

GEOLOGICAL SURVEY OF OHIO

FOURTH SERIES, BULLETIN 37

Brines of Ohio

By

**WILBER STOUT
R. E. LAMBORN
DOWNS SCHAAF**

GEOLOGICAL SURVEY OF OHIO

WILBER STOUT, State Geologist

FOURTH SERIES, BULLETIN 37

**OHIO DIV. OF GEOLOGICAL SURVEY
P. O. BOX 650
SANDUSKY, OHIO**

BRINES OF OHIO

(A Preliminary Report)

By

**WILBER STOUT, R. E. LAMBORN,
DOWNS SCHAAF**

**OHIO GEOL. SURVEY
LAKE ERIE SECTION
LIBRARY CARD NO. 6**

COLUMBUS

1932

Page 2 is blank

CONTENTS

	Page
Foreword.....	7
Introduction.....	9
History.....	11
Jackson County.....	11
Delaware County.....	12
Muskingum County.....	12
Gallia County.....	12
Meigs County.....	13
Athens County.....	13
Morgan County.....	13
Columbiana County.....	13
Guernsey County.....	13
Tuscarawas County.....	14
Cuyahoga County.....	14
Medina County.....	14
Summit County.....	14
Wayne County.....	14
Origin of brines.....	15
Rock formations yielding brines.....	19
Permian system.....	19
Pennsylvanian system.....	20
Cow Run member.....	20
Mahoning member, Macksburg Three Hundred-foot sand.....	20
Lower Freeport member, Second Cow Run, Pecker sand.....	21
Clarion sandstone, Macksburg Five Hundred-foot sand.....	21
Massillon member, Salt or First Salt sand.....	21
Sharon member, Maxton sand.....	22
Mississippian system.....	22
Vinton member, Keener sand.....	23
Black Hand member, Big Injun sand.....	23
Berea formation.....	23
Devonian system.....	24
Oriskany formation, horizon of First Water of Big Lime.....	25
Silurian system.....	25
Salina formation, Salt beds.....	25
Newburg formation, horizon of Second Water of Big Lime.....	26
Ordovician system.....	27
Lexington or Trenton formation.....	27
St. Peter formation.....	27
Cambrian system.....	28
Utilization of brines.....	28
Sodium and its compounds.....	28
Bromine and its compounds.....	30
Calcium and its salts.....	30
Chlorine and its compounds.....	31
Magnesium and its compounds.....	32
Strontium and its compounds.....	32
Other components of brines.....	33

	Page
Tests of brines and salt.....	33
Macksburg Five Hundred-foot sand.....	33
Noble County.....	34
Center Township.....	34
Maxton sand.....	35
Meigs County.....	35
Scipio Township.....	35
Monroe County.....	36
Malaga Township.....	36
Maxville or "Big Lime" sand.....	37
Monroe County.....	38
Malaga Township.....	38
Keener sand.....	40
Noble County.....	41
Seneca Township.....	41
Monroe County.....	42
Malaga Township.....	42
Sunsbury Township.....	46
Big Injun sand.....	47
Meigs County.....	48
Salisbury Township.....	48
Noble County.....	50
Marion Township.....	50
Monroe County.....	51
Jackson Township.....	51
Berea sand.....	52
Scioto County.....	52
Jefferson Township.....	52
Meigs County.....	53
Sutton Township.....	53
Noble County.....	54
Marion Township.....	54
Seneca Township.....	56
Monroe County.....	57
Center Township.....	57
Belmont County.....	58
Warren Township.....	58
Tuscarawas County.....	59
Dover Township.....	59
Stark County.....	60
Canton Township.....	60
Osnaburg Township.....	61
Mahoning County.....	62
Beaver Township.....	62
Medina County.....	63
Chatham Township.....	63
First Water of Big Lime.....	64
Jefferson County.....	64
Island Creek Township.....	64
Wayne County.....	65
Chester Township.....	65
Milton Township.....	66

	Page
Ashland County.....	66
Perry Township.....	66
Montgomery Township.....	67
Jackson Township.....	68
Richland County.....	68
Mifflin Township.....	68
Summit County.....	69
Bath Township.....	69
Medina County.....	70
Homer Township.....	70
Litchfield Township.....	71
Liverpool Township.....	71
Lorain County.....	72
Columbia Township.....	72
Carlisle Township.....	73
Lake County.....	74
Painesville Township.....	74
Salina formation.....	74
Stark County.....	75
Lake Township.....	75
Wayne County.....	76
Milton Township.....	76
Cuyahoga County.....	77
Cleveland.....	77
Second Water of Big Lime.....	78
Lawrence County.....	79
Elizabeth Township.....	79
Jackson County.....	80
Coal Township.....	80
Vinton County.....	81
Clinton Township.....	81
Swan Township.....	82
Athens County.....	83
York Township.....	83
Hocking County.....	85
Benton Township.....	85
Perry County.....	86
Reading Township.....	86
Madison Township.....	86
Muskingum County.....	87
Brush Creek Township.....	87
Hopewell Township.....	88
Washington Township.....	88
Falls Township.....	89
Jackson Township.....	90
Guernsey County.....	91
Knox Township.....	91
Licking County.....	92
Perry Township.....	92
Coshocton County.....	92
Perry Township.....	92

	Page
Knox County.....	94
Jackson Township.....	94
Union Township.....	95
Brown Township.....	96
Morrow County.....	97
Chester Township.....	97
Tuscarawas County.....	98
Clay Township.....	98
Fairfield Township.....	99
Sandy Township.....	99
Holmes County.....	100
Richland Township.....	100
Washington Township.....	101
Columbiana County.....	102
West Township.....	102
Stark County.....	103
Jackson Township.....	103
Ashland County.....	104
Green Township.....	104
Richland County.....	104
Worthington Township.....	104
Summit County.....	105
Franklin Township.....	105
Copley Township.....	106
Medina County.....	107
Lafayette Township.....	107
Liverpool Township.....	108
Lorain County.....	109
Carlisle Township.....	109
Wood County.....	110
Bowling Green.....	110
Index	113
	Facing page
Tabulated summary of analyses of brines and salts	110

ILLUSTRATIONS

	Page
Figure. Curve of variation of concentration with depth	18
	Facing page
Map showing location of brine and salt samples	34

FOREWORD

This report on the brines and salts of Ohio covers only a preliminary investigation. Because it would require several years to extend the investigation over the entire State and because numerous inquiries indicate that the information is needed at the present time, it is thought best to publish the results of the work done thus far.

The information contained herein will give an insight into the nature of the brines in Ohio and into their fitness for commercial utilization. It includes 62 analyses made by the Geological Survey of Ohio and 20 made by the United States Geological Survey. Short discussions are given of the rock formations or horizons that yield brine or salt and of the products made directly or indirectly from the brine components.

In the preparation of the bulletin free use has been made of other publications of the Geological Survey of Ohio, of the publications of the United States Geological Survey, of the prospectus of the Dow Chemical Company, Midland, Michigan, and of various other technical papers which treat of brines.

Blank Page

INTRODUCTION

Brines or saline waters always have been a necessity to man as salts from such solutions enter into many functions and constituents of the body that govern growth and repair. For domestic purposes common salt is used for the seasoning of foods, the curing of meats, and the preservation of certain vegetable products. Brines help the farmer, the gardener, and the fruit grower by providing at low cost materials for both fertilizers and insecticides.

Directly or indirectly, components of the brines are converted into numerous pharmaceutical and industrial chemicals. The manufacture of such products now constitutes large and important industries, involving millions of dollars of capital. Elements derived from the deep-seated brines, combined chemically with certain organic compounds, yield dyes, flavors, and perfumes. At present (1932) the metal magnesium, obtained mainly from strong saline waters, forms the basis of a light-weight alloy which has many uses. Thus the elements of the brines, either in the natural forms or in their chemical modifications, are now a distinct necessity to our modern civilization.

Blank Page

HISTORY

The salt used in the early settlements of Ohio was brought in by pack-horse and boat from works east of the Appalachian Mountains, hence the article was not only scarce but costly, the price ranging from \$4.00 to \$8.00 a bushel. A vigorous search for brines soon led to the finding of licks throughout most of the area occupied by the coal formations. Although these saline solutions were weak, they yielded sufficient salt for the requirements of the settlers.¹

Jackson County. Near Jackson weak brines issuing from the base of the Sharon conglomerate were utilized by the aborigines for making salt. Such solutions were simply placed in basins hewn from the sandstone, concentrated by evaporation by the heat of the sun, and then reduced to saturation by boiling. As shown by the many fossils in the surface formations, these licks had been frequented for a long period in the quest for salt by the animals of the plains and forests, such as the mastodon, mammoth, and elephant, long extinct, and the bison, elk, deer, bear, and many smaller kinds.

The first attempt by the whites at the manufacture of salt at the Scioto saline springs near Jackson was after the close of the Indian War in the year 1797. The greatest quantity of salt made at these licks was between 1806 and 1808, when twenty furnaces were in operation, making on the average from 50 to 70 bushels per week. During this period salt was worth \$2.50 per bushel or 5 cents per pound. The roads then were mere "bridle paths" through the woods and nearly the whole amount of salt made was transported in bags on pack-horses and distributed through the middle and western parts of the State.

¹The history of salt making in Ohio before 1838 is fully described by S. P. Hildreth in the First Annual Report of the Geological Survey of Ohio, 1838, pp. 57-61. The facts set forth by him are freely drawn upon by the authors.

Additional references are found in the following reports of the Geological Survey of Ohio:

Second Annual Report, 1838, pp. 69, 94-99.

Report of Progress, 1869, Part I, pp. 127-128, 132-133.

Report of Progress, 1870, p. 234.

Volume I, Part I, pp. 255-256, 263, 295. 1873.

Volume II, Part I, pp. 270, 486, 487. 1874.

Volume III, pp. 84-85, 713-714. 1878.

Volume V, p. 285. 1884.

Volume VI, pp. 157, 376, 653-670: The Manufacture of Salt and Bromine. 1888.

Bulletin 8, Salt Deposits and the Salt Industry of Ohio. 1906.

Bulletin 24, pp. 137-141. 1921.

So necessary was salt to the future prosperity of the territory that legislation was enacted to preserve and control the main salt springs. Congress in 1796 reserved the salt springs and expressly stipulated that the State should never sell or lease them for a longer period than ten years. In the year 1803 among the earliest proceedings of the Ohio Legislature was an act regulating the leasing and the managing of the "Public Salt Works." An agent was appointed to take charge of the lands, to lease small lots for digging wells and erecting furnaces, and to see that no individual or company monopolized the manufacture of salt. To prevent this the enactment expressed that no one person, or company, should work more than 120 kettles nor less than 30. For this privilege the lessee paid a rent to the State of 12 cents per gallon on the amount of capacity of his kettles annually. A fine of \$5.00 per kettle was laid on every person who made salt without a license. In the year 1804 the rent was reduced to 4 cents per gallon and the amount limited to 4,000 gallons of capacity. In 1805 the rent was again reduced to 2 cents and in 1810 to 5 mills. In 1818 the Legislature announced that the salt licks were no longer a success, and asked Congress to permit the State to sell the lands. This request was not granted until the closing days of 1824. In June, 1826, a three-day public sale was held and all lands not sold during that time were disposed of privately.

Delaware County. The saline springs in this county were located in Brown Township within the belt of Ohio shale. The brines were obtained from shallow wells about 200 feet in depth, were of moderate concentration, but were small in quantity. Salt was made here only in a desultory way between 1809 and 1818.

Muskingum County. The State-owned reservation in Muskingum County was on Salt Creek in Salt Creek Township, where between the years 1804 and 1820 much salt was produced. In 1826 the State land was sold at public auction. The brines in this locality were from a depth of about 300 feet and were of such concentration that 250 to 300 gallons of solution yielded 50 pounds of salt. In other parts of the county many independent works had one or more kettles in operation. The brines were obtained from borings 200 to 600 feet deep. Salt was made to some extent in Blue Rock, Brush Creek, Newton, Salt Creek, Wayne, Perry, Springfield, Washington, Falls, Muskingum, and Madison townships.

Gallia County. Near the mouth of Chickamauga Creek, just south of Gallipolis, Fletcher and Tupper began in 1807 the making of salt by the evaporation of a weak brine found at the surface of the bedrock. Nearly 600 gallons of this solution was required to make 50 pounds of salt. In 1809 these enterprising men penetrated the strata by boring to a depth of 100 feet, the result being a brine much stronger than that found near the surface. This was the earliest attempt made in Ohio at

boring the rocks in the search for saline waters. The success of this venture, however, caused deeper and deeper wells to be drilled in many of the salt-producing areas.

Meigs County. The search for brines in Meigs County began in the western part on Leading Creek. Hamilton Kerr, a celebrated ranger, had made salt here in the year 1796 by boiling in his camp kettle the water collected by digging holes in the sand at a time when the creek was nearly dry. The first salt well was opened in 1822 by B. Stout at a point about 8 miles above the mouth of the stream. Other works were soon in operation in that vicinity. The average depth of the wells was about 450 feet. The brine was of fair strength as only about 100 gallons of solution would produce 50 pounds of salt. The industry was active on Leading Creek until after 1840, when it declined.

Because of shipping facilities and an abundance of slack coal for fuel, salt making began in an active way in 1850 at Pomeroy on the Ohio River. In this locality the brines are mainly from the Black Hand or Big Injun sand, ranging usually from 1,000 to 1,200 feet in depth.

Athens County. Wells were drilled and furnaces erected about 1820 on the Hocking River and its tributary, Sunday Creek, in Dover and York townships, Athens County. The brines, obtained from the Big Injun sand at a depth of approximately 530 feet, were considered very strong as 75 gallons produced 50 pounds of salt. Central Ohio was largely supplied with salt from these works shipped by way of the old Hocking and Ohio canals. The industry survived as late as 1877 at Salina, now Beaumont.

Morgan County. The salt industry in this county was located principally along the Muskingum River near Eagleport, about 10 miles above McConnelsville. Thirty-seven furnaces flourished along the valley. These were kettle furnaces designed either to burn the wood found near by or to utilize the slack coal obtained from mines of Middle Kittanning coal on the Muskingum River above Philo and transported to the works by flatboats. The brine was struck in the Black Hand or Big Injun member at a depth not far from 700 feet. In this locality the industry began about 1825 and survived until 1905.

Columbiana County. The first well in this county was put down in 1809 by George James at Salineville, where salt was made for a number of years. At New Lisbon the industry began in 1866 through drilling for oil and finding instead a strong flow of rich brine at a depth of 687 feet. The Kittanning coal was used for fuel. The New Lisbon Salt Company had a daily capacity of 65 barrels which was mainly sold locally. It was active until 1891. Salt was made, but with no great success, along the Ohio River between Wellsville and East Liverpool.

Guernsey County. Guernsey County was never a large producer of salt. The first operation was begun by Addison Alexander in 1859

at Millers Station, about 8 miles north of Cambridge. The brine, supplied by one well with a depth of 430 feet, was comparatively weak in concentration but yielded a good clear product. In 1865 Elza Scott started a furnace near Cambridge and made from 25 to 30 barrels of salt daily. The brine was strong and was found at a depth of about 1,000 feet. Salt making was attempted at a few other places in Guernsey County.

Tuscarawas County. The salt industry in Tuscarawas County was centered around Dover, where three works with a yearly capacity of 65,000 barrels were in operation. Bodey's furnace, built in 1865, was located along Sugar Creek just west of Dover. The Dover furnace, operated by Hilt and Shields, was situated on the canal about 2 miles northeast of the town, and the Goshen salt works was established to the east just across the Tuscarawas River. The brines were obtained from the Berea sand at depths of 850 to 900 feet. The Lower Kittanning coal was drawn upon for the fuel. The industry closed through the abandonment of the furnaces in 1890.

Cuyahoga County. An impetus to the salt industry of Ohio was given by the finding of rock salt in the deep-seated strata at the plant of the Cleveland Rolling Mill Company at Newburg. Thick beds of rock salt in the Salina formation were penetrated between the depths of 2,154 and 2,475 feet. Based on solution of these salt beds by water pumped from the surface, a plant, which was improved in design and machinery and which had a daily capacity of 1,800 barrels, was erected in 1889. These heavy saturated brines cheapened considerably the cost of manufacture. Other plants were soon placed in operation in the Cleveland area, some of which are still active.

Medina County. Through drilling for oil, rock salt of Salina age was discovered near Wadsworth in 1886. A company was organized in 1891 and soon afterwards a factory was in operation. The wells in which the rock salt is dissolved by fresh water are about 2,700 feet in depth.

Summit County. The Colonial Salt Company, with works at Kenmore, near Akron, was incorporated in 1901. The company depends on the natural salt in the Salina formation reached by wells approximately 2,800 feet in depth. At Barberton these beds contribute also the salt component for the manufacture of soda ash and chemicals.

Wayne County. The Ohio Salt Company at Rittman began the manufacture of salt in 1898. The Salina salt beds through solution provide the necessary brine. The production at present is 5,000 barrels per day.

ORIGIN OF BRINES

Brines of the deep-seated rocks appear to be only "fossil sea water" with some modification as to components and with considerable change as to concentration. They are the solution remnants of the sea water that filled the interstices of the sediments at the time of deposition. Their modification came about through both physical and chemical factors.

In most cases these water-laden silts or sands were buried, during succeeding geological time, by hundreds or even thousands of feet of other rock materials. Such a suppression of the bed developed in the brine solutions a high hydrostatic pressure and gave rise to some increase in temperature. The amounts of such changes are relatively proportional to the depth of burial. Internal forces also played a part. They caused a contorting or bending of the rock strata and thus produced a movement of the connate waters to different levels or to certain parts of the structure. All these factors aided in the chemical exchange, to a limited extent, of bases and acids of the brines for various constituents of the encasing rocks. In comparison to sea water the deep-seated brines show an enrichment in some elements, an impoverishment in others, and in general a far greater concentration. The common relations are shown by the following analyses:

	Brines					
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
	Sea water	From Berea sand	From First Water of Big Lime	From Second Water of Big Lime, Summit County	From Second Water of Big Lime, Muskingum County	From Second Water of Big Lime, Tuscarawas County
Chlorine, Cl	55.292	62.78	64.22	62.81	62.38	62.39
Bromine, Br .....	.188	.47	.69	.24	.89	.62
Sulphur tetra-oxide, SO ₄	7.692	.05	.12	.19	.09	.035
Carbon trioxide, CO ₂ .....	.207	None	None	None	None	None
Acid carbonate, HCO ₃ .....		.02	.13	.002	.02	.015
Sodium, Na	30.593	22.86	12.16	20.45	18.54	17.79
Potassium, K	1.106	.20	.15	.85	.77	.98
Calcium, Ca	1.197	10.80	16.63	12.50	14.33	14.93
Magnesium, Mg	3.725	2.65	5.63	2.77	2.63	2.37
Aluminum and iron oxides, (Al,Fe) ₂ O ₃ .....		.15	.05	.044	.032	.02
Silica, SiO ₂ .....		.02	.03	.004	.008	.02
Strontium, Sr .....			.19	.14	.31	.83
Total	100.000	100.000	100.00	100.000	100.000	100.000
Total solids, grams per kilogram	37.37	102.0	158.1	210.0	259.0	286.7
Depth of sample below surface, in feet	0	264	1260	2295	3464	4530

No. 1. Mean of 77 analyses of sea water, U. S. Geol. Survey, Bull. 330, p. 95.

No. 2. From Zeigler farm, Jefferson Township, Scioto County.

No. 3. From Huene well, Carlisle Township, Lorain County.

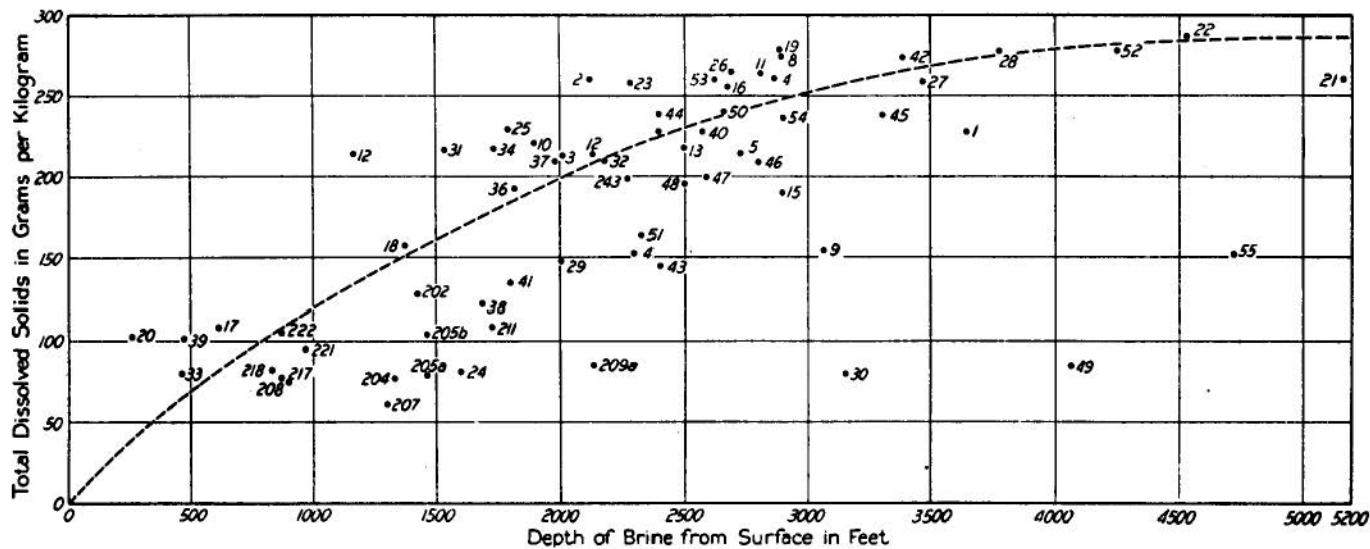
No. 4. From Burkhart well, Bath Township, Summit County.

No. 5. From Martha Myers well, Washington Township, Muskingum County.

No. 6. From J. H. Weaver well, Fairfield Township, Tuscarawas County.

An inspection of the analyses shows that the chief constituents of sea water and also of the deep-seated brines are sodium and chlorine, which elements on the evaporation of such solutions combine to form the compound, sodium chloride or common salt. In the brines the chlorine remains practically constant regardless of depth, concentration, wall rock, structural formations, etc. It is the only element of the brines that shows stability. Sea water is rather rich in sulphates of the predominating bases, calcium, magnesium, sodium, and potassium; whereas the brines are, with few exceptions, low in such salts. In some brines, due to the presence of barium chloride, the sulphates are absent as they have been lost through precipitation. The content of bromine is low in both sea water and brines. The carbonates are found in small quantities in sea water but appear to be practically insoluble in the more concentrated saline solutions. Sodium as sodium chloride reaches full saturation at about 38 per cent, but, as it is easily replaced by any of the other common bases, the quantity present in the brines varies through a wide range. Occasionally some of the more unusual elements like iodine, strontium, lithium, and selenium, occur in the deep-seated waters in appreciable amounts. Such substances may have been derived either from the original connate waters or from the wall rock. Brines from the limestone or dolomite formations are not uncommonly highly saturated with hydrogen sulphide gas, which appears to have been formed from the breaking down of the fleshy tissues of the animal life that flourished during the time of deposition of the strata. Brines of this type are often rich in the element, magnesium, the quantity varying from 3 to more than 5 per cent of the saline matter.

In a general way, the concentration, or the quantity of salts held in solution in a brine, increases with the depth of the water-bearing formation from the surface. This increase, however, is not regular but varies with the depth. The resultant graph as diagrammed is not a straight line but a decided curve which approaches a maximum at a depth approximating 5,000 feet. For general economy the brines of most value are those that occur at depths between 1,500 and 3,000 feet. These brines have good concentration as they vary on the average from 170 to 240 grams of total solids per kilogram of solution. Further, they are present at such depths that the expense of drilling and pumping is not excessive. The curve of concentration for the Ohio brines is shown in the figure.



Curve of variation of concentration with depth

SYSTEM	SERIES OR FORMATION	MEMBER OR BED YIELDING BRINE		Thick-ness of member or of un-divided parts	Thick-ness of series or formation	GENERAL REMARKS	
		GEOLOGICAL NAME	DRILLERS TERM				
Permian	Greene				405	No brines.	
	Washington				221	No brines.	
	Monongahela				248	No brines.	
	Conemaugh	Various strata		243	400	Massive, coarse-grained sandstone, 10 to 60 feet thick.	
		Cow Run	Cow Run	20			
		Various strata		112			
		Mahoning	Macksburg, Three Hundred-foot	25		Locally distributed, variable in thickness and texture.	
Pennsylvanian	Allegheny	Various strata		55	212	Persistent over wide areas; thick-ness 10 to 60 feet.	
		Lower Freeport	Second Cow Run, Peeker	25			
		Various strata		73			
		Clarion	Macksburg, Five Hundred-foot	25		Widely distributed, generally mas-sive, medium texture.	
		Various strata		34			
		Pottsville	Various strata		152	256	Persistent, open-textured sand-stone; yields large flows of brine.
			Massillon	First Salt	25		
	Various strata			49			
		Sharon	Maxton, Lower Salt	30		Fine to coarse conglomerate, local distribution, variable thickness.	
Mississippian	Maxville			20	20	Limestone, very unsteady, mainly wanting.	
	Logan	Vinton	Keener	80	170	Fine-grained sandstone, with shale, prominent in southeastern Ohio.	
		Various strata		90			
	Cuyahoga	Black Hand	Big Injun	120	335	Coarse sandstone to pebbly con-glomerate, thickness 50 to 200 ft.	
		Various strata		215			
		Sunbury			20	20	Shale.
		Berea	Berea	Berea	45	45	Fine-grained sandstone, source of much brine.
	Bedford			85	85	Shale.	
Devonian	Ohio			600	600	Shales, thickness varies from 400 to 3,400 feet.	
	Olentangy			30	30	Shale.	
	Delaware			45	45	Limestone.	
	Columbus			100	100	Limestone.	
	Oriskany	Oriskany	Oriskany	20	20	About horizon of First Water of Big Lime.	
		Detroit River			185	185	Limestones and dolomites.
Silurian	Bass Island			230	230	Mainly dolomites.	
	Salina	Salina	Salt beds	460	460	Variable strata of shale, limestone, dolomite, and rock salt.	
	Newburg	Newburg	Newburg	10	10	About horizon of Second Water of Big Lime.	
	Niagara			110	110	Dolomites.	
	Clinton			160	160	Mainly shales with some lime-stones.	
		Medina			75	75	Contains "Clinton sand" of driller.
Ordovician	Richmond			385	385	Shales with thin limestones.	
	Maysville			270	270	Shales with thin limestones.	
	Eden			305	305	Shales with thin limestones.	
	Cynthiana			100	100	Limestones with thin shale part-ings.	
	Lexington			260	260	Limestones or dolomites, locally yield brines.	
	Highbridge			390	390	Limestones or dolomites.	
		St. Peter	St. Peter	St. Peter	30	30	Sandstone, very patchy, yields large flow of brine.
	Lower Magnesian			350	350	Dolomites.	
Cambrian						Dolomites, maximum thickness recorded 1,200 feet.	
Algonkian						Metamorphic and crystalline rocks	
Archean						Crystalline rocks.	

ROCK FORMATIONS YIELDING BRINES

Brines are usually present in most of the open, porous beds of sedimentary origin that are within the groups of strata partially or entirely of marine derivation. They are not found in the formations deposited under fresh water conditions. The common rocks containing such salt solutions are sandstones, conglomerates, dolomites, and open-textured limestones. Brines often appear also along zones of disconformity, along fault planes, and in broken strata.

In Ohio, saline solutions are encountered at various horizons throughout the rock column from the base of the Cambrian system to the middle of the Conemaugh series of the Pennsylvanian system. The thickness of the stratified beds varies from 2,700 feet in northwestern Ohio to approximately 12,000 feet along the Ohio River in the southeastern part. Further, strong flows of brines are encountered at the general horizon of such depositional irregularities as represented by the shore phases of the St. Peter, Newburg, and Oriskany formations and by the uneven Mississippian-Pennsylvanian contact. The brines are accurately located by the driller for oil or gas as these flows of saline waters are a source of much trouble and expense in his work. The chief brine-bearing strata of Ohio are listed below.

PERMIAN SYSTEM

In Ohio, rocks of the Permian system cover an area of 1,830 square miles along the Ohio River in Jefferson, Belmont, Monroe, Washington, Noble, Morgan, Athens, and Meigs counties. The maximum thickness of such strata is about 600 feet. The deposits are entirely of fresh water origin and consist of shales, sandstones, and limestones with a few thin or impure coals and coal formation clays. The shales vary widely in texture, color, and composition. They are more abundant than any other rock in the system. The limestone members consist of irregular, nodular, or lenticular layers of limestone bedded in calcareous shale. They are subject to much change both laterally and vertically. The coal beds are lacking in both development and purity as are also the associated clays. In general, the sandstones in the Permian system are massive in form, open in texture, rather coarse in grain, decidedly micaceous in mineral content, and gray to buff in color. Locally the deposits may be conglomeratic in the lower portion. Some of these sandstone members, as the Waynesburg, Mannington, Upper Marietta, and Hundred, are of wide distribution, being present with few wants over large areas. As the sandstone strata were deposited under fresh water conditions, they contain no true brines useful for salt making or for chemical work.

PENNSYLVANIAN SYSTEM

The Pennsylvanian system of rocks at the surface or under cover extends over an area of approximately 12,340 square miles in southern and southeastern Ohio. It is made up of shales, sandstones, conglomerates, coals, clays, limestones, and iron ores. Roughly, the sandstones compose about 50 per cent of the total. Shales and sandstones are always interchangeable, that is, one may give way through gradation or through substitution partially or completely to the other. Such sandstones may also directly replace, locally, coals, clays, limestones, or iron ores. These sandstones are both of marine and fresh water origin. Many members below the Ames limestone, however, appear to be of marine derivation as the accompanying shales are of this character. With few exceptions the sandstones in the Pottsville, Allegheny, and lower Conemaugh series are more or less charged with brine, the amount depending on porosity of rock, thickness of the bed, extent of deposit, relation to structural features, and other factors. In general, the saline solutions in these beds are of moderate concentration, as they occur at no great depth, and belong to the class rich in sodium chloride. Only the most prominent sandstone members are considered in the following discussion.

COW RUN MEMBER

The Cow Run is the highest sandstone of any importance in the geological column of Ohio that carries a brine of marine origin. The position of the member in the Conemaugh series is between the easily recognized Cambridge and Ames limestones or more definitely between the Anderson and Barton coals. Where well developed the stratum lies on or only a few feet above the Anderson coal. The Cow Run member varies from 5 to 60 feet in thickness but averages not more than 20 feet. It is massive in character, coarse in texture, low in bonding components, and light gray to drab in color. This member is widely distributed throughout southeastern Ohio but reaches its best development and continuity in Washington, Morgan, Noble, Athens, and Muskingum counties. The brines of the Cow Run member have not been tested or utilized in Ohio.

MAHONING MEMBER

The Mahoning sandstone or the Macksburg Three Hundred-foot sand of the driller lies at the base of the Conemaugh series. Its place is more readily fixed by its position either directly or only a few feet above the Upper Freeport or No. 7 coal of the Allegheny series. This sandstone is locally present from Columbiana County on the east to Lawrence County on the south. It is variable in thickness and in many places coalesces with the Buffalo sandstone above. It is of the usual character for a coal formation sandstone, that is, it is open in texture,

ferruginous and micaceous in composition, and light gray to buff in color. No application has been made in Ohio of brines from the Mahoning horizon.

LOWER FREEPORT MEMBER

The most prominent sandstone in the upper part of the Allegheny series is the Lower Freeport, which lies directly or not far above the great stratum of Middle Kittanning coal and which is a massive, persistent bed over large areas throughout the coal fields of southeastern Ohio. As designated by the driller, it is the Second Cow Run or Peeker sand. The deposits vary in thickness from 10 to 60 feet. The stone is commonly massive in character, medium coarse in texture, and, where weathered, light gray in color. Locally the Lower Freeport sandstone yields large flows of brine of moderate concentration.

CLARION SANDSTONE

Next to the Massillon the Clarion is probably the most conspicuous sandstone in the Pennsylvanian system of Ohio as it is a massive sheet deposit over large areas throughout a field including parts or all of twenty-five counties in the southern and southeastern parts of the State. The drillers in the early sixties gave it the name Macksburg Five Hundred-foot sand, which designation is still retained for it by present drillers. Stratigraphically the Clarion sandstone lies below the Clarion coal or in the interval between the Clarion coal and the Putnam Hill limestone. The thickness of the deposits varies from 5 to 50 feet. The stone is usually massive in structure, definitely marked by cross-bedded planes, rather fine in texture, and light gray in color. The brines from the Clarion sandstone are rich in sodium chloride or common salt but are rather low in concentration.

MASSILLON MEMBER

The Massillon sandstone of Ohio is correlative with the Connoquenessing sandstone of Pennsylvania and is known to the driller as the Salt or First Salt sand. It has excellent continuity over a wide area in western Pennsylvania, eastern and southern Ohio, northern and western West Virginia, and northeastern Kentucky. In Ohio its position in the Pottsville series is commonly about 70 feet below the Lower Mercer limestone and directly or not far above the Quakertown coal. Locally, owing to the absence of basal Pottsville members, the Massillon sandstone lies close to the Mississippian rocks and hence may be mistaken for the Sharon conglomerate. Deposits of Massillon sandstone in many places maintain a thickness of 20 to 40 feet over large areas. This sandstone is generally coarse grained and often conspicuously conglomeratic in the basal portion. It is also prominently cross bedded, indicating shallow water origin. The Massillon sandstone was the source of brine

for some of the early salt works along the Hocking River in Athens County and in the Pomeroy district of Meigs County.

SHARON MEMBER

The Sharon conglomerate, the basal member of the Pottsville series, is very patchily developed in Ohio; in fact such strata are absent far more often than present. Deposits of this material occur only in irregular trough-like depressions which were eroded in the Mississippian formations, while elevated to a land surface, and which again on submergence at the beginning of Pennsylvanian time were filled with great quantities of sand and pebbles, both of quartz, originating in the crystalline rock areas of either Appalachia or the Canadian Shield. The Sharon deposits are irregular in outline, vary in thickness from 10 to 200 feet, and may change laterally or vertically from a coarse-textured conglomerate to a fine-grained sandstone. To the driller the Sharon is known as the Maxton or Lower Salt sand. The first brines utilized in the State of Ohio by the white man were those issuing from the base of the Sharon conglomerate near Jackson. Later they were used to some extent in the Pomeroy field. Under deep covering the member yields large flows of brines the salinity of which is largely that of sodium chloride.

MISSISSIPPIAN SYSTEM

Rocks of the Mississippian system are present at the surface or under covering in an area of approximately 20,390 square miles in the eastern part of Ohio and 540 square miles in the northwestern corner. The total thickness of these strata varies greatly owing to the loss in many areas of the upper formations through erosion that occurred during the closing stages of the period. In places, the Maxville limestone, the Logan shales and sandstones, and even part of the Cuyahoga beds are wanting. The effect of such sculpturing and loss is to modify erratically the measurements of the system from a minimum of not more than 150 feet to a maximum of over 800 feet.

In Ohio the great bodies of Mississippian rocks are shales and sandstones which are of marine origin but which were laid down in shallow and moderately quiet waters. The Maxville limestone, the youngest formation, has good thickness but is very patchily developed, as it is present only locally in the southern and southeastern parts of the area. In the Logan and Cuyahoga formations the sandstones show considerable lenticularity and irregularity, in many places being replaced by shale. However, the formations near the base of the system, that is, the Sunbury shale, the Berea sandstone, and the Bedford shale, are regional in extent and very uniform in thickness, composition, and physical properties. The sandstone members of prominence are the Vinton, Black Hand, and Berea; others of less importance are the

Allensville, Byer, Berne, and Buena Vista. All of these formations yield brine in varying quantities, although only a few are consistent producers of large flows of saline waters. In this State, Mississippian brines have been used for salt making for over one hundred years. Only the principal saline-producing sandstones will be considered in this discussion.

VINTON MEMBER

The Vinton member is the upper formation of the Logan group. Owing to the disconformity at the top of the Mississippian system, Vinton strata may lie below the Maxville limestone or, where this is absent, below the Pottsville beds of the coal-bearing series. The member is made up of a series of sandstones and shales with little irregularity in deposition except that in general the sandstones are most abundant and massive in the upper half of the formation. These sandstones are rather fine but open in texture, medium to massive in bedding, and light gray to buff in color. They are usually from 25 to 35 feet in thickness and directly overlain by 10 to 25 feet of shale. The sandstones of the Vinton member are correlative with the Keener sand of the driller, which sand is an important source of oil and gas in Monroe, Washington, Belmont, Noble, Guernsey, Morgan, and Athens counties and which yields large flows of brines over a wide area.

BLACK HAND MEMBER

The Black Hand, the youngest member in the Cuyahoga group, is identified as the Big Injun sand by the driller. These deposits extend over a wide area in southeastern Ohio, outcropping prominently in western Hocking, central Fairfield, and eastern Licking counties, extending on southeastward to the Ohio River and far into West Virginia. It is absent in southern and eastern Ohio, its place being taken by shales with small quantities of sandstones with different properties. The Black Hand member varies in character from a sandstone to a conglomerate. It is always coarse grained and in typical exposures contains many pebbly layers distributed as lenses along bedding and cross-bedding planes. The material is open in texture, the main cement being iron oxide. The color of the stone changes from light gray for unweathered material to drab, pink, or brown shades for exposed surfaces. The deposits vary in thickness from 10 to 260 feet but average about 120 feet. Because of the massive character of the bed, its continuity over wide areas, and its open, porous texture, the Black Hand member is a source of large flows of brine of sufficient concentration and mineral content for utilization in the salt, chemical, and allied industries.

BEREA FORMATION

The Berea formation is in the lower division of the Mississippian system and is made up largely of sandstones. It outcrops in a broad

belt extending from Ashtabula County west to Huron and thence south to Adams and Scioto counties on the Ohio River. To the east and south of this outcrop in eastern, southeastern, and southern Ohio, the formation has exceptional continuity, few wants being recorded. It is easily recognized stratigraphically as the deposits are overlain by the Sunbury shale, which is brown to black in color and fissile in character; and it is underlain by the Bedford shale which is soft and clay-like, and light gray, chocolate, or pink in color. In general, the Berea sandstone is fine in texture, argillaceous in composition, and bluish gray in color.

Two distinct types of deposits make up the Berea formation. The common phase, which is of wide distribution, is a sheet deposit with no radical variation in thickness or in character. The measurements are usually between 20 and 60 feet with an average of about 45 feet. These deposits are made up of alternate layers of sandstone and shale, the former greatly predominating in quantity. The second type of deposit is a thick, stringer-like mass of sandstone extending trough-fashion into or even through the underlying Bedford shale. The thickness may reach more than 200 feet. Usually the sandstones in these bodies are massive in character and rather open in texture. The Berea is not only a large producer of oil and gas in eastern Ohio but has been at several places a producer of brines.

DEVONIAN SYSTEM

The Devonian system of rocks outcrops in an area of 5,661 square miles but is present both at the surface and under covering in a total of 26,542 square miles. This includes three districts: The main one is practically the eastern half of the State; a small one occurs around the Bellefontaine outlier; and another is in the northwest corner of the State.

Owing to the eastward and northward expansions of the Ohio shale and other formations, the system undergoes wide variation in thickness, the minimum and maximum measurements being roughly 700 and 3,800 feet respectively. As indicated by the fossil content, all the rocks in the Devonian unit are of marine origin. They were laid down in the sea where the waters were comparatively quiet and shallow. Shales, limestones, and dolomites are the common rocks but sandstones are present in minor quantities. In general, the strata in the Devonian system are regional in distribution and fairly constant in physical and chemical character. Some beds, however, change from limestone to dolomite with attendant modifications in texture. The sandstones in the system appear to be rather wide spread but to be lacking in uniformity and continuity. Brines occur in the sandstone layers, along disconformity horizons, and in porous dolomites. Only one horizon, however, is important as a source of large flows of concentrated saline solutions.

ORISKANY FORMATION, HORIZON OF FIRST WATER OF BIG LIME

The position of the Oriskany sandstone is in the Devonian system between the Columbus and Detroit River formations. It is known only under deep covering in eastern Ohio, where it is reached by the drill in the search for oil and gas. The deposits are very patchy in distribution, being wanting or at least unrecognizable over large areas. The thickness of the deposits, as revealed by the drill, varies from 1 to 100 feet but the common measurement is between 10 and 30 feet. The material is a fine-grained sandstone which is loosely cemented with a calcareous bond. The horizon, that of the First Water of the Big Lime, is reached by the drill at a depth of approximately 1,290 feet at Elyria, Lorain County; 1,950 feet near Austinburg, Ashtabula County; 5,200 feet near Steubenville, Jefferson County; and 2,200 feet at Ironton, Lawrence County. The strongest flows of brine are obtained in northern and northeastern Ohio. Such solutions are very rich in magnesium in Lorain, Ashland, Medina, Richland, and Wayne counties.

SILURIAN SYSTEM

Rocks belonging to the Silurian system outcrop over an area of 11,456 square miles in Ohio. Excepting the southwestern and northwestern corners, they appear at the surface throughout nearly two-fifths of the western part of the State. As they are present under covering over an area of 26,544 square miles, the total for these rocks is thus 38,000 square miles. The thickness of Silurian strata varies through rather wide limits, the minimum being roughly 450 feet and the maximum 2,000 feet. The deposits are all of marine origin in that they were laid down in the sea and much of the material was gathered from that source. The rocks consist largely of dolomites and limestones with smaller quantities of shale and sandstone. Further, in local fields, rock salt and gypsum appear. Salt interstratified with dolomite is present over approximately 7,330 square miles in northeastern and eastern Ohio; and gypsum occurs in a few small fields in the north central part of the State. In general, the formations in the Silurian system maintain excellent continuity and uniformity over wide areas. The system is of interest to the chemical engineer on account of the great quantities of rock salt in the Salina formation and the large flows of rich brines at the horizon of the Newburg sand.

SALINA FORMATION

The Salina formation is the lowest division of the New Bass Island series of the Silurian system. In Ohio it is represented only under deep covering in the eastern part of the State and is known therefore only through drill records and cuttings. The formation consists of a series of shales and dolomites in which from one to a large number of layers

of rock salt are interstratified. The evidence, as obtained from the drill, indicates that the Salina formation is 200 to 600 feet in thickness in eastern Ohio but that westward it thins rapidly and disappears before reaching the outcrop in western Ohio. This group of rocks is of interest economically for the salt beds which yield strong brines for making salt, soda ash, and chemicals. As outlined by the drill, the area in which rock salt occurs with more or less constancy is approximately 7,330 square miles in eastern Lorain, Cuyahoga, Lake, Geauga, Ashtabula, Trumbull, Medina, Summit, Portage, Mahoning, Wayne, Stark, Columbiana, eastern Tuscarawas, Carroll, Jefferson, Harrison, and northern Belmont counties. The western boundary is along a line drawn from Lorain on Lake Erie through the towns of Litchfield, Spencer, Homerville, West Salem, Wooster, Apple Creek, Brewster, Dover, Stillwater, Freeport, and Morristown to Bellaire on the Ohio River. The thickness of individual layers of rock salt varies from 1 to 75 feet and the total thickness for the salt strata alone ranges from 25 to 200 feet. Owing to the dip of the rocks to the east and to the south, the depth at which the salt beds occur changes from 1,500 in Carlisle Township, Lorain County, to 2,300 feet in Harpersfield Township, Ashtabula County; to 2,400 feet in Canaan Township, Wayne County; to 4,200 feet in West Township, Columbiana County; to 4,600 feet in Freeport Township, Harrison County; to 5,800 feet (estimated) in Island Creek Township, Jefferson County. Brines from the solution of rock salt in place by the circulation of water through drill holes are used for commercial salt at Kenmore, Summit County; Rittman, Wayne County; Cleveland, Cuyahoga County; and Wadsworth, Medina County; and for soda ash and chemicals at Fairport, Lake County; and Barberton, Summit County.

NEWBURG FORMATION, HORIZON OF SECOND WATER OF BIG LIME

The Newburg or Stadler sand of the driller first came into prominence in 1915 with the opening of a small gas field at Newburg, southeast of Cleveland. In fact, the so-called sand is usually an impure, porous dolomite varying from light gray to pink in color. The horizon appears to mark a regional line of disconformity and locally bears thin lenses of sandstone, apparently deposits left along an old shore line. The position of the Newburg formation is variable but commonly it is found from 150 to 250 feet above the base of the great body of Silurian-Devonian limestones, known to the driller as the Big Lime. Stratigraphically, the deposits are interpreted to lie at or near the line of separation of the Salina formation from the underlying Guelph dolomite. The deposits which are considered to belong to the Newburg formation vary from 1 to 30 feet in thickness but commonly measure between 8 and 15 feet. The Newburg member is of no great importance as a producer of oil or gas but it is one of the chief water-bearing horizons in the deep-seated rocks. The flow is so great that it is known to the driller as the Big

Water in the Big Lime. It is also commonly referred to as the Second Water. Brines at this horizon are widely distributed; in fact they are seldom wanting in any part of the eastern half of Ohio. They are rich in saline matter and offer many useful components for the salt, soda ash, and chemical industries.

ORDOVICIAN SYSTEM

Rocks belonging to the Ordovician system appear at the surface over an area of 3,262 square miles in the southwestern corner of the State and underlie all the remaining part. Thus the strata of this period may be found at the surface or by the drill under covering in the entire State. The deposits have a mean thickness of about 2,000 feet and consist almost entirely of calcareous shale, limestone, or dolomite. The one exception is the St. Peter sandstone, the horizon of which is marked more definitely by large flows of brine than by deposits of siliceous sediments. For saline solutions the only formations of interest are the Trenton and the St. Peter.

LEXINGTON OR TRENTON FORMATION

The Trenton formation, named for deposits originally examined in Trenton Township, Oneida County, New York, is of regional distribution, being present over thousands of square miles in the Allegheny Plateau and in the Mississippi Valley Plain. The Trenton of the driller includes two formations, the Lexington and Highbridge, with eight members; lies between the Utica shale and the St. Peter sandstone; and is on the average about 650 feet in thickness. Throughout most of the area, where reached by the drill, the formation is a limestone carrying only small quantities of magnesium carbonate. Locally, however, it may change either laterally or vertically to a rather pure dolomite, grainy in texture and open or even cavernous in structure. This is the type of rock that may be productive of oil or gas or may yield brines in moderate quantities. In most fields the reservoir layers are confined to the upper 50 feet of the formation. In Ohio the main area for brines in the Trenton formation is in the northwestern part.

ST. PETER FORMATION

The St. Peter sandstone near the base of the Ordovician system is widely distributed in Ohio, but is very poorly developed. The horizon appears to be represented by local lenses of sandstone, by sandy matter in dolomite, and by only a plane of unconformity. It is most commonly recognized by a strong flow of brine highly saturated by hydrogen sulphide gas and known to the driller as Blue Lick water. The position of the St. Peter formation is normally about 2,300 feet below the base of the Big Lime of the driller and 650 feet below the top of the Trenton. It has been reached or passed by the drill in more than 100 places in Ohio,

distributed roughly over the western three-fifths of the State. Owing to the dip of the strata, the horizon of the St. Peter formation is reached at 1,980 feet in Woodville Township, Sandusky County; at 5,575 feet in Sheffield Township, Ashtabula County; at 1,900 feet at Springfield; at 4,600 feet at Newark; at 840 feet at Cincinnati; and at 4,425 feet in Jefferson Township, Jackson County. Brines from the St. Peter horizon were utilized formerly for salt making at Cincinnati and at the present time offer much material for the chemical industries

CAMBRIAN SYSTEM

Little is known regarding the rocks of the Cambrian system in Ohio as they have been reached by the drill only in western Ohio and there in only a few places. Where penetrated these rocks appear to be thin or absent in northwestern Ohio but to be approximately 1,300 feet in thickness in the southwestern part. The strata are mainly massive sandstones with smaller quantities of dolomite, limestone, and shale. No brines from this system of rocks have been tested in this State.

UTILIZATION OF BRINES

During the early stages of the salt industry in Ohio, the brines were considered as valuable only for the production of common salt, which was the only component of the brine needed to supply the immediate needs of the household and farm. The bittern waters, left after the evaporating of the salt and containing several ingredients, were considered worthless and were consequently wasted. Bromine, the first of the so-called by-products to be saved, was extracted from the bittern waters in 1868 at the old Dabney Salt Works at Pomeroy. This reddish-brown liquid with a very disagreeable odor soon became a regular product of commerce at other works in the Pomeroy field and also at those near Dover in the Tuscarawas Valley. Calcium chloride, the chief salt left in the bittern solution after the expulsion of the bromine, was also extracted and placed on the market to meet the demand, but the trade in this was not important until after 1880. At present (1932) brines are a source of great value as they are utilized for a wide variety of purposes. Several hundred products made directly or indirectly from brines are now on the market and others are appearing rapidly. Some of the more important commercial applications of brines are listed below.

SODIUM AND ITS COMPOUNDS

The element sodium (Na) in combination with some acid radicle, usually chlorine, occurs in all brines. The quantity varies from 10 to 39 per cent but ranges usually between 17 and 30 per cent. Directly or

indirectly the sodium of the brines enters into many compounds that are of much use in the home, in the industries, or on the farm. Only the most important need be described.

The common or granulated salt, NaCl , of commerce is made up of white, flaky crystals varying in size in accordance with the physical conditions under which precipitated. It is placed on the market in a number of grades, determined by fineness of grain and by purity of the material. Salt is readily soluble in water, either hot or cold. The purity of commercial salt as commonly refined is about 98 per cent sodium chloride. Salt is used for a great variety of purposes, chief of which are as a seasoning for foods and dairy products, for the preservation and curing of meats, for the canning and pickling of vegetables, for tanning of leather, setting of dyes, softening of water (Zeolite method), salt glazing of ceramic wares, and salting of cattle; as a secondary ingredient of certain fertilizers, for the wet extraction of copper and silver from ores, for a direct basis for many chemicals, and for various other uses.

The manufacture of soda ash or sodium carbonate, Na_2CO_3 , now constitutes a special and important branch of the chemical industry. Commonly the manufacture of this salt is carried out by the Solvay process in which a solution of salt, NaCl , saturated with ammonia, NH_3 , and warmed to 40°C ., reacts with carbon dioxide, CO_2 , to form a precipitate of sodium bicarbonate, NaHCO_3 . Through heating, sodium bicarbonate is converted to sodium carbonate, Na_2CO_3 , or soda ash.

Sodium carbonate is a white salt which readily dissolves in water, giving an alkaline reaction and yielding various hydrates, depending on the physical conditions for crystallization. It melts at 850°C . This salt is extensively used in the making of glass, in the softening of water, in the manufacture of soap, in compounds for cleaning, and in many ways in the manufacturing industries.

The sodium bicarbonate, NaHCO_3 , purified and recrystallized, is placed on the market for baking purposes, for the manufacture of soda water, and for other uses where a mild alkali is required. Washing soda is the hydrate, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$.

Caustic soda or sodium hydroxide, NaOH , is made commercially in a large way by the electrolysis of sodium chloride, NaCl , in concentrated aqueous solution, the end products being chlorine, Cl_2 , and sodium hydroxide, NaOH , both valuable. It is a white crystalline salt, soluble in water, alcohol, and ether, and is very stable, being melted but not decomposed by heat. Sodium hydroxide finds a wide application in many fields. It is used in the manufacture of soap; in bleaching, dyeing, and printing of textile fabrics; as an important chemical reagent in making rayon; in the digestion of wood for paper pulp; in the refining of petroleum, vegetable oils, and fats; and in various other chemical processes where an alkali is required.

Aside from the above, the list of sodium compounds that may be derived directly or indirectly from the sodium chloride of the brines is large and important. A few others may be mentioned, as sodium sulphate, $\text{Na}_2\text{SO}_4 \cdot 10 \text{H}_2\text{O}$, employed in the manufacture of glass; sodium sulphite, Na_2S , used in the cleaning and dyeing of cotton and silk fabrics; sodium silicate, Na_2SiO_3 , employed in making cheap soaps and in preserving and fireproofing wood; sodium picrate, $\text{C}_6\text{H}_2(\text{NO}_2)_3 \cdot \text{ONa}$, for percussion explosives.

BROMINE AND ITS COMPOUNDS

Bromine, Br_2 , in the form of bromides, is found in small amounts in practically all of the deep-seated saline water of Ohio. The quantities vary from 0.20 to 1.00 per cent of the total solids. Bromine is a dark brown-red liquid; has a density of 3.13; has a boiling point of 58.7°C .; solidifies at -7.3°C . to a dark-colored crystalline mass; evaporates rapidly under ordinary conditions; has a penetrating, unpleasant odor; has a strong corrosive action on the mucous membranes; dissolves up to 3.2 per cent in water; and is soluble in carbon disulphide, alcohol, and ether.

The following bromine compounds are employed in medicines but also have many additional uses: Solution of bromine in water, $\text{Br}_2 + \text{H}_2\text{O}$; bromoform, CHBr_3 ; ammonium bromide, NH_4Br ; calcium bromide, $\text{CaBr}_2 \cdot 2\text{H}_2\text{O}$; hydrobromic acid, $\text{HBr} + \text{H}_2\text{O}$; lithium bromide, LiBr ; monobromated camphor, $\text{C}_{10}\text{H}_{16}\text{OBr}$; potassium bromide, KBr ; sodium bromide, NaBr , and strontium bromide, $\text{SrBr}_2 \cdot 6\text{H}_2\text{O}$.

In photography silver bromide, AgBr , is precipitated on films and plates through the action of ammonium bromide on silver nitrate. Tribromophenol, $\text{C}_6\text{H}_2\text{Br}_3 \cdot \text{OH}$, is employed extensively as a disinfectant. In the dye industry ethyl bromide, $\text{C}_2\text{H}_5\text{Br}$, and methyl bromide, CH_3Br , are employed as reagents. A number of bromoaniline dyes of bright colors are also produced, the general formula of which is $\text{C}_6\text{H}_2 \cdot \text{NH}_2 \cdot \text{Br}_3$. For gold extraction, acetylene tetrabromide, $\text{C}_2\text{H}_2\text{Br}_4$, is widely used. Bromine and many of its compounds are very serviceable as reagents in both the laboratory and the chemical industries.

Bromine may be derived from the brine directly by (a) an electrolytic treatment of a weak current of four or five volts, or (b) replacement of the bromine in the bromide salt by chloride. On the other hand bromine may be derived from the bittern by treatment with sulphuric acid and manganese dioxide followed by distillation.

CALCIUM, Ca, AND ITS SALTS

Calcium, Ca, in the combined form, occurs in all the deep-seated brines, the normal range being from 3 to 17 per cent of the total saline

matter. The quantity held in solution varies somewhat with different producing members. Calcium chloride is a common constituent of brines, the quantity varying from 1 to 50 per cent of the total saline matter. Through substitution from natural causes during geological ages, calcium replaced a part of the sodium of the sodium chloride of the original saline solution. It is a colorless salt, separating in small flakes to form a rather open porous mass. The calcium chloride, CaCl_2 , unites with water in loose combination in forms containing from 1 to 6 molecules of water of crystallization. Commonly the salt occurring is $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$. This salt has a specific gravity of 1.78, melts at 163°C ., and is readily soluble in water and in alcohol. It is extracted from the bitterns after the treatment of the latter for bromine. Calcium chloride has a wide variety of uses, chief of which are the following; Large quantities of this salt are sold for the laying of dust on public roads and in coal mines. It is one of the common reagents in producing freezing mixtures for refrigeration for cold storage plants and for the production of ice. Owing to the low freezing point of the saturated solution, -37°C ., calcium chloride is employed for thawing frozen pipes, for ice removal, and for anti-freezing solutions. As the salt is very deliquescent, it has a value as a desiccating agent and as a control of humidity. It is employed to some extent in gun powder, fireproofing, sizing compounds, textile softeners, leather goods, paper, and certain adhesives.

CHLORINE AND ITS COMPOUNDS

Chlorine, Cl_2 , is very active chemically, hence in nature it occurs only in the combined forms or in the form of salts. In all the deep-seated brines of Ohio chlorine is the prominent acid component, the others such as Br_2 , SO_4 , and HCO_3 , are of only minor importance. It forms about 63 per cent of the total saline matter and has a variation of less than 2 per cent from this amount. Chlorine is a yellowish-green colored gas with a powerful smell and with harmful action on life of all kinds. By lowering the temperature to 0°C . and increasing the pressure to 3.7 atmospheres, the gas is condensed to a deep yellowish-green liquid with a density of 1.56.

Chlorine is used in innumerable ways in medicines, in the laboratory, in the arts, and in the industries. It is used directly for the chlorination of many compounds, for water purification, for military poisonous gas, for the extraction of gold, silver, lead, copper, zinc, tungsten, and vanadium from their ores, for the recovery of tin and zinc from scrap, for a bleaching agent, and for organic synthesis. Chlorine enters into many compounds which have a wide application. Some of the most important ones are hydrochloric acid, HCl , the acid for many chloride salts; chloride of lime, $\text{CaCl} \cdot \text{OCl} + \text{H}_2\text{O}$, for bleaching purposes; potassium chlorate, KClO_3 , for fireworks, explosives, and matches; hypochlorous

acid, HClO , a powerful bleaching and disinfecting agent; sulphur chloride, S_2Cl_2 , used in the manufacture of rubber goods; and many others with useful properties. Directly or indirectly chlorine reacts with many organic compounds, yielding a long list of derivatives, a part of which find employment commercially. Mention may be made of only a few as chloroform, CHCl_3 , an anesthetic; carbon tetrachloride, CCl_4 , as a solvent for organic compounds and as a cleaning agent; hexachlorethane, C_2Cl_6 , for generation of smoke screens; monochlorobenzene, $\text{C}_6\text{H}_5\text{Cl}$, for organic synthesis; acetylene tetrachloride, $\text{C}_2\text{H}_2\text{Cl}_4$, a solvent for shellac, gums, and resins; and paradichlorobenzene, $\text{C}_6\text{H}_4\text{Cl}_2$, for control of peach tree borers.

MAGNESIUM AND ITS COMPOUNDS

Magnesium, Mg , in the form of salts, mainly chloride, is present in all brines in Ohio. The quantity varies from 1 to 5.5 per cent of the total saline matter. Brines highly charged with hydrogen sulphide gas, H_2S , are usually richer in magnesium than others. Magnesium is a silvery white, rather tough metal with a specific gravity of 1.74. It melts at 750°C . and volatilizes at a bright white heat. It is stable in dry air but oxidizes and tarnishes under humid conditions. In the finely divided form it ignites and burns in air with an intense white light, which property determines some of its commercial uses.

Magnesium, as the chloride, is separated from brines by simple fractional crystallization, after the salt, NaCl , has been removed. It is precipitated as $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$, then dried to MgCl_2 , and finally electrolyzed to Mg , the metal, and Cl_2 , chlorine gas. Magnesium is used in instantaneous photography, in brightening fireworks and signal lights, and is an effective reducing agent at high temperatures. When combined with a small per cent of aluminum, it forms the alloy, Dowmetal, which is finding wide application on account of its lightness and strength compared to that of other materials. Dowmetal is especially suitable for castings, forgings, pistons, gear housings, blower impellers, connecting rods, and aircraft construction.

A number of the compounds of magnesium are of common utilization. In medicine, magnesium hydroxide, $\text{Mg}(\text{OH})_2$, is used as a mild alkali and magnesium sulphate, Epsom salts, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, as a laxative. Magnesium chloride, $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$, is employed in stucco and flooring cements; magnesium oxide, MgO , as a high temperature refractory; and magnesium arsenate, $\text{Mg}_3\text{As}_2\text{O}_8$, as an important insecticide for beans and strawberries.

STRONTIUM AND ITS COMPOUNDS

Small quantities of strontium, Sr , occur in most brines, the amount varying from 0.10 to 1.00 per cent of the total saline matter. It is

commonly precipitated from the bittern waters as strontium sulphate, SrSO_4 , which is then purified and converted into other forms. Only a few strontium salts find commercial application. The most important one is strontium nitrate, $\text{Sr}(\text{NO}_3)_2$, which is used for making red flames in pyrotechnics and signals.

OTHER COMPONENTS OF BRINES

Potassium, K, in the form of salts, occurs in all brines tested in Ohio. The quantity, however, is usually so small (from 0.20 to 0.80 per cent of the total saline matter) that it is not commercially profitable to separate it from the other salts. In most brines, iodine, I, is present but the quantity is not often more than a mere trace. Much the same is true of lithium, Li, barium, Ba, and manganese, Mn. Many brines from the limestone or dolomite formations are highly charged with hydrogen sulphide gas, H_2S , which escapes when the solution is exposed to the air. Common constituents of no value are silica, SiO_2 , alumina, Al_2O_3 , and iron salts.

TESTS OF BRINES AND SALT

Although the horizons or formations that yield brines in the deep-seated rocks of Ohio are large in number, not many of them are really important as providing material for industrial operations. The Geological Survey was able to sample to some extent most of those that give promise for utilization. This report on the brines, although far from complete, gives a fair idea as to the locations of the brine fields, as to the concentration, as to the depth below the surface, and as to the nature and amount of components in the saline matter. Samples 1 to 55 represent original work by the Geological Survey of Ohio during 1930 and 1931, whereas Samples 200 to 243 were gathered from various creditable sources.

MACKSBURG FIVE HUNDRED-FOOT SAND

The sample of brine from the Macksburg Five Hundred-foot sand, correlative with the Clarion member, in Noble County is of little interest commercially as it is of the ordinary common salt or sodium chloride type and is low in concentration. Additional samples may change this view somewhat, but at no place within the field in Washington, Noble, Morgan, and Monroe counties would the depth be sufficient to yield a brine of high density. Locally the flow of brine should be large as this sandstone maintains good thickness and continuity over wide areas.

Sample No. 213

Brines from the P. Vorhies No. 7 well, southwest Section 18, Center Township, Noble County; taken by the United States Geological Survey, December, 1915; Chase Palmer, analyst.¹

Brine from the Five Hundred-foot sand at depth of 420 feet. The well from which the sample was collected is one of a group of several shallow-sand wells that yielded small amounts of oil for a few years. In March, 1917, the well was not being pumped. The sample was clear when collected but a rusty yellow precipitate formed during the first twenty-four hours after the water was collected. On standing a few weeks this yellowish precipitate was replaced by a black precipitate of ferrous sulphide. It is not known whether the iron was originally present or was contributed by the iron pipe in the well, but it is evident that a soluble sulphide was present and that it reacted with the iron upon standing.

	Grams per liter	Composition of saline matter, ²
Cl.....	17.28	60.72
Br.....	.....	.....
SO ₄.....	.....	.....
CO ₃.....	.....	.....
HCO ₃	0.16	0.56
Na.....	9.81	34.47
K.....	.....	.....
Ca.....	0.89	3.13
Mg.....	0.32	1.12
(Al,Fe) ₂ O ₃	Present	.....
SiO ₂	Present	.....
	<hr/> 28.46	<hr/> 100.00

Reacting values, in milligram equivalents per liter

Ca.....	22.3
Mg.....	25.9
Na.....	426.4

Total basic radicles..... 474.6

HCO ₃	2.5
Cl.....	487.3

Total acid radicles..... 489.8

Reacting values, in per cent

Ca.....	2.3
Mg.....	2.6
Na.....	45.1
HCO ₃	0.2
Cl.....	49.8
	<hr/> 100.0

¹U. S. Geol. Survey, Bull. 693, pp. 34-35.

²Computed by Geol. Survey of Ohio.

Approximate percentage of principal salts

CaCl ₂	4.4
MgCl ₂	4.3
NaCl }.....	91.3
KCl }.....	
	100.0

MAXTON SAND

The few tests of brine from the Maxton sand, or Sharon conglomerate, indicate that these solutions are of the common salt type as the saline matter contains 75 per cent or more of sodium chloride. This brine also yields about 10 per cent of calcium chloride and 4 per cent of magnesium chloride. Locally for the depth the Maxton sand shows excellent concentration. As the deposits are massive in character and very open in texture, the flow of brine should be large. Although this sand is more or less local, it is most common in southern and eastern Ohio.

Sample No. 39

Brine from the Lydia Rowley No. 5 well (Kiggins No. 4), northeast Section 13, Scipio Township, Meigs County; taken by J. W. Cummins, Geological Survey of Ohio, August 30, 1931; Downs Schaaf, analyst.

Specific gravity, 1.08 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.01
Br.....	0.34
SO ₄	Trace
CO ₃	None
HCO ₃	0.003
Na.....	30.02
K.....	0.20
Ca.....	5.41
Mg.....	1.97
(Al,Fe) ₂ O ₃	0.044
SiO ₂	0.003
Sr.....	None
	100.000

Total dissolved solids.....	{	110.16 grams per liter
		102.0 grams per kilogram

Drillers Record

Sample of brine from depth of 474 feet. Elevation of well head, 778 feet.

	Top	Bottom
Red rock.....	100	146 •
Lime.....	146	150
Red rock.....	170	200
Lime.....	235	240
Red rock.....	240	265
Sand.....	265	278
Lime.....	304	307
Lime.....	347	352
Sand.....	359	383
Lime.....	403	412
Sand, <i>Maxton</i>	466	474
Sand.....	500	512
Sand.....	540	573
Sand.....	600	672
Sand.....	720	777

Sample No. 208

Brine from the David Bintz No. 1 well, near Monroefield, Section 33, Malaga Township, Monroe County; taken by United States Geological Survey, November, 1916; R. C. Wells, analyst.¹

Brine from Maxton sand at depth of 905 feet. Well drilled in August, 1912; sample collected in November, 1916.

Very dark green to black oil, containing brownish-yellow specks collected with the water. Rust-colored precipitate at bottom of bottle after standing 48 hours.

Specific gravity, 1.044.

	Grams per liter	Composition of saline matter ²
Cl.....	38.54	61.58
Br.....	0.16	0.26
SO ₄	None	None
CO ₂.....	.....	.....
HCO ₃	0.26	0.41
Na.....	19.50	31.15
K.....	0.23	0.37
Ca.....	2.89	4.62
Mg.....	0.80	1.28
(Al,Fe) ₂ O ₃	0.09	0.14
SiO ₂	0.05	0.08
Sr.....	0.07	0.11
	62.59	100.00

Total dissolved solids..... { 62.59 grams per liter
59.95 grams per kilogram

¹U. S. Geol. Survey, Bull. 693, pp. 34-35.

²Computed by Geol. Survey of Ohio.

Reacting values, in milligram equivalents per liter

Fe.....	None
Ca.....	144.3
Mg.....	65.8
Na.....	847.8
K.....	5.9
Sr.....	1.6
<hr/>	
Total basic radicles.....	1,065.4
HCO ₃	4.3
SO ₄	None
Cl.....	1,087.0
Br.....	2.0
<hr/>	
Total acid radicles.....	1,093.3

Reacting values, in per cent

Ca.....	6.6
Mg.....	3.1
Na.....	40.0
K.....	0.3
HCO ₃	0.2
Cl.....	49.7
Br.....	0.1
<hr/>	
	100.0

Approximate percentages of principal salts

CaCl ₂	12.7
MgCl ₂	5.0
NaCl.....	81.6
KCl.....	0.7
<hr/>	
	100.0

Drillers Record

	Top	Bottom
Coal.....	40	.....
Red rock.....	180	.....
Salt sand.....	805	.....
Maxton sand.....	905	.....
Lime sand.....	1,010	.....
<hr/>		
Total depth.....		1,023

MAXVILLE OR "BIG LIME" SAND

In Ohio the Maxville horizon has produced brines in only a few townships of Monroe County as elsewhere the formation is either absent or is too dense to act as a reservoir for such accumulations. These brines are similar in character to others found in the shallow Pennsylvanian and Mississippian systems, that is, they are rich in sodium chloride and are of a density corresponding to the depth.

Sample No. 204

Brine from the Egger Bros. No. 1 well, near Miltonsburg, Section 10, Malaga Township, Monroe County; taken by the United States Geological Survey, September, 1916; R. C. Wells, analyst.¹

Brine from the "Big Lime" or Maxville sand at depth of 1,339 to 1,349 feet. Well completed in January, 1916; sample collected in September, 1916. Gas well, initial open-flow production 1,500,000 cubic feet a day; initial gas pressure 360 pounds to the square inch. Production of water 1½ barrels a week. Black deposit on inside of bottle in air space just above water, also dirty gray flocculent precipitate floating at top of water and a somewhat lighter-colored gray flocculent precipitate at bottom of bottle. No oil was present.

Specific gravity, 1.056.

	Grams per liter	Composition of saline matter, ²
Cl.....	50.33	61.62
Br.....	0.15	0.17
SO ₄	None	None
CO ₂.....	.....	.....
HCO ₃	0.32	0.39
Na.....	23.85	29.20
K.....	0.25	0.31
Ca.....	5.58	6.83
Mg.....	1.03	1.26
(Al,Fe) ₂ O ₃	0.11	0.14
SiO ₂	0.02	0.03
Sr.....	0.04	0.05
	81.68	100.00

Total dissolved solids..... { 81.68 grams per liter
77.35 grams per kilogram

Reacting values, in milligram equivalents per liter

Fe.....	3.0
Ca.....	278.6
Mg.....	84.8
Na.....	1,037.0
K.....	6.4
Sr.....	0.9

Total basic radicles..... 1,410.7

HCO ₃	5.3
SO ₄	None
Cl.....	1,419.0
Br.....	1.9

Total acid radicles..... 1,426.2

¹U. S. Geol. Survey, Bull. 693, pp. 34-35.

²Computed by Geol. Survey of Ohio.

Reacting values, in per cent

Fe.....	0.1
Ca.....	9.8
Mg.....	3.0
Na.....	36.9
K.....	0.2
HCO ₃	0.2
Cl.....	49.8
	100.0

Approximate percentage of principal salts

CaCl ₂	18.9
MgCl ₂	4.9
NaCl.....	75.6
KCl.....	0.6
	100.0

Drillers Record

	Top	Bottom
"Big Lime" or Maxville sand.....	1,339	1,349
Keener sand.....	1,408	1,422
Berea sand.....	1,986	1,991
Total depth.....		2,000

Sample No. 202

Brine from the F. K. Mellotte No. 5 well, northeast Section 30, Malaga Township, Monroe County; taken by the United States Geological Survey, April 24, 1915; S. C. Dinsmore, analyst.¹

Brine from "Big Lime" or Maxville sand at depth of 1,431 to 1,444 feet. Specific gravity, 1.102 (calculated from salt content).

	Grams per liter	Composition of saline matter, ²
Cl.....	87.50	61.93
Br.....		
SO ₄	None	None
CO ₂		
HCO ₃	0.03	0.02
Na.....	39.27	27.79
K.....	0.70	0.50
Ca.....	11.56	8.18
Mg.....	1.83	1.30
(Al.Fe) ₂ O ₃	0.31	0.22
SiO ₂	0.09	0.06
Sr.....		
	141.29	100.00

Total dissolved solids..... { 141.29 grams per liter
128.21 grams per kilogram

¹U. S. Geol. Survey, Bull. 693, pp. 34-35.
²Computed by Geol. Survey of Ohio.

Reacting values, in milligram equivalents per liter

Fe.....	0.6
Ca.....	577.9
Mg.....	150.6
Na.....	1,707.0
K.....	17.8
<hr/>	
Total basic radicles.....	2,453.9
HCO ₃	1.0
SO ₄	None
Cl.....	2,468.0
Br.....	
<hr/>	
Total acid radicles.....	2,469.0

Reacting values, in per cent

Fe.....	
Ca.....	11.8
Mg.....	3.0
Na.....	34.8
K.....	0.4
HCO ₃	
Cl.....	50.0
Br.....	
<hr/>	
	100.0

Approximate percentages of principal salts

CaCl ₂	22.7
MgCl ₂	5.1
NaCl.....	71.3
KCl.....	0.9
<hr/>	
	100.0

KEENER SAND

The Keener sand, conforming to the rock structure, yields strong flows of brine in Monroe, Belmont, Noble, Guernsey, Washington, Morgan, and Athens counties. The concentration is somewhat erratic but on the whole about normal for the depth, the maximum of which is approximately 2,000 feet near the Ohio River in Monroe County. Considered in terms of salts, the saline matter contains about 73 per cent sodium chloride, 21 per cent calcium chloride, 5 per cent magnesium chloride, and small quantities of various other compounds.

Brines from the Keener formation have possibilities both for salt making and for the chemical industries as the quantity available is large, as the concentration is fair, and as productive fields may be secured along the Ohio River, which location is favorable for fuel and transportation.

Sample No. 212

Brine from the Mancel Secrest No. 2 well, one and one-fourth miles southeast of Chaseville, southwest Section 19, Seneca Township, Noble County; taken by United States Geological Survey, May 1, 1915; S. C. Dinsmore, analyst.¹

Brine from Keener sand at depth of 870 to 880 feet.

	Grams per liter	Composition of saline matter,
Cl.....	97.96	61.27
Br.....	.....	.....
SO ₄	None	None
CO ₂.....	.....	.....
HCO ₃	0.04	0.03
Na.....	43.40	27.14
K.....	2.47	1.54
Ca.....	12.98	8.12
Mg.....	1.69	1.06
(Al.Fe) ₂ O ₃	1.20	0.75
SiO ₂	0.14	0.09
Sr.....	.....	.....
	<hr/> 159.88	<hr/> 100.00

Total dissolved solids, 159.88 grams per liter.

Reacting values, in milligram equivalents per liter

Fe.....	0.6
Ca.....	648.0
Mg.....	139.5
Na.....	1,887.0
K.....	63.0
Sr.....	.....
	<hr/> Total basic radicles..... 2,738.1
HCO ₃	0.6
SO ₄	None
Cl.....	2,763.0
Br.....	.....
	<hr/> Total acid radicles..... 2,763.6

Reacting values, in per cent

Sr.....	.....
Ca.....	11.7
Mg.....	2.5
Na.....	34.7
K.....	1.1
HCO ₃.....	.....
Cl.....	50.0
	<hr/> 100.0

¹U. S. Geol. Survey, Bull. 693, p. 36.
*Computed by Geol. Survey of Ohio.

Approximate percentages of principal salts

CaCl ₂	22.6
MgCl ₂	4.1
NaCl.....	70.3
KCl.....	3.0
	100.0

*Drillers Record**(Approximates Secrest No. 1)*

	Top	Bottom
Surface.....	0	60
Ames limestone.....	60	64
Shale.....	64	100
Sand.....	100	160
Shale.....	160	280
Sand.....	280	380 Water at 330
Coal marker at.....	380	.....
Shale.....	380	680
Sand.....	680	710
Shale.....	710	770
Sand.....	770	845
Shale.....	845	870
Keener sand.....	870	886

Sample No. 207

Brine from the C. J. Clause No. 4 well, Section 27, Malaga Township, Monroe County; taken by the United States Geological Survey, November 7, 1916; R. C. Wells, analyst¹

Brine from Keener sand at depth of 1,302 feet. Well drilled in July, 1913; sample collected November 7, 1916. Dull amber-colored oil was collected with the water. The water was clear when collected, but a reddish rusty precipitate settled at the bottom of the bottle within 24 hours.

Specific gravity, 1.043.

	Grams per liter	Composition of saline matter ₂
Cl.....	38.89	61.50
Br.....	0.11	0.17
SO ₄	None	None
CO ₂.....	.....	.....
HCO ₃	0.17	0.27
Na.....	19.85	31.39
K.....	0.23	0.36
Ca.....	2.98	4.71
Mg.....	0.82	1.30
(Al.Fe) ₂ O ₃	0.06	0.09
SiO ₂	0.05	0.08
Sr.....	0.08	0.13
	63.24	100.00
Total dissolved solids.....	{ 63.24 grams per liter { 60.63 grams per kilogram	

¹U. S. Geol. Survey, Bull. 693, p. 36.

²Computed by Geol. Survey of Ohio.

Reacting values, in milligram equivalents per liter

Fe.....	Trace
Ca.....	148.8
Mg.....	67.5
Na.....	863.1
K.....	5.9
Sr.....	1.9
<hr/>	
Total basic radicles.....	1,087.2
HCO ₃	2.8
SO ₄	None
Cl.....	1,097.0
Br.....	1.4
<hr/>	
Total acid radicles.....	1,101.2

Reacting values, in per cent

Sr.....	0.1
Ca.....	6.7
Mg.....	3.1
Na.....	39.8
K.....	0.3
HCO ₃	0.1
Cl.....	49.9
<hr/>	
	100.0

Approximate percentages of principal salts

CaCl ₂	13.2
MgCl ₂	5.1
NaCl.....	81.0
KCl.....	0.7
<hr/>	
	100.0

Drillers Record

		Top	Bottom
Sand, hard } Keener.....		1,302	1,303
Sand, pay }		1,303	1,308

Sample No. 205, A and B

Brine from the Schroeder heirs No. 1 well, one and one-fourth miles south of Miltonsburg, northwest Section 9, Malaga Township, Monroe County; A taken April 24, 1915, and B, September, 1916; S. C. Dinsmore and Chase Palmer, analysts.¹

Brine from Keener sand. Depth of sand 1,465 to 1,471 feet. Well was the first in the field and was drilled in March, 1915.

¹U. S. Geol. Survey, Bull. 693, p. 36.

BRINES OF OHIO

	A		B	
	Grams per liter	Composition of saline matter ¹	Grams per liter	Composition of saline matter ¹
Cl.....	48.46	60.99	64.10	61.79
Br.....	.....	.....	.....	.....
SO ₄	None	None	None	None
CO ₃.....	.....	.....	.....	.....
HCO ₃	0.08	0.10	0.03	0.03
Na.....	22.84	28.75	29.74	28.67
K.....	0.60	0.76	.....	.....
Ca.....	5.68	7.15	8.34	8.04
Mg.....	1.04	1.31	1.48	1.43
(Al,Fe) ₂ O ₃	0.67	0.84	.....	.....
SiO ₂	0.08	0.10	0.04	0.04
Sr.....	.....	.....	.....	.....
	<hr/>	<hr/>	<hr/>	<hr/>
	79.45	100.00	103.73	100.00
Total dissolved solids.....	{ A 79.45 grams per liter { B 103.73 grams per liter			

Reacting values, in milligram equivalents per liter

	A	B
Fe.....	0.4	.....
Ca.....	283.9	416.0
Mg.....	85.5	122.0
Na.....	993.0	1,293.0
K.....	15.0	.....
Sr.....	.....	.....
Total basic radicles.....	1,377.8	1,831.0
HCO ₃	1.0	Trace
SO ₄	None	None
Cl.....	1,367.0	1,808.0
Br.....	.....	.....
Total acid radicles.....	1,368.0	1,808.0

Reacting values, in per cent

	A	B
Sr.....	.....	.....
Ca.....	10.4	11.5
Mg.....	3.1	3.4
Na.....	36.0	35.1
K.....	0.5	.....
HCO ₃.....	.....	.....
Cl.....	50.0	50.0
	<hr/>	<hr/>
	100.00	100.0

¹Computed by Geol. Survey of Ohio.

Approximate percentages of principal salts

	A	B
CaCl ₂	20.2	22.5
MgCl ₂	5.2	5.6
NaCl.....	73.2	71.9
KCl.....	1.4	.....
	100.0	100.0

Sample No. 206

Brine from the Adolph H. Clause No. 1 well, near Miltonsburg, northeast quarter Section 10, Malaga Township, Monroe County; taken by the United States Geological Survey, September, 1916; Chase Palmer, analyst.¹

Gas well in Keener sand. Completed February 18, 1916. Sample brine collected in September, 1916. In this well the Keener sand is approximately 1,400 feet in depth.

	Grams per liter	Composition of saline matter ₂
Cl.....	62.48	62.04
Br.....	.....	.....
SO ₄.....	.....	.....
CO ₂.....	.....	.....
HCO ₃	0.03	0.03
Na.....	28.76	28.56
K.....	.....	.....
Ca.....	8.02	7.96
Mg.....	1.42	1.41
(Al.Fe) ₂ O ₃.....	.....	.....
SiO ₂.....	.....	.....
Sr.....	.....	.....
	100.71	100.00

Total dissolved solids, 100.71 grams per liter.

Reacting values, in milligram equivalents per liter

Fe.....	.....
Ca.....	400.3
Mg.....	116.9
Na.....	1,250.0
K.....	.....
Sr.....	.....
Total basic radicles.....	1,767.2
HCO ₃	0.6
SO ₄	1,762.0
Cl.....	.....
Br.....	.....
Total acid radicles.....	1,762.6

¹U. S. Geol. Survey, Bull. 693, p. 36.

²Computed by Geol. Survey of Ohio.

Reacting values, in per cent

Sr.....	.....
Ca.....	11.3
Mg.....	3.3
Na.....	35.4
K.....	.....
HCO ₃.....	.....
Cl.....	50.0
	<hr/>
	100.0

Approximate percentages of principal salts

CaCl ₂	22.0
MgCl ₂	5.6
NaCl.....	72.4
KCl.....	.....
	<hr/>
	100.0

Sample No. 203, A and B

Brine from the J. R. Scott No. 2 well, one-half mile southeast of Jerusalem, northeast quarter Section 23, Sunbury Township, Monroe County; taken by the United States Geological Survey, A, April 24, 1915, and B, August, 1916; Chase Palmer, analyst.¹

Brine from Keener sand of an old oil well drilled in 1904. This well is reported to have flowed and sprayed oil at the rate of 350 barrels a day with very little water at first. In June, 1916, it was yielding daily 2 barrels of oil together with 5 barrels of water.

	A		B	
	Grams per liter	Composition of saline matter ₂	Grams per liter	Composition of saline matter ₂
Cl.....	84.71	61.51	83.88	61.80
Br.....	.....	.....	.....	.....
SO ₄	None	None	.....	.....
CO ₂.....	.....	.....	.....	.....
HCO ₃	0.03	0.02	0.04	0.03
Na.....	38.32	27.83	38.64	28.47
K.....	0.51	0.37	.....	.....
Ca.....	11.36	8.25	11.20	8.25
Mg.....	1.63	1.18	1.82	1.34
(Al.Fe) ₂ O ₃ ..	1.07	0.78	0.08	0.06
SiO ₂	0.08	0.06	0.06	0.05
Sr.....	.....	.....	.....	.....
	<hr/>	<hr/>	<hr/>	<hr/>
	137.71	100.00	135.72	100.00

¹U. S. Geol. Survey, Bull. 693, pp. 34-36.

²Computed by Geol. Survey of Ohio.

Reacting values, in milligram equivalents per liter

	A	B
Fe.....	0.5	.....
Ca.....	567.8	559.2
Mg.....	134.0	149.7
Na.....	1,666.0	1,680.0
K.....	13.0	.....
Sr.....	.....	.....
Total basic radicles.....	2,381.3	2,388.9
HCO ₃	1.0	0.7
SO ₄	None	.....
Cl.....	2,389.0	2,366.0
Br.....	.....	.....
Total acid radicles.....	2,390.0	2,366.7

Reacting values, in per cent

	A	B
Fe.....	.....	.....
Ca.....	11.9	11.8
Mg.....	2.8	3.2
Na.....	35.0	35.0
K.....	0.3	.....
HCO ₃.....	.....	.....
Cl.....	50.0	50.0
Br.....	.....	.....
	100.0	100.0

Approximate percentages of principal salts

	A	B
CaCl ₂	23.0	23.0
MgCl ₂	4.7	5.3
NaCl.....	71.6	71.7
KCl.....	0.7	.....
	100.0	100.0

Drillers Record

	Top	Bottom
Coal, <i>Pittsburgh</i>	415	.....
Sand, <i>First Cow Run</i>	600	.....
Sand, <i>Second Cow Run</i>	800	.....
Sand, <i>Keener</i>	1,451	1,469

BIG INJUN SAND

The Big Injun or Black Hand sand yields exceptionally large flows of brine as the formation is massive in character, coarse and often pebbly in texture, and persistent over rather wide areas in Belmont, Monroe, Washington, Noble, Guernsey, Morgan, Muskingum, Vinton, Athens,

and Meigs counties. These brines differ little in character from those in the Keener formation, both belonging to the common salt type. Big Injun brines have been the main reliance for salt making at Pomeroy for many years, the commercial products being salt, calcium chloride, and bromine. The conditions for utilization appear to be equally good in other areas.

Sample No. 221, A and B

Brines from the Coal Ridge Salt Company at the east end of Pomeroy, Salisbury Township, Meigs County; A taken by W. J. Root, about 1888, and B by C. W. Foulk, about 1905.¹

A

Analysis by W. J. Root in 1888.

Specific gravity, 1.0713.

Composition of brine

Water.....	90.472
Total solids.....	9.528
	100.000

Percentage of principal salts

NaCl.....	79.273
CaCl ₂	14.397
MgCl ₂	6.097
MgBr ₂.....	.097
NaI.....	.012
SiO ₂.....	.043
(Al.Fe) ₂ O ₃.....	.082
	100.001

Composition of saline matter

Cl.....	61.82
Br.....	.09
SO ₄	
CO ₃	
HCO ₃	
Na.....	31.19
K.....	
Ca.....	5.20
Mg.....	1.57
(Al.Fe) ₂ O ₃.....	.08
SiO ₂.....	.04
Sr.....	
I.....	.01
	100.00

Total dissolved solids..... { 102.07 grams per liter
95.28 grams per kilogram

¹Geol. Survey Ohio, A, Vol. VI, pp. 62-63; and B, Bull. 8, pp. 20-27.

B

Analysis by C. W. Foulk in 1905.

Specific gravity, 1.075.

Grams per liter

SiO ₂.....	.012
(Al.Fe) ₂ O ₃.....	.083
CaCl ₂	14.340
MgCl ₂	5.590
MgBr ₂.....	.155
SrCl ₂.....	.257
BaCl ₂.....	.343
NaCl.....	84.300
NaI.....	.004
Na ₂ SO ₄.....	.000
KCl.....	.114
Li.....	Trace
	<hr/>
	105.198

Composition of saline matter

Cl.....	61.546
Br.....	.128
SO ₄.....	.000
CO ₂.....	.....
HCO ₃.....	.....
Na.....	31.528
K.....	.057
Ca.....	4.921
Mg.....	1.377
(Al.Fe) ₂ O ₃.....	.079
SiO ₂.....	.011
Sr.....	.135
I.....	.003
Li.....	Trace
Ba.....	.215
	<hr/>
	100.000

Total dissolved solids..... { 105.198 grams per liter
 { 97.859 grams per kilogram

Drillers Record

	Top	Bottom
Surface.....	0	58
Shale.....	58	550
Sand, white and gray.....	550	870
Sand, white, with shale.....	870	960
Sand, <i>Big Injun</i>	960	1,130 Main brine used
Sand and light shale.....	1,130	1,495
Shales.....	1,495	1,545
Sand, <i>Berea</i>	1,545	1,570 With some brine
Shales.....	1,570	1,590

Sample No. 216

Brine from the Henry Moore No. 1 well, near Summerfield, southwest Section 28, Marion Township, Noble County; taken by the United States Geological Survey, April 27, 1915; S. C. Dinsmore, analyst.¹

Brine from Big Injun sand at depth of 1,200 feet.

	Grams per liter	Composition of saline matter, ²
Cl.....	102.14	61.77
Br.....	.....	.....
SO ₄	None	None
CO ₂.....	.....	.....
HCO ₃	0.02	0.01
Na.....	45.88	27.75
K.....	0.35	0.21
Ca.....	12.22	7.39
Mg.....	2.89	1.75
(Al.Fe) ₂ O ₃	1.16	0.70
SiO ₂	0.70	0.42
Sr.....	.....	.....
	165.36	100.00

Total dissolved solids, 165.36 grams per liter.

Reacting values, in milligram equivalents per liter

Fe.....	0.6
Ca.....	610.1
Mg.....	236.6
Na.....	1,995.0
K.....	9.0
Total basic radicles.....	2,851.3
HCO ₃	0.3
SO ₄	None
Cl.....	2,881.0
Total acid radicles.....	2,881.3

Reacting values, in per cent

Ca.....	10.6
Mg.....	4.1
Na.....	35.1
K.....	0.2
Cl.....	50.0
	100.0

¹U. S. Geol. Survey, Bull. 693, p. 37.

²Computed by Geol. Survey of Ohio.

Approximate percentages of principal salts

CaCl ₂	20.8
MgCl ₂	6.9
NaCl.....	71.9
KCl.....	0.4
	100.0

Sample No. 210

Brine from the Fiel No. 2 well, operated by E. A. Bradley, central Section 23, Jackson Township, Monroe County; taken by the United States Geological Survey, about 1916; S. C. Dinsmore, analyst.¹

Brine from Big Injun sand at depth of 1,355 feet. Produced 3 barrels water per day

	Grams per liter	Composition of saline matter ₂
Cl.....	74.38	62.01
Br.....		
SO ₄	None	None
CO ₂		
HCO ₃	0.01	0.01
Na }.....	33.47	27.90
K }		
Ca.....	10.24	8.54
Mg.....	1.63	1.36
(Al.Fe) ₂ O ₃	0.03	0.02
SiO ₂	0.19	0.16
Sr.....		
	119.95	100.00

Total dissolved solids, 119.95 grams per liter.

Reacting values, in milligram equivalents per liter

Fe.....	1.0
Ca.....	511.0
Mg.....	134.0
Na.....	1,455.0
K.....	
Total basic radicles.....	2,101.0
HCO ₃	
SO ₄	None
Cl.....	2,097.0
Total acid radicles.....	2,097.0

¹U. S. Geol. Survey, Bull. 693, p. 37, and Frank Reeves in Economic Geology, Vol. 12, p. 374. 1917.

²Computed by Geol. Survey of Ohio.

Reacting values, in per cent

Ca.....	12.2
Mg.....	3.2
Na.....	34.6
K.....	
Cl.....	50.0
	<hr/>
	100.0

Approximate percentages of principal salts

CaCl ₂	23.7
MgCl ₂	5.3
NaCl.....	71.0
KCl.....	
	<hr/>
	100.0

BEREA SAND

The Berea sand, widely distributed throughout eastern and south-eastern Ohio, is a consistent producer of brine except where structural relief is such as to impede its migration. As the stone is rather fine in texture and high in bonding components and as the beds are separated by shale partings, the flow of brine is usually not large although the deposits may be completely saturated. The yield from a small field, however, would be ample for industrial purposes. Neither the concentration nor the composition of Berea brines is unusual. They are rich in sodium chloride, this salt making up about 73 per cent of the total saline matter. Other common components are calcium chloride, magnesium chloride, and bromine salts. Brines from the Berea formation were utilized in the early days of salt making in Ohio at many places from Columbiana to Gallia counties.

Sample No. 20

Brine from the Charles Zeigler No. 2 well, held by a local company from Portsmouth, in Houston Hollow, Section 9, Jefferson Township, Scioto County; taken by W. M. Knight of Portsmouth, March, 1931; Downs Schaaf, Geological Survey of Ohio, analyst.

Specific gravity, 1.078 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.78
Br.....	0.47
SO ₄	0.05
CO ₂	None
HCO ₃	0.02
Na.....	22.86
K.....	0.20

Ca.....	10.80
Mg.....	2.65
(Al.Fe) ₂ O ₃	0.15
SiO ₂	0.02
Sr.....	
	100.00

Total dissolved solids..... { 110.0 grams per liter
102.0 grams per kilogram

Drillers Record

Elevation of well head, 655 feet.

	Top	Bottom
<i>Berea</i> sand.....	256	315
Total depth.....		339

Pumps about one-inch stream of brine regularly. Water 8 feet in sand or at 264 feet.

Sample No. 41

Brine from the Jacob Krider No. 4 well of the Pure Oil Company, southwest Section 20, Sutton Township, Meigs County; taken by J. W. Cummins, Geological Survey of Ohio, September 8, 1931; Downs Schaaf, analyst.

Specific gravity, 1.115 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	61.86
Br.....	0.30
SO ₄	None
CO ₃	None
HCO ₃	None
Na.....	29.07
K.....	0.08
Ca.....	6.56
Mg.....	2.01
(Al.Fe) ₂ O ₃	0.11
SiO ₂	0.01
Sr.....	Trace
	100.00

Total dissolved solids..... { 151.0 grams per liter
135.0 grams per kilogram

Drillers Record

Sample from bottom of Berea sand at 1,816 feet.

	Top	Bottom
Surface.....	0	23
Lime.....	23	35
Slate and shells.....	35	227
Sand.....	227	257
Coal, <i>Pomeroy</i>	257	262
Slate.....	262	300
Lime.....	300	315
Slate and shells.....	315	360
Red shale.....	360	420
Slate and shells.....	420	460
Red shale.....	460	480
Slate and shells.....	480	500
Red shale.....	500	540
Slate and shells.....	540	570
Red shale.....	570	580
Lime shells.....	580	600
Slate.....	600	620
Lime.....	620	640
Slate.....	640	685
Red shale.....	685	700
Slate and shells.....	700	785
<i>Cow Run</i> sand.....	785	805
Slate and shells.....	805	880
Sand.....	880	905
Slate and shells.....	905	980
Sand.....	980	1,110
Lime.....	1,110	1,135
Sand.....	1,135	1,150
Slate.....	1,150	1,160
Sand.....	1,160	1,210
Lime.....	1,210	1,255
Slate.....	1,255	1,265
<i>Big Injun</i> sand.....	1,265	1,285
Slate.....	1,285	1,295
Sand.....	1,295	1,315
Slate.....	1,315	1,325
Lime.....	1,325	1,345
Slate and shells.....	1,345	1,412
Lime shells.....	1,412	1,418
Slate and shells.....	1,418	1,790
<i>Coffee</i> slate.....	1,790	1,802½
<i>Berea</i> sand.....	1,802½	1,816
Total depth.....		1,822½

Sample No. 215

Brine from the R. P. Gulic No. 2 well, one mile west of Summerfield, north central Section 13, Marion Township, Noble County; taken by

the United States Geological Survey, April 28, 1915; S. C. Dinsmore, analyst.¹

Brine from Berea sand at depth of 1,748 to 1,760 feet.

	Grams per liter	Composition of saline matter, ²
Cl.....	32.07	60.03
Br.....		
SO ₄	None	None
CO ₃		
HCO ₃	0.37	0.69
Na.....	15.85	29.67
K.....	0.51	0.96
Ca.....	2.75	5.15
Mg.....	0.86	1.61
(Al.Fe) ₂ O ₃	0.79	1.48
SiO ₂	0.22	0.41
Sr.....		
	53.42	100.00

Total dissolved solids, 53.42 grams per liter.

Reacting values, in milligram equivalents per liter

Fe.....	2.0
Ca.....	137.3
Mg.....	71.0
Na.....	689.1
K.....	13.0
Total basic radicles.....	912.4
HCO ₃	6.1
SO ₄	None
Cl.....	904.4
Total acid radicles.....	910.5

Reacting values, in per cent

Fe.....	0.1
Ca.....	7.5
Mg.....	3.9
Na.....	37.8
K.....	0.7
HCO ₃	0.3
Cl.....	49.7
	100.0

Approximate percentages of principal salts

CaCl ₂	14.6
MgCl ₂	6.5
NaCl.....	77.1
KCl.....	1.8
	100.0

¹U. S. Geol. Survey, Bull. 693, p. 38.
²Computed by Geol. Survey of Ohio.

Sample No. 214

Brine from the S. L. Murphy No. 2 well, near Chaseville, southwest Section 18, Seneca Township, Noble County; taken by United States Geological Survey, April 30, 1915; S. C. Dinsmore, analyst.¹

Brine from Berea sand at depth of 1,570 to 1,592 feet.

	Grams per liter	Composition of saline matter ₂
Cl.....	38.69	60.81
Br.....	.....	.....
SO ₄	None	None
CO ₂.....	.....	.....
HCO ₃	0.05	0.08
Na.....	19.49	30.63
K.....	0.50	0.79
Ca.....	2.79	4.39
Mg.....	1.01	1.59
(Al.Fe) ₂ O ₃	0.95	1.49
SiO ₂	0.14	0.22
Sr.....	.....	.....
	63.62	100.00

Total dissolved solids, 63.62 grams per liter.

Reacting values, in milligram equivalents per liter

Fe.....	0.3
Ca.....	139.3
Mg.....	83.0
Na.....	847.4
K.....	13.0
Total basic radicles.....	1,083.0
HCO ₃	0.8
SO ₄	None
Cl.....	1,091.0
Total acid radicles.....	1,091.8

Reacting values, in per cent

Fe.....	.....
Ca.....	6.4
Mg.....	3.8
Na.....	39.2
K.....	0.6
HCO ₃.....	.....
Cl.....	50.0
	100.0

¹U. S. Geol. Survey, Bull. 693, p. 38.

*Computed by Geol. Survey of Ohio.

Approximate percentages of principal salts

CaCl ₂	12.3
MgCl ₂	6.3
NaCl.....	79.9
KCl.....	1.5
	100.0

Drillers Record

	Top	Bottom
Berea sand.....	1,570	1,592
Total depth.....		1,593

Sample No. 209

Brine from the Taylor heirs No. 4 well, (Joel Taylor), two miles east of Woodsfield, east central Section 18, Center Township, Monroe County; taken by United States Geological Survey, July 25, 1916; Chase Palmer, analyst.¹

Brine from Berea sand at depth of 2,141 to 2,162 feet. This well had been yielding oil and salt water since 1905.

Specific gravity, 1.06.

	Grams per liter	Composition of saline matter ₂
Cl.....	55.46	61.73
Br.....	.....	.....
SO ₄	None	None
CO ₂.....	.....	.....
HCO ₃	0.06	0.07
Na.....	25.82	28.74
K.....	.....	.....
Ca.....	7.34	8.17
Mg.....	1.16	1.29
(Al,Fe) ₂ O ₃.....	.....	.....
SiO ₂.....	.....	.....
Sr.....	.....	.....
	89.84	100.00
Total dissolved solids.....	{ 89.84 grams per liter 84.75 grams per kilogram	

Reacting values, in milligram equivalents per liter

Fe.....	.....
Ca.....	366.5
Mg.....	95.5
Na.....	1,123.0
K.....	.....
	1,585.0

¹U. S. Geol. Survey, Bull. 693, p. 38.
²Computed by Geol. Survey of Ohio.

HCO ₃	0.9
SO ₄	None
Cl.....	1,564.0
Total acid radicles.....	1,564.9

Reacting values, in per cent

Fe.....	
Ca.....	11.7
Mg.....	3.1
Na.....	35.2
K.....	
HCO ₃	
Cl.....	50.0
	100.0

Approximate percentages of principal salts

CaCl ₂	23.1
MgCl ₂	5.1
NaCl }.....	71.8
KCl }.....	
	100.0

Sample No. 211

Brine from the J. A. Adams No. 1 well, one-half mile west of Barnesville, Section 21, Warren Township, Belmont County; taken by the United States Geological Survey, July 24, 1916; Chase Palmer, analyst.¹

Brine from Berea sand at depth of 1,727 to 1,740 feet. The well was yielding 48 barrels of oil and 8 barrels of salt water a month when visited in June, 1916. The initial yield of oil from the well 20 years prior to this was about 180 barrels of oil per month.

Specific gravity, 1.08.

	Grams per liter	Composition of saline matter, ²
Cl.....	72.60	62.23
Br.....		
SO ₄	None	None
CO ₂		
HCO ₃	0.02	0.02
Na.....	32.66	28.00
K.....		
Ca.....	9.24	7.92
Mg.....	2.06	1.76
(Al.Fe) ₂ O ₃		
SiO ₂	0.08	0.07
Sr.....		
	116.66	100.00
Total dissolved solids.....		{ 116.66 grams per liter 108.02 grams per kilogram

¹U. S. Geol. Survey, Bull. 693, p. 38.

²Computed by Geol. Survey of Ohio.

Reacting values, in milligram equivalents per liter

Fe.....	.....
Ca.....	461.3
Mg.....	169.6
Na.....	1,420.0
K.....	.....
<hr/>	
Total basic radicles.....	2,050.9
HCO ₃	0.4
SO ₄	None
Cl.....	2,047.0
<hr/>	
Total acid radicles.....	2,047.4

Reacting values, in per cent

Fe.....	.....
Ca.....	11.3
Mg.....	4.1
Na.....	34.6
K.....	.....
HCO ₃.....	.....
Cl.....	50.0
<hr/>	
	100.0

Approximate percentages of principal salts

CaCl ₂	21.8
MgCl ₂	6.9
NaCl }.....	71.3
KCl }.....	.....
<hr/>	
	100.0

Sample No. 222

Brine from the Dover furnace of Hilt and Shields, two miles east of Dover and on the canal, Dover Township, Tuscarawas County; taken by W. J. Root, Geological Survey of Ohio, about 1888; W. J. Root, analyst.¹

Specific gravity, 1.0732.

Composition of brine

Water.....	89.545
Total solids.....	10.455
<hr/>	
	100.000

Percentages of principal salts

NaCl.....	71.645
CaCl ₂	18.665
MgCl ₂	9.286
MgBr ₂.....	.271
NaI.....	.013
SiO ₂.....	.024
(Al.Fe) ₂ O ₃.....	.096
<hr/>	
	100.000

¹Geol. Survey Ohio, Vol. VI, pp. 662-3.

Composition of saline matter

Cl.....	62.299
Br.....	.235
SO ₄	
CO ₂	
HCO ₃	
Na.....	28.189
K.....	
Ca.....	6.739
Mg.....	2.407
(Al.Fe) ₂ O ₃.....	.096
SiO ₂.....	.024
Sr.....	
I.....	.011
	100.000

Total dissolved solids..... { 112.20 grams per liter
 { 104.55 grams per kilogram

Drillers Record

	Top	Bottom
Shales and sandstones, <i>coal formations</i> ..	0	235
Shales, sandstones, and conglomerates, <i>Logan group</i>	235	430
<i>Shales, Cuyahoga group</i>	430	849
<i>Shale, black, Sunbury</i>	849	860
<i>Sandstone, Berea</i>	860	886

Sample No. 217

Brine from the Jacob Bowman No. 2 well, drilled by O. Evans Mikesell, in southwest quarter of the northeast quarter of Section 35, Canton Township, Stark County; taken by O. Evans Mikesell, July 12, 1921; analyzed by C. S. Howard of the Water Resources Branch, United States Geological Survey.¹

Brine from well 930 feet in depth in Canton-Osnaburg oil field. Water at 871 feet.

	Principal salts, parts per thousand	Composition of saline matter
Cl.....	47.25	61.688
Br.....	.38	.496
SO ₄.....	.014	.018
CO ₂.....	.000	.000
HCO ₃.....	.060	.078
Na.....	23.03	30.067
K.....		
Ca.....	4.37	5.705
Mg.....	1.45	1.893
(Al.Fe) ₂ O ₃.....	.027	.035

¹Published by permission of the U. S. Geol. Survey.

SiO ₂.....	.009	.012
Sr.....	.....	.....
I.....	.006	.008
	76.596	100.000

Total dissolved solids at 180° C., 78.47 grams per kilogram.

Drillers Record

	Top	Bottom
Clay, soft.....	1	20
Soft blue shale.....	20	56
Coal.....	56	60
Soft blue shale.....	60	145 Fresh water at 70 feet.
Hard gray lime.....	145	148
Coal.....	148	152
Soft light shale.....	152	252
Soft gray sand.....	252	320
Soft light shale.....	320	435
Medium light sand.....	435	500
Soft light shale.....	500	520
Soft light sand.....	520	540 Fresh water at 525 feet.
Soft light shale.....	540	550
Medium gray sand.....	550	565
Soft blue shale.....	565	615
Medium gray sand.....	615	635 Show of gas.
Soft blue shale.....	635	775
Medium gray sand.....	775	795
Soft blue shale.....	795	829
Medium light sand	829	834 Show of gas and oil
Medium light sand	834	857 Shale break, below good showing of oil and large flow of salt water.
	<i>Berea</i>	
Soft light sand	857	930 Water from 857 to 930 feet.

Sample No. 218

Brine from the Otis Eaton No. 1 well, drilled by O. Evans Mikesell in Section 30, Osnaburg Township, Stark County; taken by O. Evans Mikesell, April 26, 1921; analyzed by C. S. Howard, Water Resources Branch, United States Geological Survey.¹

Sample of brine from a depth of 835 feet in a test well in the Canton-Osnaburg oil field.

¹Published by permission of the U. S. Geol. Survey.

Parts per thousand

SiO ₂	0.013
Fe.....	0.005
Ca.....	4.81
Mg.....	1.46
NaK.....	24.46
CO ₂	0.00
HCO ₃	0.076
SO ₄	0.008
Cl.....	50.44
NO ₃	Trace
Br.....	0.189
I.....	0.016
	<hr/>
	81.477

Composition of saline matter

Cl.....	61.907
Br.....	0.232
SO ₄	0.010
CO ₂	0.000
HCO ₃	0.093
Na.....	29.922
K.....	0.098
Ca.....	5.904
Mg.....	1.792
(Al.Fe) ₂ O ₃	0.006
SiO ₂	0.016
Sr.....	.....
I.....	0.020
	<hr/>
	100.000

Total dissolved solids at 180° C., 82.80 grams per kilogram.

Sample No. 17

Brine from the S. E. Feicht No. 3 well, operated by the Natural Gas Company of West Virginia, Section 17, Beaver Township, Mahoning County; taken by R. E. Lamborn, Geological Survey of Ohio, November 18, 1930; analyst, Downs Schaaf.

Specific gravity, 1.064 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.07
Br.....	0.41
SO ₄	0.055
CO ₂	None
HCO ₃	0.065
Na.....	26.80
K.....	0.025
Ca.....	7.83

Mg.....	2.30
(Al.Fe) ₂ O ₃	0.415*
SiO ₂	0.03
Sr.....	.....
	100.000
Total dissolved solids.....	{ 115.55 grams per liter 108.6 grams per kilogram

Drillers Record

This well was completed November 12, 1924. At the time of sampling the well was making some water. Sample was collected by opening pipe and allowing gas pressure to blow brine from bottom.

Elevation of well head, 1,150 feet.

	Top	Bottom
<i>Big Injun</i> sand.....	288	330
<i>Berea</i> sand.....	600	
Total depth.....		620

Sample No. 33

Brine from the W. B. Hostetler No. 6 well of the Pure Oil Company, one-fourth mile west of Chatham, Chatham Township, Medina County; taken by J. W. Cummins, Geological Survey of Ohio, August 7, 1931; analyst, Downs Schaaf.

Specific gravity, 1.063 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	61.77
Br.....	0.37
SO ₄	0.04
CO ₂	None
HCO ₃	0.02
Na.....	30.39
K.....	0.25
Ca.....	5.35
Mg.....	1.74
(Al.Fe) ₂ O ₃	0.06
SiO ₂	0.01
Sr.....	Trace**
	100.00
Total dissolved solids.....	{ 85.36 grams per liter 80.3 grams per kilogram

Drillers Record

Elevation of well head, 1,062 feet. Sample of brine from bottom of Berea sand at about 460 feet.

	Top	Bottom
<i>Berea</i> sand.....	401	463

*Fe₂O₃ 0.37; Al₂O₃ 0.045.

**Less than 0.01 per cent.

FIRST WATER OF BIG LIME

The brines from the horizon of the First Water of the Big Lime present a distinct departure from those in the higher formations as they are much less rich in sodium chloride and contain much more calcium chloride and magnesium chloride. The average salt composition of the saline matter of the First Water from thirteen analyses is as follows: sodium chloride 40 per cent; potassium chloride 1.4 per cent; calcium chloride 41.7 per cent; and magnesium chloride 15.7 per cent. These magnesium rich brines with few exceptions are highly charged with hydrogen sulphide gas, H_2S , which in some way appears to be responsible for the replacement of sodium by magnesium. For the depth many of these First Water brines are considerably above the average in concentration, containing more than 200 grams of solid matter per kilogram of solution for depths approximating 2,000 feet. In the area so far tested in Ohio the fields of most importance and offering good opportunities for chemical industries are those in north central Ohio in Lorain, Medina, Richland, Ashland, and Wayne counties.

Sample No. 21

Brine from the well on the property of the Wayne Coal Company, drilled by the Eastern Ohio Development Company, northwest Section 26, Island Creek Township, Jefferson County; taken by Blackburn Brothers, drillers, May 16, 1931; Downs Schaaf, Geological Survey of Ohio, analyst.

Specific gravity, 1.211 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	61.09
Br.....	0.66
SO ₄	0.03
CO ₂	None
HCO ₃	0.005
Na.....	27.34
K.....	0.75
Ca.....	8.19
Mg.....	1.29
(Al.Fe) ₂ O ₃	0.06
SiO ₂	0.015
Sr.....	0.57
	100.000

Total dissolved solids..... { 316.1 grams per liter
261.0 grams per kilogram

Drillers Record

Elevation of well head, 1,172 feet. Sample of brine from a depth of about 5,165 feet.

	Top	Bottom	
<i>Upper Freeport</i> coal.....	527	530	
<i>Middle Kittanning</i> coal.....	606	610	
<i>Berea</i> sand.....	1,473	1,523	
Top <i>Big Lime</i>	4,956		
<i>Oriskany</i> sand.....	5,145	5,175	Sample of water.
Lime.....	5,175	5,300	
Total depth.....		5,300	

Sample No. 12

Brine from the Howard P. Ogden No. 1 well of the Ohio Fuel Gas Company, southwest Section 17, Chester Township, Wayne County; taken by the Ohio Fuel Gas Company, October, 1930; Downs Schaaf, Geological Survey of Ohio, analyst.

Specific gravity, 1.179 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	64.14
Br.....	0.50
SO ₄	0.09*
CO ₂	None
HCO ₂	0.06
Na.....	12.45
K.....	0.79
Ca.....	17.22
Mg.....	4.66
(Al,Fe) ₂ O ₃	0.05
SiO ₂	0.04
Sr.....	.....
	100.00
Total dissolved solids.....	{ 252.9 grams per liter 214.5 grams per kilogram

Drillers Record

Sample of brine from First Water at depth of 2,140 feet. Elevation of well head, 1,170 feet.

	Top	Bottom	
<i>Berea</i> sand.....	775	790	No oil, gas, or water.
<i>Little Cinnamon</i> shale.....	1,340	1,520	No oil, gas, or water.
<i>Big Cinnamon</i> shale.....	1,565	1,755	No oil, gas, or water.
Lime, <i>Big Lime</i>	1,926	2,987	3 bbl. water per hr. at 2,140 feet.
Shale.....	3,000	3,036	Hole full water.
<i>Packer shell</i>	3,036	3,060	
<i>Clinton</i> sand.....	3,122	3,140	185,000 cu. ft. gas.
Slate.....	3,140	3,159	
Total depth.....		3,161	

*Sample of brine when received contained 50 parts per 1,000,000 of H₂S

Sample No. 243

Brine from the Ohio Salt Company at Rittman, Section 12, Milton Township, Wayne County; taken by the Ohio Salt Company about 1921; C. A. Parkinson, analyst.¹

Brine from a depth of about 2,272 feet.

Specific gravity, 1.164.

<i>Grams per liter</i>	
CaSO ₄.....	.79
CaCl ₂	74.00
MgBr ₂	1.55
MgCl ₂	23.15
NaCl.....	131.60
	<hr/>
	231.09

<i>Composition of saline matter</i>	
Cl.....	62.46
Br.....	.58
SO ₄.....	.24
CO ₃.....	.....
HCO ₃.....	.....
Na.....	22.41
K.....	.....
Ca.....	11.66
Mg.....	2.65
(Al,Fe) ₂ O ₃.....	.....
SiO ₂.....	.....
Sr.....	.....
	<hr/>
	100.00
Total dissolved solids.....	{ 231.09 grams per liter
	{ 198.53 grams per kilogram

Sample No. 37

Brine from Ira Culler No. 1 well, Ohio Fuel Gas Company, Section 15, Perry Township, Ashland County, taken by J. W. Cummins, Geological Survey of Ohio, August 18, 1931; Downs Schaaf, analyst.

Specific gravity, 1.175 at 15° C. Mineral sediment, dolomitic.

<i>Composition of saline matter</i>	
Cl.....	63.52
Br.....	0.67
SO ₄	0.05
CO ₃	None
HCO ₃	0.01
Na.....	13.33
K.....	1.05

¹Geol. Survey Ohio, Bull. 24, p. 141.

Ca.....	16.85
Mg.....	4.00
(Al.Fe) ₂ O ₃	0.045
SiO ₂	0.005
Sr.....	0.47
	100.000
Total dissolved solids.....	{ 246.8 grams per liter
	{ 210.0 grams per kilogram

Drillers Record

Sample of brine from depth of 1,980 feet.

	Top	Bottom	
<i>Berea</i> sand.....	650	685	
Lime, <i>Big Lime</i>	1,710	2,772	Sample 1,980
<i>Shell</i>	2,814	2,844	
<i>Clinton</i> sand.....	2,892	2,899	
Total depth.....		2,947	

Sample No. 38

Brine from the H. W. Martin No. 1 well, Ohio Fuel Gas Company, northeast corner of Section 4, Montgomery Township, Ashland County; taken by J. W. Cummins, Geological Survey of Ohio, August 25, 1931; Downs Schaaf, analyst. (Sample diluted somewhat by rain.)

Specific gravity, 1.096 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	63.83
Br.....	0.70
SO ₄	0.41
CO ₃	None
HCO ₃	0.04
Na.....	13.14
K.....	0.75
Ca.....	16.17
Mg.....	4.92
(Al.Fe) ₂ O ₃	0.038
SiO ₂	0.002
Sr.....	Trace
	100.000
Total dissolved solids.....	{ 133.7 grams per liter
	{ 122.0 grams per kilogram

Drillers Record

Sample of brine from depth of 1,690 feet.

	Top	Bottom	
<i>Berea</i> sand.....	490	505	
Lime, <i>Big Lime</i>	1,420	2,442	Sample 1,690
<i>Shell</i>	2,482	2,506	
<i>Clinton</i> sand.....	No sand		
Total depth.....		2,642	

Sample No. 3

Brine from the G. M. Harbaugh No. 1 well, Ohio Fuel Gas Company, Section 11, Jackson Township, Ashland County; taken by R. E. Lamborn, Geological Survey of Ohio, October 7, 1930; Downs Schaaf, analyst.

Specific gravity, 1.179 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	63.93
Br.....	0.47
SO ₄	0.14*
CO ₃	None
HCO ₃	0.07
Na.....	12.40
K.....	0.75
Ca.....	17.28
Mg.....	4.69
(Al,Fe) ₂ O ₃	0.23
SiO ₂	0.04
Sr.....	.....
	100.00
Total dissolved solids.....	{ 251.2 grams per liter
	{ 213.1 grams per kilogram

Drillers Record

The First Water was reached at a depth of 1,995 and sampled when hole had a depth of almost 2,010. The sample was taken directly from the bailer which had been lowered to the bottom of the hole. Elevation of well head, 1,105 feet.

	Top	Bottom	
Shale.....	63	115	Hole full water.
Berea sand.....	640	655	No oil, gas, or water.
Red rock.....	655	670	
Cinnamon shale.....	1,140	1,540	No oil, gas, or water.
Niagara lime.....	1,725	2,645	Hole full water 1,990- 2,024.
Newburg sand.....	2,645	2,650	5,000 cu. ft. gas.
Niagara lime.....	2,650	2,765	3 bailers water per hr.
Lime shell.....	2,810	2,825	
Little shell.....	2,840	2,855	
Clinton sand.....	2,887	2,892	221,000 cu. ft. gas.
Total depth.....		2,946	

Sample No. 29

Brine from the William Hines No. 1 well, Upham and others, north-east Section 21, Mifflin Township, Richland County; taken by J. W. Cummins, Geological Survey of Ohio, July 27, 1931; Downs Schaaf, analyst.

*Sample of brine when received contained 100 parts per 1,000,000 of H₂S.

Specific gravity, 1.115 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	63.08
Br.....	0.37
SO ₄	0.47*
CO ₃	None
HCO ₃	0.07
Na.....	21.35
K.....	0.50
Ca.....	10.10
Mg.....	4.04
(Al.Fe) ₂ O ₃	0.017
SiO ₂	0.003
Sr.....	Trace
	<hr/>
	100.000

Total dissolved solids..... { 165.6 grams per liter
 { 148.5 grams per kilogram

Drillers Record

Sample of brine taken from bailer at a depth of 2,005 feet. Elevation of well head, 1,137 feet.

	Top	Bottom	
<i>Berea sand</i>	534	583	
<i>Big Lime</i>	1,380	2,314	Water at 2,000 feet. Sample at 2,005 feet.
<i>Little Lime</i>	2,330	2,362	
<i>Clinton sand</i>	2,425	2,430	Some gas.
<i>Medina red shale</i>	2,516	2,524	

Sample No. 32

Brine from the Burkhart No. 1 well, Wiser Oil Company, one mile southwest of Ghent, Lot 85, Bath Township, Summit County; taken by J. W. Cummins, Geological Survey of Ohio, August 6, 1931; Downs Schaaf, analyst.

Specific gravity, 1.175 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.81
Br.....	0.24
SO ₄	0.19
CO ₃	None
HCO ₃	0.002
Na.....	20.45
K.....	0.85
Ca.....	12.50
Mg.....	2.77
(Al.Fe) ₂ O ₃	0.044
SiO ₂	0.004
Sr.....	0.14
	<hr/>
	100.000

*Sample of brine at well contained 60 parts per 1,000,000 of H₂S.

Total dissolved solids.....	{	246.75 grams per liter
		210.00 grams per kilogram

Drillers Record

Sample of brine from depth of 2,140 feet. Elevation of well head, 1,044 feet.

	Top	Bottom	
<i>Berea</i> sand.....	323	335	
<i>Big Lime</i>	1,940	3,373	Top of water 2,133.
Water.....	2,295		Sample 2,140.
<i>Clinton</i> sand.....	3,557	3,573	Hole full.

Sample No. 36

Brine from the J. A. Holschue No. 1 well, operated by F. E. Barnhart, one and one-fourth miles north of Homerville, Section 17, Homer Township, Medina County; taken by J. W. Cummins, Geological Survey of Ohio, August 24, 1931; Downs Schaaf, analyst.

Specific gravity, 1.159 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	63.43
Br.....	0.72
SO ₄	0.15
CO ₃	None
HCO ₃	0.001
Na.....	12.39
K.....	0.93
Ca.....	16.88
Mg.....	4.64
(Al,Fe) ₂ O ₃	0.036
SiO ₂	0.003
Sr.....	0.82
	100.000

Total dissolved solids.....	{	224.8 grams per liter
		194.0 grams per kilogram

Drillers Record

Sample of brine taken from bailer at a depth of 1,820 feet. Elevation of well head, 1,090 feet.

	Top	Bottom	
<i>Berea</i> sand.....	515	525	
<i>Big Lime</i>	1,575	2,656	
<i>First Water</i>	1,820		Sampled.
<i>Newburg</i> sand.....	2,305	2,511	
<i>Little Lime</i>	2,702	2,716	
<i>Clinton</i> sand.....	2,776	2,800	
Total depth.....		2,902	

Sample No. 34

Brine from the W. Barton No. 1 well, operated by Willis and Ramage, Cushing, and others, Lot 48, Litchfield Township, Medina County; taken by J. W. Cummins, Geological Survey of Ohio, August 27, 1931; Downs Schaaf, analyst.

Specific gravity, 1.182 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	63.58
Br.....	0.73
SO ₄	0.09
CO ₃	None
HCO ₃	0.05
Na.....	12.37
K.....	1.05
Ca.....	17.29
Mg.....	4.27
(Al.Fe) ₂ O ₃	0.017
SiO ₂	0.003
Sr.....	0.55
	100.000
Total dissolved solids.....	{ 257.7 grams per liter 218.0 grams per kilogram

Drillers Record

Elevation of well head, 887 feet.

	Top	Bottom	
<i>Berea sand</i>	295	535	
<i>Big Lime</i>	1,500	2,732	
<i>First Water</i>	1,740		Sampled.
<i>Second Water</i>	2,590	2,715	
<i>Salt, Salina</i>	1,985	2,060	
<i>Little Lime</i>	2,781	2,790	
<i>Clinton sand</i>	2,858	2,860	
Total depth.....		2,877	

Sample No. 25

Brine from the Metzger No. 1 well, operated by J. W. Cushing, three-fourths mile southeast of Liverpool Station, Liverpool Township, Medina County; taken by A. A. L. Mathews, Geological Survey of Ohio, June, 1931; Downs Schaaf, analyst.

Specific gravity, 1.195 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	63.67
Br.....	0.74
SO ₄	0.08
CO ₃	None
HCO ₃	0.08
Na.....	12.23
K.....	0.74
Ca.....	17.92
Mg.....	4.15
(Al, Fe) ₂ O ₃	0.02
SiO ₂	0.02
Sr.....	0.35
	100.00
Total dissolved solids.....	{ 273.5 grams per liter 228.9 grams per kilogram

Drillers Record

Depth of First Water, 1,795 feet; brine one bailer per minute.

	Top	Bottom	
<i>Berea sand</i>	326	489	
<i>Big Lime</i>	1,565	2,800	
<i>First Water</i>	1,795		Sample of brine.
<i>Salt, Salina</i>	2,085	2,140	
<i>Second Water</i>	2,695		
<i>Little Lime</i>	2,903	2,927	
<i>Clinton sand</i>	2,983		

Sample No. 31

Brine from the John Tomes No. 2 well, Ohio Fuel Gas Company, southwest corner of Columbia Township, Lorain County; taken by J. W. Cummins, Geological Survey of Ohio, July 10, 1931; Downs Schaaf, analyst.

Specific gravity, 1.18 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	64.24
Br.....	0.23
SO ₄	0.14*
CO ₃	None
HCO ₃	0.05
Na.....	12.66
K.....	0.55
Ca.....	17.07
Mg.....	4.55

*Sample of brine as received contained 50 parts per 1,000,000 of H₂S.

(Al.Fe) ₂ O ₃	0.008
SiO ₂	0.002
Sr.....	0.50

	100.000
Total dissolved solids.....	{ 256.1 grams per liter
	{ 217.0 grams per kilogram

Drillers Record

Top of water at 1,520 feet. Sample taken at 1,540 feet. Elevation of well head, 838 feet.

	Top	Bottom
<i>Berea sand</i>	75	180
<i>Lime, Big Lime</i>	1,225	2,539
<i>Shell</i>	2,617	2,639
<i>Clinton sand</i>	2,663	2,689
Total depth.....		2,690

Sample No. 18

Brine from the Charles A. Huene No. 1 well, Steel and Tubes, Incorporated, Section 7, Carlisle Township, Lorain County; taken by R. E. Lamborn, Geological Survey of Ohio, November 19, 1930; Downs Schaaf, analyst.

Specific gravity, 1.125 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	64.22
Br.....	0.69
SO ₄	0.12*
CO ₃	None
HCO ₃	0.13
Na.....	12.16
K.....	0.15
Ca.....	16.63
Mg.....	5.63
(Al.Fe) ₂ O ₃	0.05
SiO ₂	0.03
Sr.....	0.19

	100.00
Total dissolved solids.....	{ 177.9 grams per liter
	{ 158.1 grams per kilogram

Drillers Record

Sample of brine was taken directly from bailer which had been lowered to bottom of hole. At time of sampling the hole had a depth of 1,374 feet and had approximately 1,150 feet of water.

*Sample of brine when received contained 200 parts per 1,000,000 of H₂S.

	Top	Bottom
<i>Big Lime</i>	1,074	2,280
<i>Salt, Salina</i>	1,570	1,588
<i>First Water</i>	1,260	1,310
<i>Second Water</i>	2,250	
<i>Little Lime</i>	2,320	2,355
<i>Clinton sand</i>	None	

Sample No. 244

Brine from well at the plant of the Diamond Alkali Company at Fairport, Painesville Township, Lake County; taken by W. C. Phalen of the United States Geological Survey in 1911; R. F. Gardner and A. R. Merz, analysts, United States Bureau of Soils.¹

"Only a single analysis of a natural brine or rather bittern is available from Ohio at the present time (1911), namely that of a sample collected at the Diamond Alkali Company's plant at Fairport Harbor from a well during the process of sinking. The top of this bittern stratum varies from approximately 350 to more than 400 feet above the topmost salt bed from which artificial brines are pumped in northern Ohio. It will be sufficient to state here that the bittern stratum is sharply defined and is of wide areal extent."

	Grams per liter	Composition of saline matter
Cl.....	188.4	63.71
Br.....	.....	.....
SO ₄	0.2	0.07
CO ₃.....	.....	.....
HCO ₃.....	.....	.....
Na.....	43.4	14.68
K.....	3.9	1.32
Ca.....	48.6	16.43
Mg.....	11.2	3.79
(Al,Fe) ₂ O ₃.....	.....	.....
SiO ₂.....	.....	.....
Sr.....	.....	.....
Total.....	295.7	100.00

Drillers Record

The First Water of the Big Lime was reached at a depth of approximately 1,500 feet and the salt at 1,915 feet.

SALINA FORMATION

The Salina formation, consisting of rock salt, dolomite, limestone, and shale, and extending under deep covering over an area of 7,000 square miles in northeastern and eastern Ohio, is the basis for extensive salt and chemical industries at Rittman, Kenmore, Barberton, Wadsworth, Cleveland, and Fairport. Both the rock salt and the solid matter of the brines obtained by solution of the rock salt consist of sodium

¹U. S. Geol. Survey, Bull. 530-B, pp. 18, 19.

chloride with only a few per cent of other salts. The yield of sodium chloride is commonly more than 97 per cent of the total. Through solution of the rock salt by pumping water down into the deep-seated formations, the concentration of the brine thus obtained is brought close to saturation, the specific gravity of the brine being more than 1.2 and the yield about 260 grams per kilogram. The salt beds of the Salina formation are utilized in a large way for salt, soda ash, baking soda, and caustic soda. The field holds an inexhaustible supply of rock salt for future needs.

Sample No. 7

Salt from C. K. Doriat No. 2 well, operated by Brendel Brothers, Section 28, Lake Township, Stark County; taken by J. W. Cummins, Geological Survey of Ohio, September, 1930; Downs Schaaf, analyst.

Composition of salt

Cl.....	59.66
Br.....	
SO ₄	0.55
CO ₃	None
HCO ₃	
Na.....	38.53
K.....	0.04
Ca.....	0.32
Mg.....	None
(Al.Fe) ₂ O ₃	0.01
SiO ₂	0.20
Sr.....	
Organic matter.....	Present
	99.31

Drillers Record

Sample of salt taken at a depth of about 3,510 feet. Elevation of well head, 1,215 feet.

	Top	Bottom
Coal.....	85	90
<i>Big Injun</i> sand.....	130	199
<i>Big Injun</i> sand.....	291	444
<i>Berea</i> sand.....	697	722
<i>Big Lime</i>	2,728	4,343
Salt.....	3,390	3,445
Salt } <i>Salina</i>	3,500	3,564
Salt }.....	3,625	3,650
Salt }.....	3,707	3,742
<i>Newburg</i> sand.....	4,024	4,058
Show of water.....	4,034	
Lots of water.....	4,058	
<i>Shell</i>	4,396	4,449
<i>Stray</i> sand.....	4,460	4,478
Red sand.....	4,478	4,531

	Top	Bottom
Clinton sand.....	4,531	4,541
Medina red sand.....	4,633	
Total depth.....		4,658

Sample No. 228

Brine from dissolved rock salt from the Ohio Salt Company at Rittman, Section 12, Milton Township, Wayne County; taken by Ohio Salt Company, about 1921; C. A. Parkinson, analyst.¹

Analysis of brine from dissolving rock salt by water.

Specific gravity, 1.202

<i>Grams per liter of brine</i>	
CaSO ₄	5.55
CaCl ₂.....	.47
MgCl ₂.....	.20
Ca(HCO ₃) ₂.....	.19
NaCl.....	303.40
	<hr/>
	309.81
<i>Composition of saline matter</i>	
Cl.....	59.549
Br.....	
SO ₄	1.262
CO ₃	
HCO ₃.....	.045
Na.....	38.527
K.....	
Ca.....	.600
Mg.....	.017
(Al,Fe) ₂ O ₃	
SiO ₂	
Sr.....	
	<hr/>
	100.000
Total dissolved solids.....	{ 309.81 grams per liter
	{ 257.745 grams per kilogram

Drillers Record

Log of Well No. 1

	Top	Bottom
Clay.....	0	40
Sand and gravel.....	40	173
Berea sandstone.....	173	193
Black shale.....	193	1,200
Red shale.....	1,200	1,250
Slate and shells.....	1,250	1,500
Brown shale.....	1,500	2,035
Limestone.....	2,035	2,303
Gray sandstone.....	2,303	2,333

¹Geol. Survey Ohio, Bull. 24, pp. 138-141.

	Top	Bottom
Shelly limestone.....	2,333	2,558
Rock salt.....	2,558	2,624
Total depth.....		2,624

Log of Well No. 3

Drift.....	0	171
Not recorded.....	171	2,513
Rock salt.....	2,513	2,519
Limestone.....	2,519	2,544
Rock salt.....	2,544	2,574
Limestone.....	2,574	2,579
Rock salt.....	2,579	2,614
White shale.....	2,614	2,644
Limestone.....	2,644	2,651
Total depth.....		2,651

Sample No. 220

Brine from dissolved rock salt from the Union Salt Company on the lake front at Cleveland, Cuyahoga County; taken by J. A. Bownocker, Geological Survey of Ohio, about 1906; N.W. Lord, analyst.¹

Sample of brine from a solution of rock salt from the wells of the Union Salt Company, Cleveland.

Specific gravity, 1.204.

Grams per liter of brine

SiO ₂.....	.000
(Al.Fe) ₂ O ₃.....	.000
CaCl ₂	1.033
CaSO ₄	4.857
MgCl ₂.....	.462
SrCl ₂.....	.089
BaCl ₂.....	.000
NaCl.....	310.977
KCl.....	.713
NaI.....	.000
MgBr ₂.....	.012
Li.....	Trace
	<hr/>
	318.143

Composition of saline matter

Cl.....	59.726
Br.....	.003
SO ₄	1.077
CO ₂	
HCO ₃	
Na.....	38.457
K.....	.117
Ca.....	.567
Mg.....	.038
(Al.Fe) ₂ O ₃.....	.000

¹Geol. Survey Ohio, Bull. 8, pp. 34, 35, 38.

SiO ₂.....	.000
Sr.....	.015
I.....	.000
Ba.....	.000
	100.000
Total dissolved solids.....	{ 318.143 grams per liter
	{ 264.24 grams per kilogram

Drillers Record

	Top	Bottom	
Drift.....	0	40	
Ohio and Bedford shales.....	40	1,350	
Corniferous and Monroe	{ Limestone.....	1,350	1,660
	{ Sand containing lime....	1,660	1,700
	{ Limestone.....	1,700	1,990
Salina	{ Rock salt and shale.....	1,990	2,154
	{ Shale.....	2,154	2,169
	{ Limestone.....	2,169	2,250
	{ Rock salt.....	2,250	2,300
	{ Shale, blue.....	2,300	2,340
	{ Sand.....	2,340	2,360
	{ Shale.....	2,360	2,378
	{ Limestone.....	2,378	2,400
	{ Rock salt.....	2,400	2,420
	{ Shale.....	2,420	2,430
	{ Limestone.....	2,430	2,470
	{ Rock salt.....	2,470	2,475
	{ Shale.....	2,475	2,483
Niagara	{ Limestone.....	2,483	2,650
	{ Oil sand.....	2,650	2,658
	{ Limestone.....	2,658	2,680
	{ Oil sand.....	2,680	2,686
Clinton	Limestone.....	2,686	2,750

SECOND WATER OF THE BIG LIME

The great brine-yielding horizon in Ohio is that of the Second Water of the Big Lime, which extends with few non-producing areas across the entire eastern half of the State. Ordinarily the flows of brine from these deep-seated reservoirs are exceptionally strong and not uncommonly the hydrostatic head of brine is sufficient to cause the well to flow. In a way these brines are outstanding for their content of calcium chloride, which, in proportion to the sodium chloride, is very high. Considered as chlorides, the common salts of the Second Water brines average as follows: 50.35 per cent sodium chloride; 1.22 per cent potassium chloride; 36.29 per cent calcium chloride; and 10.92 per cent magnesium chloride. The brines in both the Second Water and First Water of the Big Lime have a decided enrichment in bromine over those in

the formations higher in the geological column. The content of bromine in the Second Water ranges from 0.23 to 0.94 per cent but averages 0.59 per cent.

These brines offer much to the chemical industries as they are widely distributed, thus allowing some choice for location; as they are of high concentration, thus saving fuel in evaporation; as they occur in large volume, thus assuring an inexhaustible supply; and as often the saline solutions have a high hydrostatic head, thus aiding materially in the cost of pumping. The brines in the Second Water of the Big Lime should become an asset of importance to the State.

Sample No. 46

Brine from the Ceramic Clay Company No. 1 well, Ohio Fuel Gas Company, Section 25, Elizabeth Township, Lawrence County; taken by W. R. Maxey, Ironton, October, 1931; Downs Schaaf, Geological Survey of Ohio, analyst.

Specific gravity, 1.16 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.69
Br.....	0.81
SO ₄	0.12
CO ₃	None
HCO ₃	0.02
Na.....	18.62
K.....	0.67
Ca.....	13.12
Mg.....	3.34
(Al.Fe) ₂ O ₃	0.035
SiO ₂	0.005
Sr.....	0.57
	100.000
Total dissolved solids.....	{ 243.02 grams per liter
	{ 209.5 grams per kilogram

Drillers Record

Brine from a depth of about 2,800 feet.

	Top	Bottom	
Sand.....	520	540	No water.
Sand.....	585	597	
Salt sand.....	665	710	½ bbl. water at 675-680 feet.
Sand.....	720	760	3 bbls. water at 740 feet.
Maxton sand.....	760	770	
Big Injun sand.....	865	1,078	
Hamden sand.....	1,340	1,350	

	Top	Bottom	
<i>Berea</i> grit sand.....	1,480	1,528	Hole full water. No oil or gas.
<i>Niagara</i> lime.....	2,340	2,948	Brine sample about 2,800 feet.
<i>Clinton</i> sand.....	3,199	3,207	No oil or water.
Total depth.....		3,252	

Sample No. 43

Brine from William R. Cole No. 1 well, Ohio Fuel Gas Company, Section 12, Coal Township, Jackson County; taken by Frank C. and Ford R. Morrow, Wellston, September 1, 1931; Downs Schaaf, Geological Survey of Ohio, analyst.

Specific gravity, 1.115 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	62.06
Br.....	0.41
SO ₄	0.69
CO ₃	None
HCO ₃	0.02
Na.....	25.63
K.....	0.34
Ca.....	7.85
Mg.....	2.96
(Al,Fe) ₂ O ₃	0.035
SiO ₂	0.005
Sr.....	None

 100.000

Total dissolved solids..... { 161.8 grams per liter
145.0 grams per kilogram

Drillers Record

First Water was found in Big Injun sand (Allensville) at 300 feet, filled up to 75 feet of top. Hole started making water at 1,890 feet; brine in limestone; water-bearing formation about 4 feet thick; filled hole within 250 feet of top; very salty. Sample of brine from Second Water at 2,400 feet.

	Top	Bottom	Color
Clay.....	0	10	Yellow
Sand.....	10	30	Gray
Slate.....	30	100	Blue
Sand.....	100	135	Gray
Slate.....	135	160	Black
Coal, <i>Quakerstown</i>	160	162	Black
Slate.....	162	170	Gray
Sand.....	170	180	Gray
Slate.....	180	195	Gray
Sand, <i>Big Injun</i>	195	540	Gray
Slate.....	540	725	Gray

	Top	Bottom	Color
Sand.....	725	737	White
Slate.....	737	920	Light
Slate, <i>Sunbury</i>	920	950	Black
Sand, <i>Berea</i>	950	969	White
Shale } <i>Bedford</i>	969	979	White
Shale }	979	1,035	Red
Shale }	1,035	1,060	White
Shale }	1,060	1,145	Black
Shale }	1,145	1,280	White
Shale }	1,280	1,290	Brown
Shale }	1,290	1,330	Gray
Shale } <i>Ohio</i>	1,330	1,445	Brown
Shale }	1,445	1,470	Gray
Shale }	1,470	1,510	Brown
Shale }	1,510	1,525	Gray
Shale }	1,525	1,695	Brown
Shale }	1,695	1,830	White
Lime, <i>Big Lime</i>	1,830	2,445	Light
Brine.....	2,400		Sampled.
Shale.....	2,445	2,645	
Sand, <i>Clinton</i>	2,645		

Sample No. 23

Brine from the F. L. Ronshausen No. 1 well, Hamden Gas Company, Lot 634, Hamden, north central Section 30, Clinton Township, Vinton County; taken by Ford R. Morrow, Wellston, June, 1931; Downs Schaaf, Geological Survey of Ohio, analyst.

Specific gravity, 1.210 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.51
Br.....	0.75
SO ₄	0.075
CO ₃	None
HCO ₃	0.035
Na.....	16.80
K.....	1.70
Ca.....	15.21
Mg.....	2.62
(Al.Fe) ₂ O ₃	0.055
SiO ₂	0.025
Sr.....	0.22
	100.000
Total dissolved solids.....	{ 312.18 grams per liter 258.0 grams per kilogram

Drillers Record

Water struck at 2,230 and hole full at 2,290. Sample from this horizon.

	Top	Bottom
Surface, clay and sand.....	0	40
Shales and sandstones, <i>Waverly</i>	40	784
Shale, black, <i>Sunbury</i>	784	824
Sandstone, <i>Berea</i>	824	852
Shale and shaly sandstone, <i>Berea-Bedford</i>	852	950
Shale, black to gray, <i>Ohio</i>	950	1,745
Limestones, <i>Devonian-Silurian</i>	1,745	2,230
Limestone, with water, <i>Newburg</i>	2,230	2,290
Limestone, <i>Silurian</i>	2,290	2,406
Shales, <i>Rochester</i>	2,406	2,584
Limestones, shaly, <i>Little Lime</i>	2,584	2,591
Shale.....	2,591	2,607
Sand, <i>Clinton</i>	2,607	2,618
Total depth.....		2,627

Sample No. 6

Brine from the C. R. Rosser No. 1 well, Wittmer Oil and Gas Properties, Section 34, Swan Township, Vinton County; taken by Wilber Stout, Geological Survey of Ohio, October 11, 1930; Downs Schaaf, analyst.

Specific gravity, 1.191 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	63.03
Br.....	0.48
SO ₄	0.22
CO ₃	None
HCO ₃	0.02
Na.....	17.39
K.....	0.48
Ca.....	14.80
Mg.....	3.37
(Al.Fe) ₂ O ₃	0.17
SiO ₂	0.04
Sr.....	.....
	100.00
Total dissolved solids.....	{ 271.96 grams per liter 228.35 grams per kilogram

Drillers Record

The Second or Big Water reached at 2,395 feet; heavy flow of brine; filled hole 2,000 feet.

	Top	Bottom
Drive pipe, 10".....	0	23
<i>Big Injun</i> sand.....	200	640

	Top	Bottom
Berea sand.....	847	887
Red rock.....	887	990
Slate.....	990	1,295
Little Cinnamon slate.....	1,295	1,375
Slate.....	1,375	1,450
Big Cinnamon slate.....	1,450	1,725
Slate.....	1,725	1,865
Big Lime.....	1,865	2,585
Big Water at.....	2,395	
Pink shale.....	2,585	2,741
First shell.....	2,741	2,751
Slate.....	2,751	2,768
Second shell.....	2,768	2,774
Slate.....	2,774	2,796
Clinton sand.....	2,796	2,808
Slate.....	2,808	2,827
Total depth.....		2,827

Sample No. 15

Brine from the Schall No. 1 well, Wittmer Oil and Gas Properties, Section 24, York Township, Athens County; taken by R. E. Lamborn, Geological Survey of Ohio, October 27, 1930; Downs Schaaf, analyst.

Specific gravity, 1.156 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	62.525
Br.....	0.57
SO ₄	0.21
CO ₂	None
HCO ₃	0.025
Na.....	21.25
K.....	0.52
Ca.....	12.03
Mg.....	2.72
(Al.Fe) ₂ O ₃	0.10
SiO ₂	0.05
Sr.....	.....
	100.000
Total dissolved solids.....	{ 220.9 grams per liter 191.1 grams per kilogram

Drillers Record

At time of sampling the hole had a depth of about 2,900 feet and the drillers estimated that there was about 500 feet of water. The sample was taken directly from bailer which was filled by lowering about 100 feet below top of water. Elevation of well head, 762 feet.

	Top	Bottom	
Fire clay.....	7	80	
Sand.....	275	325	Water
Shale, white.....	325	437	

	Top	Bottom
<i>Big Injun</i>	437	467
Shale.....	467	510
Shale.....	510	625
Shell and shale.....	625	800
White shale.....	800	913
Black shale.....	913	938
<i>Berea sand</i>	938	993
Black shale.....	998	1,068
White shale.....	1,068	1,380
Brown shale.....	1,380	1,440
White shale.....	1,440	1,740
<i>Big Cinnamon</i>	1,740	2,025
White shale.....	2,025	2,175
Brown shale.....	2,175	2,232
<i>Big Lime</i>	2,232	3,071
<i>First Water</i>	None	
<i>Second Water</i>	2,865	
Shale.....	3,071	3,214
<i>Little Shell</i>	3,214	3,217
Shale.....	3,217	3,244
<i>Big Shell</i>	3,244	3,256
<i>Clinton sand</i>	3,282	3,307
Shale.....	3,307	3,347
<i>Medina red shale</i>	3,347	3,367
Shale.....	3,367	3,372
Total depth.....		3,372

Sample No. 19

Brine from the Nelsonville Lumber Company No. 1 well, Nelsonville Foundry land, of the Hocking Valley Drilling Company, at Nelsonville, York Township, Athens County; taken by Mr. Bayliss of the Dow Chemical Company, Midland, Michigan, in November, 1930; Downs Schaaf, Geological Survey of Ohio, analyst.

Specific gravity, 1.234 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	63.03
Br.....	0.69
SO ₄	0.05
CO ₂	None
HCO ₃	0.02
Na.....	17.64
K.....	0.43
Ca.....	15.08
Mg.....	2.98
(Al,Fe) ₂ O ₃	0.05
SiO ₂	0.03
Sr.....	None

100.00

Total dissolved solids..... { 343.67 grams per liter
278.5 grams per kilogram

Drillers Record

Sample of brine taken by Mr. Bayliss of Dow Chemical Company and submitted to Survey. Depth reported 2,880 feet.

	Top	Bottom	
Gravel and quicksand.....	0	91	
<i>Big Injun</i> sand.....	245	400	Water.
<i>Berea</i> sand.....	880	905	
<i>Big Lime</i>	2,190	3,035	Water at 2,835.
<i>Green Cave</i>	3,115	3,160	
<i>Little Shell</i>	3,160	3,165	
<i>Big Shell</i>	3,200	3,212	
<i>Clinton</i> sand.....	3,234	3,260	Dry.
Total depth.....		3,285	

Sample No. 10

Brine from the Cline and Benton No. 4 well, operated by Berlin and Bryan, one mile northeast of South Bloomingville, Section 4, Benton Township, Hocking County; taken by R. E. Lamborn, Geological Survey of Ohio, October 20, 1930; Downs Schaaf, analyst.

Specific gravity, 1.181 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	63.17
Br.....	0.40
SO ₄	0.14
CO ₂	None
HCO ₃	0.015
Na.....	17.925
K.....	0.49
Ca.....	14.20
Mg.....	3.39
(Al.Fe) ₂ O ₃	0.22
SiO ₂	0.05
Sr.....	.....
	100.000
Total dissolved solids.....	{ 261.0 grams per liter 221.0 grams per kilogram

Drillers Record

At the time of sampling, hole had a depth of 1,898 feet and had about 1,100 feet of water in it. Sample was taken directly from bailer which had been filled by lowering a little below the surface of the water. A show of oil was present at the top of the *Big Lime*. There is no First Water in *Big Lime* in this region.

	Top	Bottom
<i>Berea</i> sand.....	550	590
<i>Big Lime</i>	1,385	2,061
<i>Second or Big Water</i>	1,772	
<i>Clinton</i> sand.....	2,210	2,219
Total depth.....		2,243

Sample No. 11

Brine from the E. Brown well, of the Mid-East Oil Company, Section 11, Reading Township, Perry County; taken by R. E. Lamborn, Geological Survey of Ohio, October 21, 1930; Downs Schaaf, analyst.

Specific gravity, 1.225 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	63.12
Br.....	0.49
SO ₄	0.06
CO ₂	None
HCO ₃	0.025
Na.....	17.895
K.....	0.40
Ca.....	14.85
Mg.....	3.01
(Al.Fe) ₂ O ₃	0.11
SiO ₂	0.04
Sr.....	.....
	100.000

Total dissolved solids.....	}	323.6 grams per liter
		264.2 grams per kilogram

Drillers Record

The well had been drilled in at time of sampling. After setting the five-inch casing, the brines had been bailed from the well and placed in steel oil drums, from which the sample was taken. The brine had stood in these barrels about one week before sampling. Elevation of well head, 1,062 feet.

	Top	Bottom	
<i>Big Injun sand</i>	320	480	
<i>Berea sand</i>	990	1,030	
<i>Big Lime</i>	2,190	3,025	
<i>First Water</i>	2,710		
<i>Second Water</i>	2,820		Hole full.
<i>Shell</i>	3,091½	3,100½	
<i>Clinton sand</i>	3,126½		
Total depth.....		3,148½	Not through Clinton sand.

Sample No. 53

Brine from the Edward Wilkins No. 1 well, southeast Section 17, Madison Township, Perry County; taken by J. W. Cummins, Geological Survey of Ohio, November 12, 1931; Downs Schaaf, analyst.

Specific gravity, 1.224 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.56
Br.....	0.88
SO ₄	0.07
CO ₂	None

HCO ₃	0.015
Na.....	17.65
K.....	0.77
Ca.....	14.69
Mg.....	2.88
(Al.Fe) ₂ O ₃	0.023
SiO ₂	0.002
Sr.....	0.46

 100.000

Total dissolved solids..... { 319.5 grams per liter
 { 261.0 grams per kilogram

Drillers Record

Elevation of well head, 794 feet. Sample taken at depth of 2,628 feet.

	Top	Bottom	
<i>Berea</i>	710	722	
<i>Lime, Big Lime</i>	1,983	2,865	Sample 2,628.
<i>Shell</i>	2,952	2,965	
<i>Clinton</i>	2,992	3,043	
<i>Medina</i>	3,071		

Sample No. 42

Brine from Morningstar brothers No. 1 well, Gas Producing Company of Ohio, south central Section 8, Brush Creek Township, Muskingum County; taken by J. W. Cummins, Geological Survey of Ohio, August 12, 1931; Downs Schaaf, analyst.

Specific gravity, 1.23 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.77
Br.....	0.66
SO ₄	0.04
CO ₃	None
HCO ₃	0.03
Na.....	18.06
K.....	0.18
Ca.....	15.24
Mg.....	2.55
(Al.Fe) ₂ O ₃	0.028
SiO ₂	0.002
Sr.....	0.44

 100.000

Total dissolved solids..... { 337.0 grams per liter
 { 274.0 grams per kilogram

Drillers Record

Elevation of well head, 948 feet. Sample taken at 3,390 feet.

	Top	Bottom	
<i>Berea</i> sand.....	1,211	1,228	
<i>Big Lime</i>	2,786	3,813	Sample 3,390.
<i>Clinton</i> sand.....	3,981	4,031	

Sample No. 54

Brine from the Boyer No. 5 well, Whitehill Oil Company, northwest Section 6, Hopewell Township, Muskingum County; taken by J. W. Cummins, Geological Survey of Ohio, November 15, 1931; Downs Schaaf, analyst.

Specific gravity, 1.20 at 15° C. Mineral sediment, none.

<i>Composition of saline matter</i>	
Cl.....	62.91
Br.....	0.40
SO ₄	0.12
CO ₂	None
HCO ₃	0.001
Na.....	18.66
K.....	0.68
Ca.....	13.65
Mg.....	3.05
(Al.Fe) ₂ O ₃	0.027
SiO ₂	0.002
Sr.....	0.50
	100.000
Total dissolved solids.....	{ 283.2 grams per liter 236.0 grams per kilogram

Drillers Record

Sample of brine taken at depth of 2,900 feet; hole full of brine. Elevation of well head, 1,096 feet.

	Top	Bottom	
<i>Big Injun</i> sand.....	400	700	
<i>Berea</i> sand.....	995	1,005	
<i>Niagara</i> lime.....	2,249	3,123	
Hole full water.....	2,892		Sample at 2,900 feet.
Slate break.....	3,061	3,066	
Pink shell.....	3,245	3,257	
<i>Clinton</i> sand.....	3,278	3,328	
Slate.....	3,328	3,334	
Total depth.....		3,334	

Sample No. 27

Brine from the Martha Myers No. 1 well, Ohio Fuel Gas Company, Section 12, Washington Township, Muskingum County; taken by J. W. Cummins, Geological Survey of Ohio, July 21, 1931; Downs Schaaf, analyst.

Specific gravity, 1.212 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	62.38
Br.....	0.89
SO ₄	0.09
CO ₃	None
HCO ₃	0.02
Na.....	18.54
K.....	0.77
Ca.....	14.33
Mg.....	2.63
(Al,Fe) ₂ O ₃	0.032
SiO ₂	0.008
Sr.....	0.31
	100.000
Total dissolved solids.....	{ 313.9 grams per liter 259.0 grams per kilogram

Drillers Record

Sample of brine taken at depth of 3,464 feet. Elevation of well head, 953 feet.

	Top	Bottom
Coal.....	27	29
Coal.....	95	98
<i>Big Injun</i> sand, hole full of water.....	540	564
<i>Berea</i> sand, 3 bbls. water per hour.....	1.040	1.060
<i>Little Cinnamon</i> shale.....	2.075	2.155
<i>Big Cinnamon</i> shale.....	2.235	2.380
<i>Niagara</i> lime, full of water at 3,460. Sampled at 3,464.....	2.633	3.707
<i>Packer shell</i>	3.842	3.859
<i>Clinton</i> sand.....	3.889	3.916
Total depth.....		3.932

Sample No. 30

Brine from the Witt or Atha No. 3 well, Atha Drilling Company along the Muskingum River two miles above the plant of the American Encaustic Tiling Company, Falls Township, Muskingum County; taken by J. W. Cummins, Geological Survey of Ohio, July 30, 1931; Downs Schaaf, analyst.

Specific gravity, 1.062 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	61.58
Br.....	0.88
SO ₄	Trace
CO ₃	None
HCO ₃	0.01
Na.....	21.33

K.....	0.88
Ca.....	14.42
Mg.....	0.88
(Al.Fe) ₂ O ₃	0.015
SiO ₂	0.005
Sr.....	None
	100.000

Total dissolved solids..... { 84.96 grams per liter
80.0 grams per kilogram

Drillers Record

Sample of brine taken at 3,155 feet. Elevation of well head, 805 feet.

	Top	Bottom	
Coal.....	30	34	
<i>Big Injun</i> sand.....	330	370	
Black shale, <i>Sunbury</i>	800	827	
<i>Berea</i> sand.....	827	844	
<i>Little Cinnamon</i> shale	1,290	1,375	
<i>Big Cinnamon</i> shale..	1,835	2,100	
<i>Big Lime</i>	2,354	3,398	Water 3,138 feet. Hole filled to within 400 feet of top. Sampled at 3,155 feet.
Break in line.....	3,330	3,340	
<i>First shell</i>	3,502	3,512	
<i>Clinton</i> sand.....	3,558	3,574	

Sample No. 13

Brine from the Holman heirs No. 3 well, Pure Oil Company, Section 6, Jackson Township, Muskingum County; taken by R. E. Lamborn, Geological Survey of Ohio, October 22, 1930; Downs Schaaf, analyst.

Specific gravity, 1.179 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.75
Br.....	0.46
SO ₄	0.18
CO ₃	None
HCO ₃	0.01
Na.....	20.09
K.....	0.64
Ca.....	12.84
Mg.....	2.89
(Al.Fe) ₂ O ₃	0.09
SiO ₂	0.05
Sr.....	.....
	100.00

Total dissolved solids..... { 257.0 grams per liter
218.0 grams per kilogram

Drillers Record

When this location was visited the five-inch casing had been set and the hole bailed out. The brine had been placed in a 50-barrel steel tank where it had stood about 36 hours before sampling. There had been no dilution by rainfall in the meantime and practically no increased concentration by evaporation.

Sample from Second Water at 2,500 feet; large flow of brine.

	Top	Bottom	
Gravel.....	0	65	
<i>Big Injun</i> sand.....	65	300	
Shale.....	300	680	
<i>Berea</i> sand.....	680	692	
Shale.....	692	1,900	
Lime, <i>Big Lime</i>	1,900	2,803	
<i>First Water</i>			Practically none.
<i>Second Water</i>	2,500		
Shale.....	2,803	2,928	
<i>Shell</i>	2,928	2,940	
Shale.....	2,940	2,978	
<i>Clinton</i> sand.....	2,978	3,015	
Slate, break.....	3,015	3,026	
Gray lime shells and shale in lime.....	3,026	3,033	
Slate.....	3,033	3,040	
Total depth.....		3,040	

Sample No. 49

Brine from the John Mason No. 1 well, Ohio Fuel Gas Company, northwest Section 21, Knox Township, Guernsey County; taken by J. W. Cummins, Geological Survey of Ohio, September 17, 1931; Downs Schaaf, analyst.

Specific gravity, 1.07 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	61.08
Br.....	0.59
SO ₄	Trace
CO ₃	None
HCO ₃	0.01
Na.....	27.87
K.....	0.83
Ca.....	7.83
Mg.....	1.19
(Al,Fe) ₂ O ₃	0.12
SiO ₂	0.01
Sr.....	0.47
	100.00
Total dissolved solids.....	{ 90.4 grams per liter 84.5 grams per kilogram

Drillers Record

Sample of brine from depth of 4,060 feet.

	Top	Bottom	
Coal.....	195	198	
<i>Big Injun</i> sand.....	545	715	
<i>Berea</i> sand.....	1,165	1,235	
<i>Big Lime</i>	3,296	4,661	Sample 4,060.
<i>Shell</i>			
<i>Clinton</i> sand.....	4,822	4,900	

Sample No. 48

Brine from the Emmet E. Hoover No. 3 well, operated by McClay Brothers, central Section 3, Perry Township, Licking County; taken by J. W. Cummins, Geological Survey of Ohio, October 2, 1931; Downs Schaaf, analyst.

Specific gravity, 1.1157 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.81
Br.....	0.36
SO ₄	0.15
CO ₃	None
HCO ₃	0.005
Na.....	20.04
K.....	0.61
Ca.....	12.73
Mg.....	2.91
(Al.Fe) ₂ O ₃	0.02
SiO ₂	0.005
Sr.....	0.36

100.000

Total dissolved solids.....	{	218.7 grams per liter
		196.0 grams per kilogram

Drillers Record

Sample of brine from depth of 2,500 feet.

	Top	Bottom	
<i>Berea</i> sand.....	775	788	
<i>Big Lime</i>	1,915	2,785	
Salt water at.....	2,490		Sample of brine at 2,500 feet.
<i>Shell</i>	2,892	2,923	
<i>Clinton</i> , top.....	2,945		
Gas at.....	2,950	2,954	
Total depth.....		2,954	

Sample No. 8

Brine from the Elmer Clark No. 1 well, The Preston Oil Company, Section 14, Perry Township, Coshocton County; taken by R. E.

Lamborn, Geological Survey of Ohio, October 14, 1930; Downs Schaaf, analyst.

Specific gravity, 1.2295 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	63.00
Br.....	0.73
SO ₄	0.07
CO ₃	None
HCO ₃	0.03
Na.....	17.90
K.....	0.30
Ca.....	14.79
Mg.....	3.10
(Al.Fe) ₂ O ₃	0.05
SiO ₂	0.03
Sr.....	.....
	100.00

Total dissolved solids.....	{ 337.37 grams per liter
	{ 274.4 grams per kilogram

Drillers Record

Hole had 200 feet of water at time of sampling. Sample was taken directly from bailer when hole had depth of 2,897 feet. Elevation of well head, 1,090 feet.

	Top	Bottom	
<i>Big Injun sand</i>	350	410	
<i>Berea sand</i>	940	944	
<i>Cinnamon shale</i>	1,700	1,975	
<i>Niagara lime</i>	2,150	3,053	Hole filled with water 2,870-3,053.
<i>Big Shell</i>	3,163	3,186	
<i>First Clinton sand</i>	3,210	3,236	
<i>Slate</i>	3,236	3,238	
<i>Second Clinton</i>	3,238	3,255	
<i>Medina red rock</i>	3,285	3,293	
<i>Pink Shell</i>	3,293	3,300	
Total depth.....		3,300	

Sample No. 50

Brine from the J. W. Mossholder No. 5 well, operated by Moore and Son, northwestern Section 15, Perry Township, Coshocton County; taken by J. W. Cummins, Geological Survey of Ohio, October 21, 1931; Downs Schaaf, analyst.

Specific gravity, 1.200 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	63.05
Br.....	0.50
SO ₄	0.12
CO ₃	None
HCO ₃	0.01
Na.....	17.63
K.....	0.42
Ca.....	14.54
Mg.....	3.21
(Al.Fe) ₂ O ₃	0.016
SiO ₂	0.004
Sr.....	0.50
	100.000
Total dissolved solids.....	{ 288 grams per liter 240 grams per kilogram

Drillers Record

Brine sampled from bailer at a depth of 2,660 feet.

	Top	Bottom	
<i>Big Injun</i> sand.....	340	378	
<i>Sunbury</i> shale.....	875	915	
<i>Berea</i> sandstone.....	915	923	
<i>Little Cinnamon</i>	1,420	1,550	
<i>Big Cinnamon</i>	1,818	1,955	
<i>Niagara</i> lime.....	2,117	3,012	
<i>Clinton</i> sand.....	3,144	3,203	
Total depth.....		3,206	Dry.

Sample No. 40

Brine from the James Allen No. 1 well, Whitehill Oil Company northeast corner Section 3, Jackson Township, Knox County; taken by J. W. Cummins, Geological Survey of Ohio, September 6, 1931; Downs Schaaf, analyst.

Specific gravity, 1.195 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.84
Br.....	0.70
SO ₄	0.09
CO ₃	None
HCO ₃	0.037
Na.....	19.82
K.....	0.13
Ca.....	13.33
Mg.....	2.89
(Al.Fe) ₂ O ₃	0.03
SiO ₂	0.003
Sr.....	0.13
	100.000
Total dissolved solids.....	{ 272.46 grams per liter 228.0 grams per kilogram

Drillers Record

Sample of brine from depth of 2,575 feet. Hole full of water.

	Top	Bottom	
Sand and gravel.....	0	72	
Shale and shaly sandstone	72	200	
<i>Big Injun</i> sand.....	200	400	
Slate and shells.....	400	745	
<i>Berea</i> sand.....	745	752	
Red rock.....	752	825	
Slate and shells.....	825	900	
Shale.....	900	1,893	
<i>Niagara</i> lime.....	1,893	2,774	
Hole full of water at.....	2,550		Sampled at 2,575 feet.
Slate and shells.....	2,774	2,879	
<i>Pink Shell</i>	2,879	2,899	
Slate.....	2,899	2,911	
<i>Clinton</i> sand.....	2,911	2,968	
Break.....	2,944	2,952	
Slate and shells.....	2,968	3,043	
<i>Medina</i> red shale.....	3,043	3,078	
Total depth.....		3,078	

Sample No. 47

Brine from the L. E. Rogers No. 2 well, Ohio Fuel Gas Company, southwest quarter Section 23, Union Township, Knox County; taken by J. W. Cummins, Geological Survey of Ohio, October 10, 1931; Downs Schaaf, analyst.

Specific gravity, 1.159 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	62.25
Br.....	0.70
SO ₄	0.20
CO ₂	None
HCO ₃	0.02
Na.....	21.88
K.....	0.75
Ca.....	10.77
Mg.....	2.90
(Al,Fe) ₂ O ₃	0.025
SiO ₂	0.005
Sr.....	0.50
	100.000
Total dissolved solids.....	{ 231.8 grams per liter { 200.0 grams per kilogram

Drillers Record

Sample of brine from depth of 2,590 feet.

	Top	Bottom	
<i>Big Injun</i> sand.....	160	350	
<i>Berea</i> sand.....	776	783	
<i>Second Berea</i>	806	877	
<i>Big Lime</i>	1,880	2,775	Sample 2,590
<i>Shell</i>	2,775	2,863	
<i>Clinton</i> sand.....	2,913	2,956	

Sample No. 14

Brine from the W. C. Workman No. 2 well, East Ohio Gas Company, one and one-half miles southwest of Jelloway, Brown Township, Knox County; taken by Wilber Stout, Geological Survey of Ohio, October 25, 1930; Downs Schaaf, analyst.

Specific gravity, 1.125 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	62.34
Br.....	0.39
SO ₄	0.49
CO ₃	None
HCO ₃	0.02
Na.....	20.40
K.....	0.65
Ca.....	12.92
Mg.....	2.56
(Al,Fe) ₂ O ₃	0.14
SiO ₂	0.09
Sr.....	.....
	100.00
Total dissolved solids.....	{ 171.56 grams per liter 152.5 grams per kilogram

Drillers Record

No water in Berea or in top of Big Lime at Oriskany horizon. No salt in Big Lime. Hole full of water at Big Water or Newburg horizon. All water from lower horizon, sample direct from bailer at depth of 2,300 feet.

	Top	Bottom
<i>Berea</i>	795	805
<i>Big Lime</i>	1,730	2,636
<i>Second Water</i> at.....	2,300	
<i>Shell</i>	2,701	2,732
<i>First</i> sand.....	2,752	2,759
<i>Clinton</i> sand.....	2,792	2,798
Total depth.....		2,813

Sample No. 51

Brine from the Charles Pryor property No. 1 well, Upham Gas Company, east central Section 7, Brown Township, Knox County; taken by J. W. Cummins, Geological Survey of Ohio, October 30, 1931; Downs Schaaf, analyst.

Specific gravity, 1.125 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.51
Br.....	0.60
SO ₄	0.36
CO ₂	None
HCO ₃	0.01
Na.....	19.48
K.....	0.54
Ca.....	13.39
Mg.....	2.86
(Al,Fe) ₂ O ₃	0.063
SiO ₂	0.007
Sr.....	0.18

100.000

Total dissolved solids.....	{ 184.5 grams per liter
	{ 164.0 grams per kilogram

Drillers Record

The Second Water of the Big Lime was found from 2,175 to 2,211 feet. The sample was taken direct from the bailer.

	Top	Bottom
<i>Big Lime</i>	1,620	2,547
<i>Second Water</i>	2,175	2,211
<i>Shell</i>	2,627	2,652
<i>Clinton sand</i>	2,672	2,706
<i>Medina red shale</i>	2,725	
Total depth.....		2,725

Sample No. 24

Brine from the Charles Levering No. 1 well, two miles northeast of Chesterville, northeast corner of Chester Township, Morrow County; taken by Albert B. Schuff, Marietta, June, 1931; Downs Schaaf, Geological Survey of Ohio, analyst.

Specific gravity, 1.062 at 15° C. Mineral sediment, dolomitic.

BRINES OF OHIO

Composition of saline matter

Cl.....	61.74
Br.....	0.62
SO ₄	1.36*
CO ₂	None
HCO ₃	0.12
Na.....	20.19
K.....	0.99
Ca.....	11.15
Mg.....	3.71
(Al.Fe) ₂ O ₃	0.06
SiO ₂	0.06
Sr.....	None

100.00

Total dissolved solids..... { 86 grams per liter
81 grams per kilogram

Drillers Record

Sample from Second Water in Big Lime at depth of 1,605 feet. Top of Big Lime at 1,142 feet. Second Water at 1,605 feet.

Sample No. 55

Brine from the Harvey Long No. 1 well, Ohio Falls Oil, Gas, and Supply Company, one and one-fourth miles southeast of Gnadenuhthen, Lot 22, Clay Township, Tuscarawas County; taken by J. W. Cummins, Geological Survey of Ohio, November 9, 1931; Downs Schaaf, analyst.

Specific gravity, 1.124 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.42
Br.....	0.33
SO ₄	0.45
CO ₂	None
HCO ₃	0.01
Na.....	20.87
K.....	0.71
Ca.....	11.87
Mg.....	2.93
(Al.Fe) ₂ O ₃	0.088
SiO ₂	0.002
Sr.....	0.32

100.000

Total dissolved solids..... { 172 grams per liter
153 grams per kilogram

Drillers Record

Sample of brine from depth of 4,725 feet. Elevation of well head, 1,024 feet.

	Top	Bottom	
Coal.....	160	168	
Second coal.....	255	258	
Big Injun sand.....	465	680	
Squaw sand.....	710	800	
Berea sand.....	1,215	1,277	
Big Lime.....	3,325	5,000	Sample 4,725
Clinton sand.....	5,203	5,221	

*Sample of brine when received contained 100 parts per 1,000,000 of H₂S.

Sample No. 22

Brine from the J. H. Weaver No. 1 well, Rippel, Euga, and Rippel, southeast Section 3, Fairfield Township, Tuscarawas County; taken by D. R. Rippel, Dover, Ohio, May, 1931; Downs Schaaf, Geological Survey of Ohio, analyst.

Specific gravity, 1.235 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.39
Br.....	0.62
SO ₄	0.035
CO ₃	None
HCO ₃	0.015
Na.....	17.79
K.....	0.98
Ca.....	14.93
Mg.....	2.37
(Al.Fe) ₂ O ₃	0.02
SiO ₂	0.02
Sr.....	0.83
	100.000

Total dissolved solids..... { 354.07 grams per liter
286.7 grams per kilogram

Drillers Record

Heavy flow of brine sampled at a depth of about 4,530 feet. Elevation of well head, 922 feet.

	Top	Bottom	
<i>Salt sand</i>	110	125	
<i>Big Injun sand</i>	280	385	
<i>Berea sand</i>	855	947	Salt water at 870
<i>Gordon sand</i>	1,180	1,195	
<i>Big Lime</i>	3,180	4,700	
Salt beds.....	3,870	3,940	
<i>Big Water</i>	4,515	4,670	Heavy flow about 4,530. Sampled.
<i>Little Lime</i>	4,804	4,836	
<i>Clinton sand</i>	4,913	5,006	

Sample No. 52

Brine from Young and Yant well, State Development Company, one mile northeast of Sandyville, Section 2, allotted, Sandy Township, Tuscarawas County; taken by J. W. Cummins, Geological Survey of Ohio, September 10, 1931; Downs Schaaf, analyst.

Specific gravity, 1.23 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.34
Br.....	0.90
SO ₄	0.03
CO ₃	None
HCO ₃	0.02
Na.....	18.34
K.....	0.79
Ca.....	14.46
Mg.....	2.52
(Al.Fe) ₂ O ₃	0.028
SiO ₂	0.002
Sr.....	0.57
	100.000

Total dissolved solids..... { 341.94 grams per liter
 { 278.0 grams per kilogram

Drillers Record

Sample of brine from Second Water at a depth of 4,250 feet. Elevation of well head, 972 feet.

	Top	Bottom	
<i>Big Injun sand</i>	225	335	
<i>Berea sand</i>	746	855	
<i>Big Lime</i>	3,015	4,529	
<i>First Water</i>	None		
<i>Salt, Salina</i>	3,640	3,940	
<i>Second Water</i>	4,246	4,361	Sample at 4,250 feet.
<i>Little Lime</i>	4,627	4,650	
<i>Clinton</i> {	stray.....	4,682	4,695
	red.....	4,695	4,716
	white.....	4,738	4,778
Total depth.....		4,823	

Sample No. 9

Brine from the R. E. Hawkins No. 1 well, Ohio Fuel Gas Company, Section 11, Richland Township, Holmes County; taken by R. E. Lamborn, Geological Survey of Ohio, October 15, 1930; Downs Schaaf, analyst.

Specific gravity, 1.125 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	62.81
Br.....	0.45
SO ₄	0.29
CO ₃	None
HCO ₃	0.03
Na.....	20.19
K.....	0.52
Ca.....	12.04
Mg.....	3.43
(Al.Fe) ₂ O ₃	0.18

SiO ₂	0.06
Sr.....	.....
	100.00
Total dissolved solids.....	{ 174.04 grams per liter 154.7 grams per kilogram

Drillers Record

Hole had depth of about 3,060 feet at time of sampling. About 2,500 feet of water was in the hole when brine was sampled. The sample was taken from bailer which had been lowered to a depth of about 50 feet below the top of the water. Elevation of well head, 1,175 feet.

	Top	Bottom	
<i>Berea sand</i>	938	948	
<i>Cinnamon slate</i>	1,700	1,960	
<i>Brown slate</i>	2,100	2,158	
<i>Big Lime</i>	2,158	3,230	First Water, 2,320-2,457
<i>Little Lime</i>	3,251	3,301	Second Water, 2,820-3,218.
			Hole full.
<i>Stray sand</i>	3,319	3,329	
<i>Clinton sand</i>	3,341	3,368	
Total depth.....		3,368	

Sample No. 5

Brine from the L. Haudenschild No. 1 well, Ohio Fuel Gas Company, Section 9, Washington Township, Holmes County; taken by R. E. Lamborn, Geological Survey of Ohio, October 10, 1930; Downs Schaaf, analyst.

Specific gravity, 1.178 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	62.75
Br.....	0.42
SO ₄	0.23
CO ₃	None
HCO ₃	0.025
Na.....	19.60
K.....	0.69
Ca.....	13.09
Mg.....	3.02
(Al.Fe) ₂ O ₃	0.14
SiO ₂	0.035
Sr.....	.....
	100.000
Total dissolved solids.....	{ 252.8 grams per liter 214.6 grams per kilogram

Drillers Record

Sample taken directly from bailer when hole was at a depth of 2,724. No dilution of sample. Elevation of well head, 1,180 feet.

	Top	Bottom	
<i>Berea</i> sand.....	781	807	
<i>Cinnamon</i> slate.....	1,535	1,735	
<i>Big Lime</i>	1,896	2,894	Hole full water 2,085. 1 bailer per hr. at 2,680. 5 bailers per hr. at 2,724.
<i>Little Lime</i>	2,959	2,979	
<i>Stray</i> sand.....	2,999	3,011	
<i>Clinton</i> sand.....	3,039	3,052	
Slate.....	3,052	3,121	
Total depth.....		3,121	

Sample No. 200

Brine from the George Reamer No. 1 well, Natural Gas Company of West Virginia, Section 11, West Township, Columbiana County; taken by R. E. Cushing, field superintendent, Natural Gas Company of West Virginia, fall of 1920; D. J. Demorest, analyst.¹

Composition of saline matter

Cl.....	58.333
Br.....	.005
SO ₄.....	.0594
CO ₃	
HCO ₃	
Na.....	19.722
K.....	6.083
Ca.....	12.888
Mg.....	1.860
(Al.Fe) ₂ O ₃.....	.264
SiO ₂.....	.011
Sr.....	
Mn.....	.022
I.....	.024
Total dissolved solids.....	{ 360 grams per liter 292 grams per kilogram (Calculated)

Drillers Record²

This sample consisted chiefly of Second Water in the Big Lime. It was struck at a depth of 4,805 feet and filled the hole with 2,800 feet of brine. As no liner was used through the salt beds the composition as shown in the analysis may have been slightly altered by reaction of brine with the wall rock. Elevation of well head, 1,275 feet.

	Top	Bottom
Coal, <i>Middle Kittanning</i>	140	141
Coal, <i>Lower Kittanning</i>	190	192
Sand, <i>Berea</i>	721	759

¹Geol. Survey Ohio, Bull. 28, p. 368.

²For detailed drill record see Bulletin 28, p. 368.

	Top	Bottom
Shales, <i>Bedford</i> and <i>Ohio</i>	759	3,460
Limestones and dolomites, <i>Delaware</i> , <i>Columbus</i> , and <i>Monroe</i>	3,460	4,232
Dolomite with salt layers, <i>Salina</i>	4,232	4,805
Heavy flow of brine at.....		4,805
Dolomite and limestone, <i>Guelph</i> and <i>Lockport</i>	4,805	5,447
Shale, <i>Rochester</i>	5,447	5,488
Limestones and shales, <i>Irondequoit</i> and <i>Wolcott</i> ..	5,488	5,537
Shale.....	5,537	5,576
Sandstone, <i>Clinton</i>	5,576	5,689
Shales, gray and red.....	5,689	5,801
Total depth.....		5,801

Sample No. 28

Brine from the J. C. Steiner No. 1 well, Brendel Brothers, southeast Section 16, Jackson Township, Stark County; taken by J. W. Cummins, Geological Survey of Ohio, July 23, 1931; Downs Schaaf, analyst.

Specific gravity, 1.229 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	62.12
Br.....	0.77
SO ₄	0.05
CO ₃	None
HCO ₃	0.09
Na.....	20.08
K.....	0.91
Ca.....	13.48
Mg.....	2.15
(Al,Fe) ₂ O ₃	0.017
SiO ₂	0.003
Sr.....	0.33
	100.000

Total dissolved solids { 335.5 grams per liter
273.0 grams per kilogram

Drillers Record

Sample of brine taken from Second Water at a depth of 3,770 feet. Elevation of well head, 1,083 feet.

	Top	Bottom	
<i>Big Injun</i> sand..	190	325	
<i>Berea</i> sand.....	631	660	
<i>Big Lime</i>	2,538	4,048	
Salt.....	3,130	3,335	
Second water at		3,770	Sample of brine at 3,770.
<i>Shell</i>	4,158	4,178	
<i>Clinton</i> sand.....	4,256	4,292	

Sample No. 16

Brine from the John Criswell No. 1 well, Ohio Fuel Gas Company, Section 14, Green Township, Ashland County; taken by R. E. Lamborn, Geological Survey of Ohio, November 1, 1930; Downs Schaaf, analyst

Specific gravity, 1.219 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	62.93
Br.....	0.94
SO ₄	0.08
CO ₃	None
HCO ₃	0.02
Na.....	16.51
K.....	0.71
Ca.....	15.46
Mg.....	3.25
(Al.Fe) ₂ O ₃	0.06
SiO ₂	0.04
Sr.....	.....
	100.00
Total dissolved solids.....	{ 311.5 grams per liter 255.5 grams per kilogram

Drillers Record

The depth of hole at time of sampling was 2,674 feet and the water in hole measured about 600. The sample was taken from the bailer which was lowered to the bottom of hole. Elevation of well head, 1,300 feet.

	Top	Bottom	
Sand.....	145	155	
Shale and shells.....	155	822	
<i>Berea</i> sand.....	822	837	No oil, gas, or water.
<i>Niagara</i> lime.....	1,834	2,799	
Lime.....	1,834	2,020	
Sand.....	2,020	2,025	Hole full of water.
Lime.....	2,025	2,621	
Sand.....	2,621	2,631	Hole full of water.
Lime.....	2,631	2,799	
Lime shell.....	2,848	2,883	
<i>Clinton</i> sand.....	2,943	2,947	No oil, gas, or water.
Total depth.....		3,002	

Sample No. 44

Brine from the Leah Clever No. 1 well, Ohio Fuel Gas Company, central Section 15, Worthington Township, Richland County; taken by J. W. Cummins, Geological Survey of Ohio, August 15, 1931; Downs Schaaf, analyst.

Specific gravity, 1.198 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	62.81
Br.....	0.50
SO ₄	0.07
CO ₃	None
HCO ₃	0.01
Na.....	19.70
K.....	0.59
Ca.....	13.07
Mg.....	2.93
(Al.Fe) ₂ O ₃	0.025
SiO ₂	0.005
Sr.....	0.29

100.000

Total dissolved solids..... { 286.3 grams per liter
239.0 grams per kilogram

Drillers Record

Sample of brine taken at a depth of 2,400 feet.

	Top	Bottom	
<i>Big Injun</i> sand..	165	200	No oil, gas, or water.
<i>Berea</i> sand.....	595	615	¼ bbl. water per hr.
<i>Cinnamon</i> shale..	1,020	1,380	No oil, gas, or water.
<i>Niagara</i> lime.....	1,495		
Water sand.....	1,640	1,660	¼ bbl. water per hr.
Water sand.....	2,170	2,408	Hole full.
Bottom of lime..		2,408	
<i>Packer shell</i>	2,443	2,462	
Slate.....	2,462	2,633	
<i>Clinton</i> sand.....	None		
Total depth		2,633	Plugged and abandoned.

Sample No. 1

Brine from the Roy C. Milner No. 1 well, Brendel Brothers, Section 25, Franklin Township, Summit County; taken by R. E. Lamborn, Geological Survey of Ohio, September 16, 1930; Downs Schaaf, analyst.

Specific gravity, 1.185 at 15° C. Mineral sediment, stone gray-colored dolomite.

Composition of saline matter

Cl.....	62.53
Br.....	0.48
SO ₄	0.13
CO ₃	None
HCO ₃	0.025
Na.....	20.84
K.....	0.79
Ca.....	12.575
Mg.....	2.59

(Al.Fe) ₂ O ₃	0.03
SiO ₂	0.01
Sr.....	.....
	100.000
Total dissolved solids.....	{ 269.6 grams per liter
	{ 227.5 grams per kilogram

Drillers Record

The Big Water reached at 3,640 feet and cased out by 5-inch casing extending to depth of 3,821 feet. Sample was taken from water bailed from well after casing was set.

	Top	Bottom	
<i>Big Injun</i> sand.....	90	300	
<i>Berea</i> sand.....	650	705	
<i>Big Lime</i>	2,473	3,892	
Salt.....	3,165	3,195	
<i>Big Water</i>	3,640		Hole full.
<i>Shell</i>	3,974	3,988	
<i>Stray</i> sand.....	4,024	4,035	
Red sand.....	4,035	4,076	
<i>Clinton</i> sand.....	4,076	4,112	
Total depth.....		4,113	

Sample No. 45

Brine from the M. Thornton No. 1 well, operated by Bacon and White, one and one-half miles northeast of Bates Corners, Lot 47, Copley Township, Summit County; taken by J. W. Cummins, Geological Survey of Ohio, September 16, 1931; Downs Schaaf, analyst.

Specific gravity, 1.197 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	62.35
Br.....	0.51
SO ₄	0.08
CO ₂	None
HCO ₃	0.04
Na.....	21.68
K.....	0.63
Ca.....	11.70
Mg.....	2.48
(Al.Fe) ₂ O ₃	0.015
SiO ₂	0.005
Sr.....	0.51
	100.000
Total dissolved solids.....	{ 284.9 grams per liter
	{ 238.0 grams per kilogram

Drillers Record

Elevation of well head, 982 feet. Sample of brine from Second Water at 3,300 feet.

	Top	Bottom	
<i>Berea</i> sand.....	390	430	
<i>Big Lime</i>	2,011	3,487	
<i>First Water</i> in <i>Big Lime</i>	2,290	2,415	
Salt.....	2,647	2,864	
<i>Newburg</i> sand.....	3,240	3,260	
<i>Second Water</i> in <i>Big Lime</i>	3,240		Sample of brine at 3,300 feet.
<i>Little Lime</i>	3,556	3,581	
{ red sand.....	3,620	3,647	
<i>Clinton</i> { shale.....	3,647	3,658	
{ white sand.....	3,658	3,662	
{ sand, broken.....	3,662	3,678	
Total depth.....		3,733	

Sample No. 4

Brine from the Emma F. Hutton No. 2 well, Ohio Fuel Gas Company, Lot 22, Lafayette Township, Medina County; taken by R. E. Lamborn, Geological Survey of Ohio, October 10, 1930; Downs Schaaf, analyst.

Specific gravity, 1.211 at 15° C. Mineral sediment, dolomitic.

Composition of saline matter

Cl.....	61.79
Br.....	0.23
SO ₄	0.17
CO ₂	None
HCO ₃	0.015
Na.....	28.365
K.....	0.38
Ca.....	7.32
Mg.....	1.69
(Al.Fe) ₂ O ₃	0.03
SiO ₂	0.01
Sr.....	.....
	100.000
Total dissolved solids.....	{ 315.95 grams per liter 260.9 grams per kilogram

Drillers Record

Sample was taken directly from bailer when hole had a depth of 2,869 feet. Hole only made about two bailers per screw in Second Water. Elevation of well head, 1,120 feet.

	Top	Bottom
Soil.....	0	13
Clay.....	13	18
Quicksand.....	18	40

	Top	Bottom	
Shale.....	40	518	
Berea sand.....	518	522	
Red rock.....	522	598	
Sand.....	598	618	
Red rock.....	618	660	
Brown shale.....	660	700	
White shale.....	700	1,175	
Brown Cinnamon shale.....	1,175	1,325	
White shale.....	1,325	1,350	
Cinnamon shale.....	1,350	1,420	
White shale.....	1,420	1,430	
Cinnamon shale.....	1,430	1,590	
White shale.....	1,590	1,740	
Brown shale.....	1,740	1,791	
Lime.....	1,791		
First Water of Big Lime.....	1,795		1 bailer per hr.
Water.....	2,022		Hole full.
Salt, Salina.....	2,279	2,329	
Lime.....	2,329	2,490	
Shale.....	2,490	2,520	
Lime.....	2,520		
Second Water of Big Lime.....	2,860		2 bailers perscrew.
Lime.....	2,860	2,988	
Packer Shell.....	3,036	3,056	
Stray sand.....	3,101	3,115	
Clinton sand.....	3,126	3,146	
Broken sand and shale.....	3,146	3,183	
Total depth.....		3,183	

Sample No. 26

Brine from the Metzger No. 1 well, operated by J. W. Cushing, three-fourths mile southeast of Liverpool Station, Liverpool Township, Medina County; taken by A. A. L. Mathews, Geological Survey of Ohio, June, 1931; Downs Schaaf, analyst.

Specific gravity, 1.229 at 15° C. Mineral sediment, none.

Composition of saline matter

Cl.....	63.32
Br.....	0.64
SO ₄	0.025
CO ₃	None
HCO ₃	0.015
Na.....	16.83
K.....	0.53
Ca.....	14.83
Mg.....	3.50
(Al.Fe) ₂ O ₃	0.03
SiO ₂	0.05
Sr.....	0.23
	100.000
Total dissolved solids.....	{ 326.3 grams per liter 265.5 grams per kilogram

Drillers Record

At 2,695 feet hole full of water; seven bailers per minute; sample taken.

	Top	Bottom	
<i>Berea</i> sand.....	326	489	
<i>Big Lime</i>	1,565	2,800	
<i>First Water</i> of Big Lime.....	1,795		
Salt, <i>Salina</i>	2,085	2,140	
<i>Second Water</i> of Big Lime.....	2,695		Sampled.
<i>Little Lime</i>	2,903	2,927	
Sand, <i>Clinton</i>	2,983		

Sample No. 2

Brine from the M. Kolb No. 2 well, drilled by a local stock company, one and one-half miles southwest of Laporte, north central Section 14, Carlisle Township, Lorain County; taken by R. E. Lamborn, Geological Survey of Ohio, September 23, 1930; Downs Schaaf, analyst.

Specific gravity, 1.225 at 15° C. Mineral sediment, light gray-colored dolomite.

Composition of saline matter

Cl.....	62.89
Br.....	0.54
SO ₄	0.08
CO ₂	None
HCO ₃	0.02
Na.....	19.71
K.....	0.65
Ca.....	12.96
Mg.....	3.105
(Al,Fe) ₂ O ₃	0.03
SiO ₂	0.015
Sr.....	.....
	100.000
Total dissolved solids.....	{ 318.5 grams per liter 260.0 grams per kilogram

Drillers Record

The first screw in the Second or Big Water yielded 3½ bailers of water and the second screw 4 bailers of water per minute. One-half of the sample was taken directly from bailer after drilling in the first screw and the remainder of sample from bailer after second screw.

	Top	Bottom	
<i>Big Lime</i>	1,030	2,276	
<i>First Water</i> of Big Lime.....	1,292		Hole full brine.
<i>Second Water</i> of Big Lime.....	2,125	2,137	
<i>Clinton</i> sand.....	2,358	2,380	
Total depth.....		2,383	

Sample No. 229

Brine from the Bowling Green Natural Gas Company No. 2 well, at Bowling Green, Wood County; taken by C. W. Evers, about 1886; N. W. Lord, analyst.¹

Specific gravity, 1.117.

Principal salts, parts per thousand

NaCl.....	83.30
CaCl ₂	60.05
MgCl ₂	15.96
CaSO ₄	1.04
H ₂ S.....	Trace
	160.35

Composition of saline matter

Cl.....	62.851
Br.....	
SO ₄	0.458
CO ₃	
HCO ₃	
Na.....	20.438
K.....	
Ca.....	13.711
Mg.....	2.542
(Al.Fe) ₂ O ₃	
SiO ₂	
Sr.....	
H ₂ S.....	Trace
	100.000

Total dissolved solids.....	}	179.11 grams per liter
		160.35 grams per kilogram

Drillers Record

Record approximated by using well No. 1 instead of well No. 2. Sample of brine from base of Niagara limestone, 220 to 240 feet.

	Top	Bottom
Drift.....	0	10
Niagara limestone.....	10	240
Niagara shale (15 to 30 feet).....	240	255
Clinton group.....	255	315
Medina shale (30 to 50 feet).....	315	365
Hudson River shale.....	365	845
Utica shale.....	845	1,095
Trenton limestone.....	1,095	1,190

¹Geol. Survey Ohio, Vol. VI, p. 157.

Blank Page

Blank Page

INDEX

A

	Page
Allensville sandstone.....	23
Alumina.....	33
Ashland County	
First Water of Big Lime.....	25, 64, 66-68
Second Water of Big Lime.....	104
Ashland County	
Green Township.....	104
Jackson Township.....	68
Montgomery Township.....	67
Perry Township.....	66-67
Ashtabula County	
First Water of Big Lime.....	25
Rock salt.....	26
St. Peter sandstone.....	28
Athens County, history of brines in.....	13
Athens County	
Big Injun sand.....	47
Cow Run sandstone.....	20
Keener sand.....	23, 40
Massillon sandstone.....	22
Second Water of Big Lime.....	83-85
Athens County	
Dover Township.....	13
York Township.....	13, 83-85

B

Barium.....	33
Belmont County	
Berea sand.....	58-59
Big Injun sand.....	47
Keener sand.....	23, 40
Rock sa't.....	26
Belmont County	
Warren Township.....	58-59
Berea sand.....	14, 16, 52-63
Berea sand in	
Belmont County.....	58-59
Mahoning County.....	62-63
Medina County.....	63
Meigs County.....	53-54
Monroe County.....	57-58
Noble County.....	54-57
Scioto County.....	52-53
Stark County.....	60-62
Tuscarawas County.....	59-60
Berea sandstone.....	22, 23-24
Berne sandstone.....	23
Big Injun sand (See Black Hand).....	13, 23, 47-52

	Page
Big Injun sand	
Meigs County.....	48-49
Monroe County.....	51-52
Noble County.....	50-51
Big Lime.....	26-27
Big Water.....	26-27
Black Hand formation.....	13
Black Hand sandstone (See Big Injun).....	22, 23, 47-52
Bromine.....	28, 30, 48, 52, 78, 79
Bromine from	
Berea sand.....	52
Big Injun sand.....	48
First Water of Big Lime.....	78-79
Second Water of Big Lime.....	78-79
Bromine, compounds of.....	30
Buena Vista sandstone.....	23
Byer sandstone.....	23

C

Calcium, salts of.....	30-31
Calcium chloride.....	28, 31, 48, 52, 64, 78
Berea sand.....	52
Big Injun sand.....	48
First Water of Big Lime.....	64
Keener sand.....	40
Macksburg Five Hundred-foot sand.....	33
Maxton sand.....	35
Cambrian system.....	28
Carroll County	
Rock salt.....	26
Chemical analyses, samples from	
Berea sand.....	52-63
Big Injun sand.....	48-52
First Water of Big Lime.....	64-74
Keener sand.....	41-47
Macksburg Five Hundred-foot sand.....	34-35
Maxton sand.....	35-37
Maxville or "Big Lime" sand.....	38-40
Salina formation.....	75-78
Second Water of Big Lime.....	79-110
Chlorine, compounds of.....	31-32
Cincinnati, St. Peter sandstone at.....	28
Clarion sandstone (See Macksburg Five Hundred-foot).....	21
Columbiana County, history of brines in.....	13
Columbiana County	
Rock salt.....	26

	Page
Coshocton County	
Second Water of Big Lime.....	92-94
Coshocton County	
Perry Township.....	92-94
Cow Run sandstone.....	20
Cuyahoga County, history of brines in.....	14, 26
Cuyahoga County	
Rock salt.....	26
Salina formation.....	77-78
Cuyahoga County	
Cleveland.....	77-78
Cuyahoga formation.....	22, 23

D

Delaware County, saline springs in.....	12
Depth of brines.....	17, 18
Devonian system.....	24-25
Dover, Tuscarawas County.....	14, 28
Drillers records	
Ashland County.....	67, 68, 104
Athens County.....	83-84, 85
Columbiana County.....	102-103
Coshocton County.....	93, 94
Cuyahoga County.....	78
Guernsey County.....	92
Hocking County.....	85
Holmes County.....	101, 102
Jackson County.....	80-81
Jefferson County.....	65
Knox County.....	95, 96, 97
Lake County.....	74
Lawrence County.....	79-80
Licking County.....	92
Lorain County.....	73-74, 109
Mahoning County.....	63
Medina County.....	63, 70, 71, 72, 107-108, 109
Meigs County.....	36, 49, 54
Monroe County.....	37, 39, 42, 43, 47
Morrow County.....	97-98
Muskingum County.....	87-88, 89, 90, 91
Noble County.....	42, 57
Perry County.....	86, 87
Richland County.....	69, 104-105
Scioto County.....	53
Stark County.....	61, 75-76, 103
Summit County.....	70, 106, 107
Tuscarawas County.....	60, 98, 99, 100
Vinton County.....	82-83
Wayne County.....	65, 76-77
Wood County.....	110

	F	Page
Fairfield County		
Big Injun sand.....		23
First Salt sand (See Massillon sandstone).....		21
First Water of Big Lime (See Oriskany sandstone).....		16, 25, 64-74, 78
First Water of Big Lime		
Ashland County.....		25, 66-68
Ashtabula County.....		25
Jefferson County.....		25, 64-65
Lake County.....		74
Lawrence County.....		25
Lorain County.....		25, 72-74
Medina County.....		25, 70-72
Richland County.....		25, 68-69
Summit County.....		69-70
Wayne County.....		25, 65-66

G

Gallia County, history of brines in.....		12-13
Geauga County		
Rock salt.....		26
Geologic history.....		15
Geological Survey of Ohio, reports of.....		11
Guernsey County, history of brines in.....		13-14
Guernsey County		
Big Injun sand.....		47
Keener and.....		23, 40
Second Water of Big Lime.....		91-92
Guernsey County		
Knox Township.....		91-92

H

Harrison County		
Rock salt.....		26
Highbridge Formation.....		27
Hildreth, S. P., reference to.....		11
Hocking County		
Big Injun sand.....		23
Second Water of Big Lime.....		85
Hocking County		
Benton Township.....		85
Holmes County		
Second Water of Big Lime.....		100-102
Holmes County		
Richland Township.....		100-101
Washington Township.....		101-102

I

Iodine.....		33
Iron salts.....		33

Page

J

Jackson County, history of brines in.....	11-12
Jackson County	
St. Peter sandstone.....	28
Second Water of Big Lime.....	80-81
Jackson County	
Coal Township.....	80-81
Jefferson County	
First Water of Big Lime.....	25, 64-65
Rock salt.....	26
Jefferson County	
Island Creek Township.....	26, 64-65

K

Keener sand (See Vinton sandstone).....	23, 40-47
Keener sand	
Athens County.....	23
Belmont County.....	23
Guernsey County.....	23
Monroe County.....	23, 42-47
Morgan County.....	23
Noble County.....	23, 41-42
Washington County.....	23
Knox County	
Second Water of Big Lime.....	94-97
Knox County	
Brown Township.....	96-97
Jackson Township.....	94-95
Union Township.....	95-96

L

Lake County, use of brines in.....	26
Lake County	
First Water of Big Lime.....	74
Rock salt.....	26
Lake County	
Painesville Township.....	74
Lawrence County	
First Water of Big Lime.....	25
Second Water of Big Lime.....	79-80
Lawrence County, Elizabeth Township.....	79-80
Legislation, early.....	12
Lexington formation (See Trenton).....	27
Licking County	
Big Injun sand.....	23
Second Water of Big Lime.....	92

	Page
Licking County	
Perry Township.....	92
Lithium.....	33
Logan formation.....	22, 23
Lorain County	
First Water of Big Lime.....	16, 25, 26, 64, 72-74
Rock salt.....	26
Second Water of Big Lime.....	109
Lorain County	
Carlisle Township.....	16, 26, 73-74, 109
Columbia Township.....	72-73
Lower Freeport sandstone (See Second Cow Run).....	21
Lower Salt sand (See Sharon conglomerate or Peeker).....	22

M

Macksburg Five Hundred-foot sand (See Clarion sandstone).....	21, 33-35
Macksburg Five Hundred-foot sand	
Noble County.....	33-35
Macksburg Three Hundred-foot sand (See Mahoning sandstone).....	20-21
Magnesium, compounds of.....	32
Magnesium chloride.....	32, 52, 64, 78
Berea sand.....	52
First Water of Big Lime.....	64
Keener sand.....	40
Maxton sand.....	35
Mahoning County	
Berea sand.....	62-63
Rock salt.....	26
Mahoning County	
Beaver Township.....	62-63
Mahoning sandstone (See Macksburg Three Hundred-foot).....	20-21
Manganese.....	33
Massillon sandstone (See Salt or Salt sand).....	21
Maxton sand (See Sharon conglomerate).....	22, 35-37
Maxton sand	
Meigs County.....	35-36
Monroe County.....	36-37
Maxville or "Big Lime" sand	
Monroe County.....	37-40
Medina County, history of brines in.....	14, 26
Medina County	
Berea sand.....	63
First Water of Big Lime.....	25, 64, 70-72
Rock salt.....	26
Second Water of Big Lime.....	107-109
Medina County	
Chatham Township.....	63
Homer Township.....	70
Lafayette Township.....	107-108
Litchfield Township.....	71
Liverpool Township.....	71-72, 108-109

	Page
Meigs County, history of brines in.....	13
Meigs County	
Berea sand.....	53-54
Big Injun sand.....	47, 48-49
Massillon sandstone.....	21-22
Maxton sand.....	35-36
Meigs County	
Salisbury Township.....	48-49
Scipio Township.....	35-36
Sutton Township.....	53-54
Mississippian system.....	22-24
Monroe County	
Berea sand.....	57-58
Big Injun sand.....	47, 51-52
Keener sand.....	23, 40, 42-47
Macksburg Five Hundred-foot sand.....	33
Maxton sand.....	36-37
Maxville sand.....	37-40
Monroe County	
Center Township.....	57-58
Jackson Township.....	51-52
Malaga Township.....	36-37, 38-40, 42-46
Sunsbury Township.....	46-47
Morgan County, history of brines in.....	13
Morgan County	
Big Injun sand.....	47
Cow Run sandstone.....	20
Keener sand.....	23, 40
Macksburg Five Hundred-foot sand.....	33
Morrow County	
Second Water of Big Lime.....	97-98
Morrow County	
Chester Township.....	97-98
Muskingum County, history of brines in.....	12
Big Injun sand.....	47
Cow Run sandstone.....	20
Second Water of Big Lime.....	87-91
Muskingum County	
Brush Creek Township.....	87-88
Falls Township.....	89-90
Hopewell Township.....	88
Jackson Township.....	90-91
Salt Creek Township.....	12
Washington Township.....	16, 88-89
N	
Newark, St. Peter sandstone at.....	28
Newburg formation (See Second Water of Big Lime).....	25, 26-27
Newburg, gas field at.....	26

	Page
Noble County	
Berea sand.....	54-57
Big Injun sand.....	47, 50-51
Cow Run sandstone.....	20
Keener sand.....	23, 40, 41-42
Macksburg Five Hundred-foot sand.....	33-35
Noble County	
Center Township.....	34-35
Marion Township.....	50-51, 54-55
Seneca Township.....	41-42, 56-57
O	
Ohio shale.....	12
Ordovician system.....	27-28
Oriskany formation (See First Water of Big Lime).....	25
P	
Peeker sand (See Lower Freeport sandstone).....	21
Pennsylvanian system.....	20-22
Permian system.....	19
Perry County	
Second Water of Big Lime.....	86-87
Perry County	
Madison Township.....	86-87
Reading Township.....	86
Pomeroy, early salt making at.....	13, 22
Pomeroy, early production of bromine at.....	28
Portage County	
Rock salt.....	26
Potassium.....	33
Potassium chloride in	
First Water of Big Lime.....	64
Second Water of Big Lime.....	78
R	
Richland County	
First Water of Big Lime.....	25, 64, 68-69
Second Water of Big Lime.....	104-105
Richland County	
Miffin Township.....	68-69
Worthington Township.....	104-105
Rock salt.....	25-26
S	
St. Peter formation.....	27-28
Salina formation.....	25-26, 74-78

	Page
Salina formation	
Cuyahoga County.....	14, 77-78
Medina County.....	14
Stark County.....	75-76
Summit County.....	14
Wayne County.....	14, 76-77
Salt.....	9, 11, 12, 13, 29, 48
Salt sand (See Massillon sandstone).....	21
Sandusky County	
St. Peter sandstone.....	28
Scioto County	
Berea sand.....	16, 52-53
Scioto County	
Jefferson Township.....	16, 52-53
Scioto saline springs.....	11
Sea water, brines from.....	15, 16-17
Second Cow Run sand (See Lower Freeport).....	21
Second Water of Big Lime (See Newburg).....	16, 26-27, 78-110
Second Water of Big Lime	
Ashland County.....	104
Athens County.....	83-85
Co'umbiana County.....	102-103
Coshocton County.....	92-94
Guernsey County.....	91-92
Hocking County.....	85
Holmes County.....	100-102
Jackson County.....	80-81
Knox County.....	94-97
Lawrence County.....	79-80
Licking County.....	92
Lorain County.....	109
Medina County.....	107-109
Morrow County.....	97-98
Muskingum County.....	87-91
Perry County.....	86-87
Richland County.....	104-105
Stark County.....	103
Summit County.....	105-107
Tuscarawas County.....	98-100
Vinton County.....	81-83
Wood County.....	110
Sharon conglomerate (See Maxton or Lower Salt sand).....	11, 22, 35-37
Silica.....	33
Silurian system.....	25-27
Sodium, compounds of.....	28-30
Sodium chloride from	
Berea sand.....	52
Clarion sandstone.....	21
First Water of Big Lime.....	64
Keener sand.....	40
Maxton sand.....	35
Salina formation.....	74-75
Second Water of Big Lime.....	78

	Page
Springfield, St. Peter sandstone at.....	28
Stadler sand (See Newburg).....	26-27
Stark County	
Berea sand.....	60-62
Rock salt.....	26
Salina formation.....	75-76
Second Water of Big Lime.....	103
Stark County	
Canton Township.....	60-61
Jackson Township.....	103
Lake Township.....	75-76
Osnaburg Township.....	61-62
Strontium, compounds of.....	32-33
Summit County, history of salt in.....	14, 26
Summit County	
First Water of Big Lime.....	69-70
Rock salt.....	26
Second Water of Big Lime.....	16, 105-107
Summit County	
Bath Township.....	16, 69-70
Copley Township.....	106-107
Franklin Township.....	105-106

T

Trenton formation (See Lexington).....	27
Trumbull County, rock salt in.....	26
Tuscarawas County, history of brines in.....	14
Tuscarawas County, early production of bromine in.....	28
Tuscarawas County	
Berea sand.....	59-60
Rock salt.....	26
Second Water of Big Lime.....	16, 98-100
Tuscarawas County	
Clay Township.....	98
Dover Township.....	59-60
Fairfield Township.....	16, 99
Sandy Township.....	99-100

U

United States Bureau of Soils.....	74
United States Geological Survey, reference to.....	16, 34, 36, 38, 39, 41, 42, 43, 45, 46, 50, 51, 55, 56, 57, 58, 60, 61, 74

V

Page

Vinton County	
Big Injun sand.....	47
Second Water of Big Lime.....	81-83
Vinton County	
Clinton Township.....	81-82
Swan Township.....	82-83
Vinton sandstone.....	22, 23

W

Washington County	
Big Injun sand.....	47
Cow Run sandstone.....	20
Keener sand.....	23, 40
Macksburg Five Hundred-foot sand.....	33
Wayne County, history of salt in.....	14, 26
Wayne County	
First Water of Big Lime.....	25, 64, 65, 66
Rock salt.....	26
Salina formation.....	76-77
Wayne County	
Chester Township.....	65
Milton Township.....	66, 76-77
Wood County, Second Water of Big Lime.....	110
Wood County, Bowling Green.....	110