	8.372	.066	841.30	6,988.02	1,164.67	1.717
4	1.04	1.007	1.060	8.389	.088	629.72	5,227.03	871.17	2.295
5	1.30	1.009	1.325	8.406	.111	502.77	4,170.41	695.06	2.877
6	1.56	1.010	1.590	8.414	.133	418.56	3,456.01	577.66	3.462
7	1.82	1.012	1.855	8.431	.156	358.06	2,962.87	493.81	4.050
8	2.08	1.014	2.120	8.447	.179	312.68	2,585.50	430.91	4.641
9	2.34	1.016	2.385	8.462	.201	277.39	2,292.00	382.00	5.235
10	2.60	1.017	2.650	8.472	.224	249.41	2,057.20	342.86	5.833
11	2.86	1.019	2.915	8.489	.247	226.29	1,865.09	310.84	6.434
12	3.12	1.021	3.180	8.506	.270	207.02	1,705.00	284.16	7.038
13	3.38	1.023	3.445	8.522	.293	190.72	1,569.54	261.59	7.645
14	3.64	1.025	3.710	8.539	.316	176.76	1,453.43	242.23	8.256
15	3.90	1.026	3.975	8.547	.339	164.81	1,352.80	225.46	8.870
16	4.16	1.028	4.240	8.564	.363	154.21	1,264.75	210.79	9.488
17	4.42	1.030	4.505	8.581	.386	144.86	1,187.06	197.84	10.108
18	4.68	1.032	4.770	8.597	.410	136.54	1,118.00	186.33	10.733
19	4.94	1.034	5.035	8.614	.433	129.11	1,056.21	176.03	11.361
20	5.20	1.035	5.300	8.622	.457	122.53	1,000.60	166.76	11.992
21	5.46	1.037	5.565	8.639	.480	116.47	950.28	158.38	12.627
22	5.72	1.039	5.830	8.656	.504	110.96	904.54	150.75	13.266
23	5.98	1.041	6.095	8.672	.528	105.93	862.78	143.79	13.908
24	6.24	1.043	6.360	8.689	.552	101.33	820.50	137.41	14.554
25	6.50	1.045	6.625	8.706	.576	97.09	789.28	131.54	15.203
26	6.76	1.046	6.890	8.714	.600	93.26	756.77	126.12	15.856
27	7.02	1.048	7.155	8.731	.624	89.61	726.66	121.11	16.513
28	7.28	1.050	7.420	8.747	.649	86.27	698.71	116.45	17.173
29	7.54	1.052	7.685	8.764	.673	83.14	672.69	112.11	17.838
30	7.80	1.054	7.950	8.781	.698	80.21	648.40	108.06	18.507
31	8.06	1.056	8.215	8.797	.722	77.48	625.67	104.27	19.179
32	8.32	1.058	8.480	8.814	.747	74.92	604.37	100.72	19.855
33	8.58	1.059	8.745	8.822	.771	72.58	584.36	97.39	20.535
34	8.84	1.061	9.010	8.839	.796	70.31	565.53	94.25	21.218
35	9.10	1.063	9.275	8.856	.821	68.17	547.77	91.29	21.906
36	9.36	1.065	9.540	8.872	.846	66.15	531.00	88.50	22.598
37	9.62	1.067	9.805	8.889	.871	64.24	515.13	85.85	23.294
38	9.88	1.069	10.070	8.905	.896	62.44	500.10	83.35	23.983
39	10.14	1.071	10.335	8.922	.922	60.72	485.84	80.97	24.699
40	10.40	1.073	10.600	8.939	.947	59.09	472.30	78.71	25.407

[a] Superintendent Onondaga Salt Springs, N. Y., Rept. for 1883, pp. 36–37, 1884. Theoretical values apparently based on a pure solution of sodium chloride.

Conversion table for salt solutions—Continued.

Salimeter degrees.	Baumé degrees.	Specific gravity.	Percentage of salt (sodium chloride).	Weight of 1 gallon of brine in avoirdupois pounds (of 7,000 grains each).	Pounds of salt in 1 U. S. gallon (231 cubic inches) of brine.	Gallons of brine containing 1 bushel (56 pounds) of salt.	Pounds of water to be evaporated to produce 1 bushel of salt.	Pounds of coal required to produce 1 bushel of salt (1 pound of coal evaporating 6 pounds of water).	Bushels of salt that can be made with 1 ton (2,000 pounds) of coal.
41	10.66	1.075	10.865	8.955	.973	57.54	459.41	76.56	26.120
42	10.92	1.077	11.130	8.972	.998	56.07	447.14	74.52	26.837
43	11.18	1.079	11.395	8.989	1.024	54.66	534.44	72.57	27.558
44	11.44	1.081	11.660	9.005	1.050	53.32	424.27	70.71	23.283
45	11.70	1.083	11.925	9.022	1.075	52.04	413.60	68.93	29.013
46	11.96	1.085	12.190	9.039	1.101	50.82	403.39	67.23	29.747
47	12.22	1.087	12.455	9.055	1.127	49.64	393.61	65.60	30.486
48	12.48	1.089	12.720	9.072	1.154	48.52	384.25	64.04	31.229
49	12.74	1.091	12.985	9.089	1.180	47.44	375.26	62.54	31.977
50	13.00	1.093	13.250	9.105	1.206	46.41	366.64	61.10	32.729
51	13.26	1.095	13.515	9.122	1.232	45.42	358.34	59.72	33.487
52	13.52	1.097	13.780	9.139	1.259	44.46	350.38	58.39	34.247
53	13.78	1.100	14.045	9.164	1.287	43.50	342.71	59.11	35.015
54	14.04	1.102	14.310	9.180	1.313	42.62	335.35	55.89	35.783
55	14.30	1.104	14.575	9.197	1.340	41.77	328.21	54.70	36.560
56	14.56	1.106	14.840	9.214	1.367	40.95	321.35	53.55	37.341
57	14.82	1.108	15.105	9.230	1.394	40.16	314.74	52.45	38.126
58	15.08	1.110	15.370	9.247	1.421	39.39	308.34	51.39	38.917
59	15.34	1.112	15.635	9.264	1.448	38.66	302.17	50.36	39.712
60	15.60	1.114	15.900	9.280	1.475	37.94	296.21	49.36	40.512
61	15.86	1.116	16.165	9.297	1.502	37.26	290.43	48.40	41.317
62	16.12	1.118	16.430	9.314	1.530	36.59	284.84	47.47	42.129
63	16.38	1.121	16.695	9.339	1.559	35.91	279.42	46.57	42.945
64	16.64	1.123	16.960	9.355	1.586	35.29	274.18	45.69	43.765
65	16.90	1.125	17.225	9.372	1.614	34.68	269.10	44.85	44.591
66	17.16	1.127	17.490	9.389	1.642	34.10	264.18	44.03	45.423
67	17.42	1.129	17.755	9.405	1.670	33.53	259.40	43.23	46.260
68	17.68	1.131	18.020	9.422	1.697	32.98	254.76	42.46	47.102
69	17.94	1.133	18.285	9.439	1.725	32.44	250.26	41.71	47.949
70	18.20	1.136	18.550	9.464	1.755	31.89	245.88	40.98	43.802
71	18.46	1.138	18.815	9.480	1.783	31.39	241.63	40.27	49.662
72	18.72	1.140	19.080	9.497	1.812	30.90	237.50	39.58	50.526
73	18.98	1.142	19.345	9.514	1.840	30.42	233.47	38.91	57.397
74	19.24	1.144	19.610	9.530	1.868	29.96	229.56	38.26	52.272
75	19.50	1.147	19.875	9.555	1.899	29.48	225.76	37.62	53.153
76	19.76	1.149	20.140	9.572	1.927	29.04	222.05	37.00	54.041
77	20.02	1.151	20.405	9.589	1.956	28.62	218.44	36.40	54.934
78	20.28	1.154	20.670	9.614	1.987	28.17	214.92	35.82	55.834
79	20.54	1.156	20.935	9.630	2.016	27.77	211.49	35.24	56.739
80	20.80	1.158	21.200	9.647	2.045	27.38	208.14	34.69	57.650
81	21.06	1.160	21.465	9.664	2.074	26.99	204.88	34.14	58.568
82	21.32	1.163	21.730	9.689	2.105	26.59	201.70	33.61	59.471
83	21.58	1.165	21.995	9.705	2.134	26.23	198.60	33.10	60.421
84	21.84	1.167	22.260	9.722	2.164	25.87	195.57	32.59	61.359
85	22.10	1.170	22.525	9.747	2.195	25.50	192.61	32.10	62.301
86	22.36	1.172	22.790	9.764	2.225	25.16	189.72	31.62	63.250
87	22.62	1.175	23.055	9.789	2.256	24.81	186.89	31.14	64.206
88	22.88	1.177	23.320	9.805	2.286	24.48	184.13	30.68	65.168
89	23.14	1.179	23.585	9.822	2.316	24.17	181.44	30.24	66.137
90	23.40	1.182	23.850	9.847	2.348	23.84	178.89	29.80	67.113
91	23.66	1.184	24.115	9.864	2.378	23.54	176.22	29.37	68.096
92	23.92	1.186	24.380	9.880	2.408	23.24	173.69	28.94	69.085
93	24.18	1.189	24.645	9.905	2.441	22.93	171.22	28.53	70.086
94	24.44	1.191	24.910	9.922	2.471	22.65	168.80	28.13	71.086
95	24.70	1.194	25.175	9.947	2.504	22.36	166.44	27.73	72.105
96	24.96	1.196	25.440	9.964	2.534	22.09	164.12	27.35	73.114
97	25.22	1.198	25.705	9.980	2.565	21.82	161.85	26.97	74.140
98	25.48	1.201	25.970	10.005	2.598	21.55	159.63	26.60	75.172
99	25.74	1.203	26.235	10.022	2.629	21.29	157.45	26.24	76.212
100	26.00	1.205	26.500	10.039	2.660	21.04	155.32	25.88	77.259

Chlorine content, salinity, and specific gravity of sea water at various concentrations.[a]

Chlorine.	Salinity.	Specific gravity ($\frac{0°}{4°}$).	Chlorine.	Salinity.	Specific gravity ($\frac{0°}{4°}$).
Grams per kilogram.	*Grams per kilogram.*		*Grams per kilogram.*	*Grams per kilogram.*	
1.00	1.84	1.00140	19.60	35.41	1.02846
2.00	3.64	1.00287	19.65	35.50	1.02853
3.00	5.45	1.00433	19.70	35.59	1.02860
4.00	7.25	1.00579	19.75	35.68	1.02867
5.00	9.06	1.00725	19.80	35.77	1.02875
6.00	10.86	1.00871	19.85	35.86	1.02882
7.00	12.67	1.01016	19.90	35.95	1.02889
8.00	14.47	1.01162	19.95	36.04	1.02896
9.00	16.28	1.01307	20.00	36.13	1.02904
10.00	18.08	1.01452	20.10	36.31	1.02918
11.00	19.89	1.01597	20.20	36.49	1.02933
12.00	21.69	1.01742	20.30	36.67	1.02947
13.00	23.50	1.01887	20.40	36.85	1.02962
14.00	25.30	1.02032	20.50	37.03	1.02977
15.00	27.11	1.02177	20.60	37.21	1.02991
16.00	28.91	1.02322	20.70	37.39	1.03006
17.00	30.72	1.02468	20.80	37.57	1.03020
18.00	32.52	1.02613	20.90	37.75	1.03035
19.00	34.33	1.02758	21.00	37.94	1.03049
19.10	34.51	1.02773	21.50	38.84	1.03122
19.20	34.69	1.02787	22.00	39.74	1.03195
19.30	34.87	1.02802	22.50	40.64	1.03268
19.40	35.05	1.02816	23.00	41.55	1.03341
19.50	35.23	1.02831			

[a] Knudsen, Martin, Hydrographische Tabellen, Copenhagen, 1901.

Atomic weight of elements common in saline solutions.[a]

Element.	Symbol.	Atomic weight.	Element.	Symbol.	Atomic weight.
Aluminum	Al	27.1	Magnesium	Mg	24.32
Boron	B	11.0	Oxygen	O	16.00
Bromine	Br	79.92	Phosphorus	P	31.04
Calcium	Ca	40.07	Potassium	K	39.10
Carbon	C	12.00	Silicon	Si	28.3
Chlorine	Cl	35.46	Sodium	Na	23.00
Iodine	I	126.92	Sulphur	S	32.07
Iron	Fe	55.84			

[a] Report of the international committee on atomic weights, 1915: Am. Chem. Soc. Jour., vol. 36, pp. 1585-1589, 1914.

Factors for converting radicles to compounds.[a]

Radicle.	Compound.	Factor.	Radicle.	Compound.	Factor.
Na	$NaCl$	2.538	Cl	$NaCl$	1.650
	Na_2O	1.347		KCl	2.103
	Na_2SO_4	3.084		$MgCl_2$	1.342
	$Na_2SO_4.10H_2O$	6.992		$MgCl_2.6H_2O$	2.867
	$Na_2SO_4.7H_2O$	5.820		$CaCl_2$	1.565
	Na_2CO_3	2.301		$CaCl_2.6H_2O$	3.090
	$NaHCO_3$	3.647	Br	$NaBr$	1.288
	NaI	6.502		$NaBr.2H_2O$	1.739
	$NaI.2H_2O$	8.066		KBr	1.489
	$NaBr$	4.469		$MgBr_2$	1.152
	$NaBr.2H_2O$	6.036		$MgBr_2.6H_2O$	1.828
K	KCl	1.906		$CaBr_2$	1.251
	K_2O	1.204	I	NaI	1.182
	K_2SO_4	2.228		$NaI.2H_2O$	1.466
	K_2CO_3	1.767		KI	1.308
	$KHCO_3$	2.560		MgI_2	1.096
	KI	4.243		$MgI_2.8H_2O$	1.664
	KBr	3.044		CaI_2	1.158
Mg	$MgCl_2$	3.920	SO_4	Na_2SO_4	1.480
	$MgCl_2.6H_2O$	8.376		$Na_2SO_4.10H_2O$	3.355
	MgO	1.659		$Na_2SO_4.7H_2O$	2.792
	$MgSO_4$	4.958		K_2SO_4	1.814
	$MgSO_4.7H_2O$	10.151		$MgSO_4$	1.253
	$MgCO_3$	3.471		$MgSO_4.7H_2O$	2.565
	$Mg(HCO_3)_2$	6.028		$CaSO_4$	1.417
	MgI_2	11.449		$CaSO_4.2H_2O$	1.792
	$MgI_2.8H_2O$	17.385	CO_3	Na_2CO_3	1.768
	$MgBr_2$	7.586		K_2CO_3	2.304
	$MgBr_2.6H_2O$	12.035		$CaCO_3$	1.668
Ca	$CaCl_2$	2.769		$MgCO_3$	1.405
	$CaCl_2.6H_2O$	5.467	HCO_3	$NaHCO_3$	1.378
	CaO	1.399		$KHCO_3$	1.641
	$CaSO_4$	3.398		$Mg(HCO_3)_2$	1.199
	$CaSO_4.2H_2O$	4.297		$Ca(HCO_3)_2$	1.328
	$CaCO_3$	2.498			
	$Ca(HCO_3)_2$	4.045			
	CaI_2	7.331			
	$CaBr_2$	4.990			

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[a] Calculated by R. B. Dole, U. S. Geological Survey, from atomic weights of 1897, which differ little from those of 1915.

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