Annotated Bibliography and Index Map of Salt Deposits in the United States

GEOLOGICAL SURVEY BULLETIN 1019-J

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By WALTER B. LANG

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

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Contains references, to June 1956, on distribution of salt deposits, geologic occurrences, geophysical exploration, technology, experimental research, and historical accounts

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CONTENTS

ILLUSTRATION

CONTRIBUTIONS TO BIBLIOGRAPHY OF MINERAL RESOURCES

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ABSTRACT

Salt is abundant in the United States. Though of vital importance for domestic purposes in historic times, it has now become one of the most important commodities in industry and the demand for large tonnages of raw salt for industry is steadily increasing. The purpose of the bibliography is to serve as a ready reference to a wide range of subjects on salt which include the geographic distribution of salt deposits, geologic description of occurrences, geophysical exploration, technology, experimental research, and historical accounts.

INTRODUCTION

Common salt, the mineral halite, is of vital importance in the life of man. It was one of the first commodities to enter the arts and crafts of early man and in modern times has become one of the most essential commodities in industry. Where in the past, production of salt was for domestic use, an increasing demand now comes from the chemical industries, for food packing, refrigeration, weed and ice control, water conditioning, and many other technical applications.

The salt resources of the United States are enormous. In late years as prospecting to greater depth has been conducted for various commodities, large bodies of salt previously unknown have been discovered. These discoveries have not only added to the already large volume of known salt but also has widened our knowledge of its geographic distribution in sedimentary formations. Thus the question of adequate salt resources is not a present-day problem; but the coordination and adjustment of these natural occurrences of salt to the ever-changing requirements of economic industrial and chemical production, will be the chief concern for the future.

The great reservoir for salt is the sea. From this source, under certain conditions, concentrations of salt are made in shallow enclosed basins upon the land where they may later become buried and so preserved along with other sediments. Where ground water encounters buried salt, the latter is dissolved and returns to the surface through springs. The salt either accumulates again in internal drainage basins or is returned to the sea by streams. Where tectonic forces have pressed upon deep-seated salt beds, the salt is squeezed upward and in some places comes out at the surface. Here erosion or ground water depending upon the climatic environment, soon removes it, and the salt ultimately returns to the sea. Some of the sources of commercial salt and the methods of production are listed in the following table.

Source of salt	*Method of production*	*Example*
Sea water	Solar evaporation	San Francisco Bay, Calif.
Salt springs	Evaporation vats	Star Valley, Wyo.
Salt lakes or flats	Harvesting in dry season	Bristol Lake, Calif.
Rock brines	Drilling and pumping	Midland, Mich.
Rock-salt beds	Drilling, solution, and pumping.	Syracuse, N. Y.
Do	Underground mining	Detroit, Mich.
Rock-salt domes	do	Avery Island, La.
Rock-salt outcrop	Surface mining	Sevier Valley, Utah.

EXPLANATION OF THE ANNOTATED BIBLIOGRAPHY

This is an annotated bibliography about salt and, as such, contains information imparted or implied by the authors of the articles. It is intended to provide the reader with a general review of the variety of salt occurrences in the United States. Some references to the Canadian literature are also included because of the rapid recent developments in North Dakota and Montana and the contiguous areas of Canada. The selection covers a wide range of subjects: salt occurrences, geologic description, geophysical exploration, technology, experimental research, and historical accounts. The reader may pursue the subject of his special interest by use of the citations included in most of these references. Geologic names used in the references are those of the various authors and do not necessarily follow the usage of the U. S. Geological Survey.

To facilitate use of the bibliography, the entries are arranged in alphabetical order by the name of the author. The index provides subclassifications of the geologic and technologic subject matter. There is also a geographic classification of the references by their distribution in the States, and a map (pl. 4) which shows the distribution of the various occurrences of salt.

BIBLIOGRAPHY

Adams, J. E., 1944, Upper Permian Ochoa series of the Delaware Basin, West Texas and southeastern New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 28, p. 1596–1625.

Outlines the origin and the formations of the upper Permian evaporites that contain the major salt bodies in the Permian basin.

Adams, T. C., 1938, Recent deposition of salt from Great Salt Lake: Jour. Geology, v. 46, p. 637–646.

Great Salt Lake precipitates sodium sulphate each winter and redissolves this salt during the early spring. However, within the last 4 years (1934–38) summer precipitation of sodium chloride has also taken place as an accompaniment of the unprecedented low level of the lake. The sodium chloride returns to solution during the early winter, completing a spectacular annual cycle of salt precipitation and resolution. Winter precipitation of sodium sulphate is caused by the cooling of the water; summer precipitation of the chloride is caused by the annual reduction in volume of the lake, a result of heavy summer evaporation and reduced inflow during the season. A large tabular deposit of almost pure sodium sulphate is buried in the beach sands along the southeast shore of the lake and may be related in its formation to past winter precipitation of this salt similar to that now being observed.

Ageton, R. V., 1938, Salt occurrences in the potash mines of New Mexico: Am. Inst. Min. Metall. Eng. Trans., v. 129, p. 353–363.

Describes certain structural features found in the potash beds of the Salado formation in the mines of the United States Potash Co. and the Potash Co. of America, east of Carlsbad, N. Mex. Gives an interpretation of the manner of formation of the three identified variant types that depart from the normal seam; the depositional, erosional, and structural salt horses.

Alexander, C. W., 1946, Developments in Southeastern States in 1945: Am. Assoc. Petroleum Geologists, v. 30, p. 1023.

With respect to exploratory drilling for petroleum in Wilcox County, Ala.: "This test, abandoned at a total depth of 8,250 feet, penetrated 100 feet of Eagle Mills salt, from 8,150 feet to bottom of the hole, extending the salt basin well beyond the previous considered limits. The known presence of salt at this point will be of value as related to geophysical interpretation."

Alling, H. L., 1928, The geology and origin of the Silurian salt of New York State: N. Y. State Mus. Bull. 275, p. 5–132.

Discusses at length the stratigraphy of the Silurian in western New York and gives possible explanations for the origin of the salt.

Ames, J. A., 1950, Northern Appalachian salt: Min. Eng., v. 2 (i. e., v. 187), p. 557–559.

Reviews briefly the occurrence, distribution, and future trends in salt production in Ohio, West Virginia, Pennsylvania, and New York.

Andrickuk, J. M., 1954, stratigraphic analysis of Devonian system, *in* Western Canada Sedimentary Basin, Am. Assoc. Petroleum Geologists, p. 68-108.

Gives a review of the stratigraphy of the extensive Devonian system of rocks in western Canada and the contiguous part of the United States east of the Rocky Mountains. Exploration for petroleum in recent years has made possible correlation of the salines of the Middle Devonian.

Applin, P. L., and Applin, E. R., 1953, Cored section in George Vasen's Fee Well 1, Stone County, Miss.: U. S. Geol. Survey Circ. 298, 29 p.

In the deepest well (20,450 feet) east of the Mississippi River anhydrite and rock salt were penetrated below the base of the Smackover formation of Late Jurassic age.

Arthur, E. P., 1941, Annual Report: Denver, Colo. Bur. Mines, p. 43.

Lists U. S. Uranium Corp. as a producer of salt in Montrose County for 1941. Subsequent annual reports do not mention salt.

Bailey, G. E., 1902, Saline deposits of California: Calif. Min. Bur. Bull. 24, 216 p.

Gives a comprehensive and well-illustrated description of the geology of the great basin area of southern California, including chapters on the occurrence of borates, carbonates, chlorides, and nitrates contained within the area. It is particularly valuable for one desiring a perspective of California 50 years ago. Maps are included.

Baillie, A. D., 1953, Devonian system of the Williston basin area: Manitoba Dept. Mines and Nat. Res., Mines Br. Pub. 52–5, 105 p.

Describes by use of subsurface maps and cross sections, the stratigraphy and structural setting of the Devonian in Manitoba, Saskatchewan, Montana, North Dakota, and contiguous areas. Defines the salt-bearing Prairie and Davidson evaporites.

———1955, Devonian system of Williston basin: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 575–629.

An amplification of the author's paper on the same subject contained in the Manitoba Department of Mines and Natural Resources, Mines Branch Publication 52–5.

Baker, A. A., 1933, Geology and oil possibilities of the Moab district, Grand and San Juan Counties, Utah: U. S. Geol. Survey Bull. 841, p. 13–23.

Gives the original description and definition of the Paradox formation which contains the largest body of salt of Pennsylvanian age in North America.

Baker, A. A., Dane, C. H., Reeside, J. B., Jr., 1933, Paradox formation of eastern Utah and western Colorado: Am. Assoc. Petroleum Geologists Bull., v. 17, p. 963–980.

Compares accounts of the geology of the Paradox formation and gives a section of the Hermosa and Paradox formations. Indicates the trend and marginal boundary of the saline basin and suggests a southeastward connection to the open sea.

Balk, Robert, 1949, Structure of Grand Saline salt dome, Van Zandt County, Tex.: Am. Assoc. Petroleum Geologists Bull., v. 33, p. 1791–1829.

This detailed study describes the structure of the salt in a part of the Grand Saline salt dome exposed by mining operations. The layered salt is steeply folded but shows no fractures, faults, cross cutting salt layers, foreign inclusions,

or brine. Anhydrite inclusions display a linear alinement with the salt grain, and in places halite crystals are elongated. Deformation has been by mass molding of the salt. A structure map of the mined area and diagrams of salt doming are included.

———1953, Salt structure on Jefferson Island salt dome, Iberia and Vermilion Parishes, La.: Am. Assoc. Petroleum Geologists Bull., v. 37, p. 2455–2474.

Describes the structure and characteristics of the salt. The origin and dimensions of the salt dome are presented along with a structure map of the mined area.

Baltimore and Ohio Railroad Company, Baltimore, Md., 1949, Salt report for the Baltimore and Ohio Railroad area: Manager Indus. Devel., Traffic Dept., 56 p.

Contains a compilation of rock salt and brine resources of parts of the States of New York, Pennsylvania, West Virginia, and Ohio within the area served by the Baltimore and Ohio Railroad. The book, in looseleaf binding, is well illustrated with simple maps and diagrams, showing the areas underlain by salt and the location, depth, and thickness of brine sands in producing wells. Brines are found from the Ordovician to the Pennsylvanian and at increasing depth from west to east. Analyses of the more representative brines are given. The information provided is sufficiently comprehensive to give the reader an excellent and concise preview of the saline resources of the region.

Bangston, R. J., Moore, D. D., Ramsey, R. H., and Lund, R. J., 1950, Mineral Resources of southeastern Ohio: Ohio Dept. Nat. Res., Div. Geol. Survey, p. 79–88.

Presents a compilation of data on salt brines in southeastern Ohio, including maps showing areas of strong bromine and calcium concentrations and a geologic column indicating the brine-producing horizons. Seven companies produce salt in Ohio; 5 from rock salt and 2 from brines. Gives a list of salt producers and chlorine plants, with costs and the uses of the products.

Barksdale, Jelks, 1929, Possible salt deposits in the vicinity of the Jackson fault Alabama: Ala. Geol. Survey Circ. 10, 23 p.

Salt seeps in Clarke County apparently are related to the Jackson fault and the Hatchetigbee anticline. The regional dip is to the southwest, and it is believed that ground water descends to a source of salt and from there rises to the surface along fractures. The salinity and flow of the springs have remained constant for more than 70 years. These brines were a source of salt during the Civil War. Many shallow wells have been drilled for salt but none has so far encountered rock salt.

Barnes, R. B., 1933, Plasticity of rock salt and its dependence on water: Phys. Rev., v. 44, p. 898–902.

Measurements indicate that water actually penetrates the interior of a salt crystal when wetted. Wetting causes a high degree of plasticity and tensile strength (Joffe effect) as measured by infrared radiation. *See also* Phys. Rev., v. 43, p. 82–83.

Bartlett, Z. W., 1946, Salt and sulphur resources of Texas: Tex. Acad. Sci. Trans , v. 29, p. 186–191.

Gives a general statement on the salt resources of Texas.

Barton, D. C., 1926a, The American salt dome problems in the light of the Roumanian and German salt domes, *in* Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, p. 167–208.

Contains a long description and graphic illustration of the representative forms of salt structures found in Roumania and north Germany. In Roumania, salt domes are commonly related to overthrusting in border-mountain areas. In Germany, compressive forces caused linear ruptures along which, and at the intersections of which, salt domes formed, but some apparently were caused by local influences. The roots of American salt domes have not been studied, but it is assumed they have a similar origin in depth. The anhydrite-gypsum-calcite cap rock is a typical feature of American salt domes. This type of cap rock is seldom present in Roumanian salt domes. In Germany the cap is commonly composed of gypsum; sulphur and oil are common associates in American domes.

——— 1926b, Pine Prairie salt dome, *in* Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, p. 419–436.

The article is chiefly concerned with prospecting for petroleum but mentions the occurrence in Louisiana of massive salt at a depth of only 500 feet under a thick cap rock of limestone and gypsum.

——— 1926c, The salt domes of south Texas, *in* Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, p. 718–771.

Describes 3 major (Palangana, Piedras Pentos, and Falfurias), 3 minor (Sal del Rey, Sal Vieja, and Chapeño), and 2 probable (Smith Corkill and La Lomita) salt domes in the tip of Texas. It also gives a comparison of their indicated forms with better explored salt structures in Germany.

——— 1933, Mechanics of the formation of salt domes with special reference to Gulf Coast salt domes of Texas and Louisiana: Am. Assoc. Petroleum Geologists, v. 17, 9, p. 1025–1083.

The salt in salt domes is believed to be of sedimentary origin and to have come from salt beds at depth. Gulf Coast salt domes were formed by static thrust and by downbuilding, a term used for differential compaction of the surrounding sediments. Salt domes may be formed along the crests of folds, zones of faulting, convexities in the top of the salt bed, or over deep canyons. Rim synclines, the limit of upthrust, and isotatic compensation are discussed. A map of the distribution of salt domes and other structural features of the Gulf Coast is included.

The volume of salt contained in Gulf Coast salt domes of Texas and Louisiana is calculated as 520 cubic miles and the age of the source bed is considered as Early Cretaceous or older. A table of compaction figures is also given. In the absence of evidence of dynamic thrust which might explain salt-dome formation, emphasis is placed on the relative merits of static thrust and downbuilding.

Barton, D. C., and Paxton, R. B., 1926, The Spindletop salt dome and oil field, Jefferson County, Tex., *in* Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, p. 478–496.

The report gives little useful information on salt, but contains descriptive data on a salt dome now famous for its early exploitation and prolific production of oil.

Bell, H. W., 1933, Discovery of rock salt deposits in a deep well in Union County, Ark.: Ark. Geol. Survey Inf. Circ. 5, p. 1–21.

The Lion Oil Refining Co. drilled a well 7,255 feet deep in Union County, Ark. Rock salt was drilled into at a depth of 5,960 feet which continued to the

bottom of the hole. The salt is placed in the Trinity group of the Lower Cretaceous.

Berliner, J. F. T., 1930, Potash bibliography to 1928 (annotated): U. S. Bur. Mines Bull. 327, 530 p.

Many of the 3,967 entries of world literature on potash contain information about salt.

Blake, W. P., 1857, Geological Report, *in* Reports of Explorations and Surveys * * * from the Mississippi River to the Pacific Ocean: 33d Cong., 2d sess. S. Doc. 78, v. 5, p. 47, 309–310.

Mentions Casteca (Castaic) Lake in Tejon Pass as containing a thick crust of salt formerly used by the Indians, also a similar occurrence on the eastern side of the elevated plain of Taheechaypah. Briefly describes the saline bed of dry lake of the Colorado Desert (Salton Sea) and the occurrence of salts in Cajon Pass and the Mojave Desert.

——— 1915, Sketch of the region at the head of the Gulf of California, a review and history, *in* Corey, H. T., The Imperial Valley and Salton Sink: San Francisco, Calif., John J. Newbegin, pt. 1, p. 30–31.

Gives a sketch of the early records of Salton Sink; Emory, 1848; Williamson, 1853, and the changes made by New River. The New Liverpool Salt Co. bored a well 3 miles west of the tracks of the Southern Pacific where a 7-inch crust of salt (sodium chloride and magnesium chloride) was penetrated. The flood of 1891 is mentioned.

Brownocker, J. A., 1906, Salt deposits and the salt industry in Ohio: Ohio Geol. Survey, 4th ser., Bull. 8, 42 p.

Presents the occurrences of salt by county and the methods of production and preparation as practiced before 1906.

Bradley, W. W., 1945, Economic mineral resources and production of California: Calif. Div. Mines Bull. 130, p. 196–199.

Lists the areas of salt production from dry lakes and locations of plants where salt is extracted by solar evaporation from sea water in California. Gives tonnage and value of salt production in California since 1887, markets, prices, and estimated reserves.

Breger, C. L., 1909, The salt resources of the Idaho-Wyoming border: U. S. Geol. Survey Bull. 430, p. 555–569.

Brine springs and rock salt occur in the area of Star Valley near Afton, Wyo. The brines are saturated and served in the early years as a source of salt for many mining camps of the region and for domestic use. The article contains a review of regional geology; considers the salt originally disseminated in the Beckwith formation, later accumulated in anticlines when folding took place, and subsequently transferred to Tertiary or Quaternary lake deposits when the latter were formed. Estimates of the quantity are given.

Browdesh, F. W., 1951, Beneficiation of Kansas number four salt: Kans. Geol. Survey Bull. 90, pt. 8, p. 192–218.

Discusses the methods of improving the quality of crude salt for market.

Brown, L. S., 1934, Age of Gulf Border salt deposits. Am. Assoc. Petroleum Geologists Bull., v. 18, p. 1227–1296.

The author contends that a basin must be isolated from the sea before halite beds form and that no large basin can be isolated from land drainage. From

Usiglio's succession the postulated sequence of deposition, in ascending order, is limestone, anhydrite, and halite. Salt deposits are not found throughout the Coastal Plain, but at Smackover, Ark., in Texas and Louisiana interior areas, and in the Gulf Coast proper. They are shown to be of different ages. The Comanche rocks occur upon the Pennsylvanian without intervening Permian, Triassic, or Jurassic. The salt at Smackover is said to be in the lowest lower Comanche, and the Louisiana-Texas salt to be of Glen Rose age.

Brown, W. F., 1952, Metals and nonmetallic minerals in the Arkansas River Basin, Kans.—preliminary report: U. S. Interagency Comm. Arkansas—White–Red Basins, Minerals and Geology Work Group, p. 9–11.

Gives annual production figures, estimate of reserves, and a map showing the subsurface distribution of salt in Kansas.

Buchen, J. C., 1937, Evaporating salt from the world's largest mineral deposit. Am. Inst. Min. Metall. Eng., v. 18, no. 367, p. 335–338.

An outline of the production of salt by the Leslie Salt Co. from sea water in San Francisco Bay. Explains preparation of vats, evaporation process, and harvesting of salt. The production months are April to October when rainfall is slight. Rainfall is 10 to 18 inches per year; the evaporational differential is 31 to 43 inches per year for salt production. The bittern removed after salt crystallization contains 16.0 percent NaCl; 6.0 percent $MgCl_2$; 4.2 percent $MgSO_4$; 1.4 percent KCl; and 0.121 percent Br at 28° Bé. The ratio of K to Br is 11.5 to 1.

Buckley, S. B., 1874, Salt: Tex. Geol. Agr. Survey 1st Ann. Rept., p. 52–54.

Gives an account of salt formed at low water, caused by tide and wind, along the Gulf Coast west of Corpus Christi. At Grand Saline, brine seeps and a well made available during the Civil War, 1,000 sacks of salt of 200 pounds each per day. Near Graham, Young County, salt was obtained from seeps along the banks of the Salt Fork. Also in Wise and Lampasas Counties, along the Red River, and at the crossing of the Pecos there were sources of salt.

——— 1876, Salt: Tex. Geol. Agr. Survey 2d Ann. Rept., p. 22.

Salt "Abounds in the country along the upper Pecos above the road from Fort Concho to Fort Stockton. Near the Horse Head crossing of the Pecos are large deposits of salt in the bed of what is called Salt Lake. To this place wagons resort for supplies of salt for El Paso, Presidio and other counties."

California Division of Mines Mineral Information Service, 1954, Salt: v. 7, no. 2, p. 1–6.

Reviews the sources and methods of salt production in California and gives a supporting list of references.

Campbell, M. R., 1897, Description of the Charleston quadrangle, West Virginia: U. S. Geol. Survey Geol. Atlas, folio 72, p. 6.

The first salt furnace in Kanawha Valley was erected in 1797 at the Great Buffalo Lick. In 1808 the first salt well west of the Alleghany Mountains was drilled here. By 1844–54 salt production varied from 400,000 to 600,000 barrels annually and rivaled the output from New York State. It was found later that the salt water was coming from the Pottsville series at depths of 600 to 1,000 feet.

Campbell, M. R., 1904, Description of the Latrobe quadrangle, Pennsylvania: U. S. Geol. Survey Geol. Atlas, folio 110, p. 15.

Brine issuing from the Pocono sandstone was used in the early days to make salt, and gave name to Saltsburg, on the Conemaugh River. The salt works which stand by the old canal, and were fired with Freeport coal, ceased operations long ago.

Carsey, J. B., 1950, Geology of Gulf coastal area and continental shelf: Am. Assoc. Petroleum Geologists Bull., v. 34, p. 361–385.

Discusses in particular the characteristics and form of the continental shelf off the coast of Texas and Louisiana. Gives a stratigraphic cross section of the coast and shelf area in central Louisiana. The Eagle Mills formation is shown as the source of salt that has been squeezed into salt stocks to heights of 35,000 feet.

Clapp, F. G., 1931, Salt domes of Texas and Louisiana Gulf coast: Jour. Inst. Petroleum Technologists, v. 17, no. 91, p. 281–299.

Contains a review of the Gulf Coast salt domes and maps and tables indicating their distribution, geologic characteristics, stratigraphy, structure, and the methods and time of discovery.

Clarke, F. W., 1924, Data of Geochemistry: U. S. Geol. Survey Bull. 770 (fifth edition), p. 124–260.

Contains geochemical data on the ocean, waters of enclosed basins, mineral wells and springs, and saline residues.

Condra G. E., 1941, Industrial Nebraska in outline: Nebr. Conserv. Survey Div., Bull. 28, p. 16.

Gives a brief statement of early salt production and the possible development of a future salt industry under more favorable economic conditions.

Connolly, J. P., and O'Harra, C. C., 1929, The mineral wealth of the Black Hills: S. Dak. School Mines Bull. 16, p. 336–338.

In Wyoming, salt water issues from the Spearfish formation (Triassic) 9 miles north of Newcastle, near Cambria and the head of Salt Creek. During 1878 and later, salt was produced in wood-fired evaporating pans also used for chloridizing gold and silver ores from the Black Hills. The estimated spring flow is 60 gallons per minute. The water contains 3 percent of NaCl and minor amounts of $CaSO_4$, $MgSO_4$, $MgCO_3$, $FeCO_3$, SiO_2 but no Br or I.

Cook, C. E., 1938, Darron salt dome, Ascension Parish, La.: Am. Assoc. Petroleum Geologists Bull., v. 22, p. 1412–1422.

The Darron salt dome, believed to have been formed by faulting, is the first one found east of the Mississippi River from which there has been sustained oil production. Oil is from Miocene sands above salt or from the same sands faulted up from depth. The top of the salt is 4,627 feet below the surface. A minor deflection of the river suggests recent movement of the dome. There is no gypsum or anhydrite cap on the salt.

Cook, C. W., 1914, The brine and salt deposits of Michigan, their origin, distribution, and exploration: Mich. Geol. Survey Pub. 15, Geol. Ser. 12, 188 p.

Presents at length the history of development, processes of manufacturing, and marketing of salt, with a table of the geologic occurrence of salt in the United States as known at the time.

Discusses the theories of salt formation and the geology of the southern peninsula, with maps and sections. Each formation is treated separately and analyses are given.

Cooke, C. W., 1939, The scenery of Florida interpreted by a geologist: Fla. Geol. Survey Bull. 17, p. 90.

A spring of salty water on the north side of Lake Kerr, Marion County, has the composition of dilute sea water. Fissures in the limestone from which the spring issues are 30 feet deep and extend below the fresh-water horizon and sea level. The salt water may be siphoning out of the limestone.

Cummins, W. F., 1890, The southern border of the central coal field: Tex. Geol. Survey 1st Ann. Rept. for 1889, p. 172–174, 195–196.

Mentions the occurrence of flowing salt wells at Waldrip and San Angelo and of salt at Colorado City, Salt Flat, and Salt Croton Creek. Describes Hanna and Hancock Springs at Lampasas.

——— 1891, Report on geology of northwestern Texas: Tex. Geol. Survey 2d Ann. Rept. for 1890, p. 444–448, 505.

Describes the early known occurrences of salt springs, flats, and wells along the eastern exposures of the Permian and drained by the Red, Wichita, and Brazos Rivers. Also mentions salt production at Colorado, Tex.

Cunningham, W. A., 1934, The potassium sulphate mineral polyhalite in Texas: Tex. Univ. Bull. 3401, p. 833–867 [1935].

Discusses the occurrence of polyhalite in the Permian salt deposits of West Texas, including its mineralogic characteristics, geologic associations, and economic possibilities.

Dane, C. H., 1935, Geology of the Salt Valley anticline and adjacent areas, Grand County, Utah: U. S. Geol. Survey Bull. 863, p. 25–33.

Gives a description of the Paradox formation (salt bearing) and related geology. Salt is not exposed at the surface but occurs at depth.

Darton, N. H., 1904a, Description of the Newcastle quadrangle, Wyoming-South Dakota: U. S. Geol. Survey Geol. Atlas, folio 107, p. 9.

Map shows location of a salt spring at the head of Salt Creek in Wyoming. Considers source of salt to be in the Spearfish formation and gives an analysis and estimate of flow of the spring.

——— 1904b, Zuni salt deposits, New Mexico: U. S. Geol. Survey Bull. 260, p. 565–566.

Twenty miles northwest of Quemado in central-western New Mexico is an elliptical depression about 1 mile wide that holds a shallow salt lake. This lake is spring fed near its southern border and the shallow margins are salt encrusted. Indians and Mexicans have gathered salt here for centuries.

——— 1920, Permian salt deposits of south-central United States: U. S. Geol. Survey Bull. 715–M, p. 205–230.

Includes a list and a discussion of logs of wells drilled in the Permian basin of Kansas, Oklahoma, Texas, and New Mexico which have penetrated notable thicknesses of salt in association with potash.

Darton, N. H., 1928, "Red Beds" and associated formations in New Mexico, with an outline of the geology of the State: U. S. Geol. Survey Bull. 794, p. 235–254 [1929].

Contains logs and records of wells drilled into Permian salt in the Pecos Valley of southeastern New Mexico.

De Golyer, E. L., 1926, Origin of North American salt domes, *in* Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, p. 1–44.

Presents an excellent historical review of the evolution of opinions and concepts on the origin of salt domes in the United States. The review of the literature is grouped into periods. The theoretical concepts are classified under four headings. Domes are regarded as formed (1) from old erosional outliers, (2) as salts deposited from rising solutions, (3) from volcanic sources, and (4) as a consequence of tectonic forces applied to sedimentary beds of salt at depth. De Goyler concludes that he favors the tectonic origin for salt domes, although he admits he cannot fully document his beliefs.

——— 1931, Origin of salt domes of the Gulf Coastal Plain of the United States: Jour. Inst. Petroleum Technologists, v. 17, no. 92, p. 331–333.

Gives a brief review of the concept of the orgin of salt domes as of 1930. Also states that evidence of potash was found in the Bayou Bouillon dome of Louisiana as well as the Markham dome of Texas.

Dellwig, L. F., 1954, The process of deposition of Salina salt of Michigan: Jour. Sed. Petrology, v. 24, p. 129–130.

Compares the salt of the Salina formation with marine solar salt and concludes that as they have similar characteristics, they were formed under similar conditions. Believes seasonal or temperature changes are indicated by banding. Temperatures of deposition as indicated by liquid inclusions suggest lower temperatures of formation than previously considered.

Deussen, Alexander, and Lane, L. L., 1925, Hockley salt dome, Harris County, Tex.: Am. Assoc. Petroleum Geologists Bull., v. 9, p. 1031–1060.

Hockley salt dome, one of the largest known, has been prospected by many oil companies since 1905 with no discoveries of commercial oil or sulphur. Fifty wells have been drilled, ranging in depth from 200 to 4,600 feet.

Dobrin, M. B., 1941, Some quantitative experiments on a fluid salt-dome model and their geological implications: Am. Geophys. Union Trans., v. 22, pt. 2, p. 528–542.

An analysis of salt-dome formation made by the use of working models simulating geologic conditions. Viscous liquids assume movement comparable to salt under pressure. It is believed that plasticity is an essential for the intruded as well as the intruding rock. Movement is accelerated until a domal shape is well established, after which growth continues at a constant rate. Continued growth indicates a plentiful supply of salt, and, where the height of the dome is more than 10 times the thickness of the salt bed, additional salt is pressed from the marginal area.

Dole, R. B., 1913, Exploration of salines in Silver Peak Marsh, Nev.: U. S. Geol. Survey Bull. 530–R, p. 330–345.

The playa is estimated to contain 15 million tons of high-grade salt at depths of less than 40 feet. There were no promising indications of associated potash. The sediments to a depth of 50 feet were tested by drill and the results are presented graphically.

Donoghue, David, 1926, The Bayou Bouillon salt dome, St. Martin Parish, La., *in* Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, p. 345–351.

Gives a chronological record of prospecting the Bayou Bouillon salt dome before 1925. It is an asymmetrical salt dome with steep south and west flanks.

Dyer, B. W., 1945, Discoveries of potash in eastern Utah: Am. Inst. Min. Metall. Eng. Tech. Pub. 1755, p. 1–6.

Although this paper deals primarily with the occurrence of potash, the article also presents data on wells drilled into the salt of the Paradox formation in the Moab-Thompson area of Utah.

Eckel, E. C., 1903, Salt and gypsum deposits of southwestern Virginia: U. S. Geol. Survey Bull. 213, p. 406–416.

Thomas Jefferson, in his Notes on Virginia in 1781, mentions the occurrence of salt springs in southwestern Virginia, but rock salt was not discovered until 1840. Eckel considered the salt and gypsum to be an integral part of the Greenbrier formation. Logs of wells drilled for gypsum and possible rock salt on the Robertson property between 1815 and 1857 are given. Concludes that the salt aggregates 175 feet in thickness.

——— 1904, The salt industry in Utah and California: U. S. Geol. Survey Bull. 225, p. 488–495.

Describes salt production from Great Salt Lake, Utah, where salt is produced by solar evaporation. In the summer season 2 inches of water is evaporated per day from the salt ponds and about 3 inches of salt is formed in an average season, although 6-inch crops have been reported. Analyses of the water and a brief history of the salt industry are given. Comments on salt production in California at San Diego and San Francisco Bay are added.

Eskew, G. L., 1948, Salt, the fifth element: Chicago, Ill., J. A. Ferguson and Associates, p. 228.

This book although of mainly commercial interest, offers the reader a comprehensive review of the nontechnical and historic phase of salt production.

Fettke, C. R., 1941, Subsurface sections across western Pennsylvania: Pa. Topog. Geol. Survey Progress Rept. 127, p. 1–51.

Consists of descriptions of sample cuttings from wells drilled in western Pennsylvania, with a discussion of the correlation of formations from the St. Peter sandstone (Ordovician) to the Pennsylvanian. A map of the location of the wells and a table of formation thicknesses accompany the article. Salt is indicated in some of the Salina sections.

——— 1955, Preliminary report, occurrence of rock salt in Pennsylvania: Pa. Geol. Survey, 4th ser., Progress Rept. 145, maps, scale 1 : 960,000, with text.

Gives a graphic presentation, by columnar sections and depth and thickness contours, of the distribution of Salina salt in northwestern Pennsylvania. Also shown are the limits of salt occurrence and the position of the outcrops of rocks of the Salina group.

Filson, John, 1784, Map of Kentucke [sic] for the Congress of the U. S. and George Washington: Washington, D. C., Libr. Cong. (Sesquicentennial reprints).

On this map are indicated the following salt licks and rivers of importance as sources of supply to the early travellers migrating westward.

Bigbone Lick
Blue Lick
Blue Licks
Blue Spring
Boonsboro Lick
Bryans Lick
Bulletts Lick
Flat Lick
Flat Licks
Knob Lick
Muddy Creek Lick
Upper Blue Licks

Licking River
Salt River

Foshag, W. F., 1926, Saline lakes of the Mojave desert region: Econ. Geology, v. 21, p. 56–64.

Reviews the geologic and mineralogic conditions in the areas of Mojave saline lakes. Concludes with four premises: (1) The chief sources of playa salts are Tertiary saline sediments, rock decay, volcanic emanations, and hot springs. (2) Concentration of saline is largely confined to the surface layers. (3) The occurrence of crystals in playa muds is due to the downward diffusion of saturated solutions. (4) The concentration of large bodies of salts are the result of special conditions seldom duplicated.

Four Corners Geological Society, 1952, Geological symposium of the Four Corners region: Durango, Colo., 145 p.

Contains a group of papers on stratigraphy of the four contiguous corners of Utah, Colorado, New Mexico, and Arizona, and a description of the saline deposits of the Paradox formation.

Gale, H. S., 1915, Salines of the Owens, Searles, and Panamint basins, southeastern California: U. S. Geol. Survey Bull. 580–L, p. 251–323.

Gives geologic descriptions of the basins, their history, composition of dissolved salts, sediments, and character of the minerals contained.

——— 1951, Geology of the saline deposits, Bristol Dry Lake, San Bernardino County, Calif.: Calif. Dept. Nat. Res., Div. Mines Special Rept. 13, 21 p.

Gives a description of the geologic setting for Bristol Dry Lake near Amboy, San Bernardino County; the deposits, and a review of exploration and production operations. On the north side of the present playa, salt is mined at shallow depth below the surface. Calcium chloride and sodium chloride brines are drained off from the top clay bed by ditches. Where the brine is concentrated, sodium chloride crystallizes out leaving a concentrate of calcium chloride which is shipped in tank cars to Los Angeles. Gypsum was mined 2 miles southeast of Amboy. Concentrations of celestite occur in the top muds of the playa.

Gambs, G. C., and White, G. W., 1946, Salt reserves *in* Ohio's mineral resources, part 3: Ohio State Univ., Eng. Expt. Sta. Circ. 49, v. 15, no. 3, 22 p.

Lists seven salt producers. Diamond Alkali Co., at Painesville, and Pittsburgh Plate Glass Co., at Barberton, are the two largest, employing 90 percent of the salt workers. Includes brief data arranged by county on rock salt and brine production with tables. Two maps show areas underlain by rock salt or containing brines.

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Goldman, M. I., 1926, Petrography of salt dome cap rock, *in* Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, p. 50–86.

Gives a detailed petrographic description of cap-rock core specimens from the Gulf Coast salt dome region. The specimens are composed mainly of anhydrite, gypsum, calcite, and sulfur. From the evidence, an attempt is made to ascertain the origin of cap rock.

——— 1952, Deformation, metamorphism, and mineralization in the gypsum-anhydrite cap rock, Sulphur Salt Dome, La.: Geol. Soc. America Mem. 50, p. 1–169.

Contains a detailed study of cores obtained by the Union Sulphur Co. from its test 194, drilled through 628 feet in the cap rock of Sulphur Salt Dome. Presents an identification of the minerals and an interpretation of their relation in the cap-rock formation.

Goldschmidt, V. M., 1954, Geochemistry: London, Oxford Univ. Press, 702 p.

A modern compilation of geochemical data. Ten pages of data on sodium appear in group IA of the alkali metals along with a statement of its place in the cycle of sedimentation. Chlorine appears in Group VIIB, requiring 14 pages to cover the subject.

Goldston, W. L., and Stevens, G. D., 1934, Esperson dome, Liberty County, Tex.: Am. Assoc. Petroleum Geologists Bull., v. 18, p. 1632–1654.

This salt dome was one of the first discovered by geophysical methods (torsion balance). Oil was found in 1928. The salt mass was thrust up at a slight angle to the north. The Beaumont clay, which occurs at the surface, does not indicate the presence of a dome.

Gould, C. N., 1901, The Oklahoma salt plains: Kans. Acad. Sci. Trans., 33d Ann. Mtg., 1900, v. 17, p. 181–184.

Presents an early description of the Big and Little Salt Plains of the Cimarron in Oklahoma just south of the Kansas boundary.

Grabau, A. W., 1920, Principles of salt deposition: New York, McGraw-Hill Book Co., 402 p.

This textbook covers rather completely the essentials of saline deposition and the geologic processes related to it. Abundant references are given.

Greter, R. E., 1949, Brine production and utilization from the salt sands of the Pottsville series: Appalachian Geol. Soc. Bull., v. 1, p. 320–324.

Briefly mentions the geology of the Pottsville series in relation to brines. Of a hundred or more companies that began production of salt products in West Virginia, only two remain, the Hartford Salt Co. and the Westvaco Chemical Division of Food Machinery and Chemical Corp. Diamond Alkali Co. is in process of building a plant on the Kanawha River. Reviews the many products that are derived in part from brines.

Grossman, I. G., 1949, Geomorphology of the interior saline basins of western North Dakota: N. Dak. Acad. Sci., v. 3, p. 14–15.

Postulates that in western North Dakota (1) where ground water drains along preglacial channels into kettle depressions with impervious bottoms, concentration of mineral matter occurs, (2) but where lakes drain through their bottoms or overflow into other lakes at lower levels during flood periods, they remain fresh.

Halbouty, M. T., and Hardin, G. C., Jr., 1954, New exploration possibilities on piercement-type salt domes, established by thrust fault at Boling Salt Dome, Wharton County, Tex.: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 1725–1740.

Includes diagrams and a discussion of an interpretation of thrust faulting along the expanded head of a salt dome. Such an explanation gives a new concept for consideration in future exploration for oil in domes of this type.

——— 1956, Genesis of salt domes of Gulf Coastal Plain: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 737–746.

The authors consider the Louann salt of the Gulf Coast to be the same age as the Castile formation (Permian) of the Delaware Basin, postulating that the Louann salt is the equivalent of the anhydrite of this basin. A connection between the two basins is proposed north of the central mineral region. Salt plugs are formed from the Louann salt by differential pressure of the overlying sediments on the lighter salt.

Hanna, M. A., and Wolf, A. G., 1934, Texas and Louisiana salt dome cap rock minerals: Am. Assoc. Petroleum Geologists Bull., v. 18, p. 212–225.

Lists 28 minerals found in a study of cap rocks. Contains illustrations of 47 specimens and a bibliography of related subjects.

Harris, F. E., 1939, Marketing of salt: U. S. Bur. Mines, Inf. Circ. 7062, 56 p.

Contains much data on the production, refining, and marketing of salt in domestic and world markets.

——— 1952, Salt *in* Mineral resources of the world: New York, Prentice-Hall, Inc., v. 2, p. 157–161.

Reviews the world production and trade in salt: world occurrences, production methods, preparatory processes, annual production by countries, and its various uses in the United States. Maps show distribution of major world deposits, world production, also salt deposits and producing plants in the United States.

Harris, G. D., 1907, Rock salt: La. Geol. Survey, Bull. 7, p. 48–259 [1908].

Gives the origin, geologic occurrences, and economic importance of rock salt in the State of Louisiana together with brief notes and references to all known salt deposits and industries of the world.

Harris, W. R., and Corell, E. J., 1945, Ohio's mineral resources, salt: Ohio Eng. Expt. Sta., Circ. 47, v. 14, no. 2, p. 13–19.

The earliest salt production by settlers was in 1797 in Jackson County where Indians had evaporated brines. In Gallia County, 1809, the first brine well was drilled 100 feet deep. Rock salt was first found in the Salina formation by the Cleveland Rolling Mill Co. at Newberg, and thus began a new era in salt production. Data on later developments are given. Salt production as an industry began in Muskingum Valley in 1817 with production rising to 400,000 bushels by 1833. (A bushel equals 80 pounds.)

Harrison, T. S., 1927, Colorado-Utah salt domes: Am. Assoc. Petroleum Geologists Bull., v. 11, p. 111–135.

The discovery and investigation of saline-bearing anticlines in southwestern Colorado and southeastern Utah has led to their classification into 4 groups, namely; saline anticlines bearing plugs, saline anticlines that bear no plugs, domes

not associated with anticlines, and structural anticlines. The regional geology and stratigraphy are presented along with maps, diagrams, and many illustrations.

Hayes, J. J., 1942, Great Salt Lake and its economic importance: Utah Mineralog. Soc. News Bull., v. 3, no. 2, p. 11–23.

Includes a geographic description of the lake, the early historical events, and analyses of the waters taken at various times. Gives the probable combination of the ions in solution, $NaCl$, Na_2SO_4, $MgCl_2$, $CaSO_4$, K_2SO_4. Estimates, as of 1942, the total worth of the salts in Great Salt Lake as $44.5 billion as compared with $3 billion for total value of mineral production in Utah since 1869. Briefly outlines the uses of the salines. Contains a bibliography.

Hazzard, R. T., Spooner, W. C., Blampied, B. W., 1945, Notes on the stratigraphy of the formations which underlie the Smackover limestone in south Arkansas, northeast Texas, and north Louisiana: Shreveport Geol. Soc., v. 1–2, p. 483–503.

Presents data for the depth to, and thickness of, the Louann salt and the underlying Werner anhydrite. Attempts to correlate these formations with the Permian of West Texas and to reconcile their thickness with the proportional volumes of salts contained in sea water. Invokes the Branson theory as a means of explaining deficiencies. Contains correlation charts and well records for the area.

Hewett, D. F., Callaghan, Eugene, Moore, B. N., and others, 1936, Mineral resources of the region around Boulder Dam: U. S. Geol. Survey Bull. 871, p. 92–98.

Lake-bed deposits of the Verde formation crop out along the Verde River valley near Camp Verde, Ariz. Some salt occurs along with thenardite in these beds. Salt crops out in the Virgin Valley.

Hildreth, S. P., 1945, Ohio's mineral resources, part 3, Salt; part 1, Salt springs, early history of the salt manufacture in Ohio; (repr.) with Foreword by W. E. Stout: Ohio State Univ. Studies, Eng. Ser. Eng. Expt. Sta. Circ. 47, p. 1–12.

This is a reprint of a paper published in 1838 and presents the conditions and sources of salt supply (salt springs or salines) from about 1800 to 1835.

Holyman, H. W., 1946, Seismograph evidence on depth of salt column, Moss Bluff dome, Texas: Geophysics, v. 11, no. 1, p. 128–134.

Presents an interpretation of seismograph data obtained from a traverse of Moss Bluff dome. Reflections yield figures of 36,000, 26,000, and 16,000 feet as the base of the salt column. Reasons are given for preferring the multiple reflection interpretation of 16,000 feet.

Hoskins, H. A., 1947, Analyses of West Virginia brines: W. Va. Geol. Econ. Survey Rept. Inv. 1, 22 p.

Gives tables of analyses of brines found in wells drilled into brine-producing formations of western West Virginia with information on the owner, location, depth to production, and the flow of the wells sampled.

Howard, K. C., 1951, Development and operation of LPG storage cavities in salt strata: Jour. Petroleum Technology, v. 3, no. 3, sec. 1, p. 10–11, sec. 2, p. 3.

Reviews the developments and experiences resultant from the operation of two reservoirs formed in salt for storage of propane: one in Winkler County and the other in Upton County, Tex. [LPG, low-pressure gas.]

Imlay, R. W., 1943, Jurassic formations of the Gulf region: Am. Assoc. Petroleum Geologists Bull., v. 27, p. 1431.

"In southwest Alabama, 108 feet of the salt facies of the Eagle Mills formation was penetrated in the Union Producing Companies M. M. Waite No. 1, sec. 27, T. 8 N., R. 1 W., Clarke County, Alabama."

Inman, A. E., 1951, Salt—an industrial potential for Kansas: Lawrence, Univ. Kans. Pubs., 83 p.

Summarizes information on the occurrence and production of salt in the United States and Kansas. Outlines methods of mining and refining, uses, markets, and chemical products requiring salt for their manufacture; costs of plant construction and operation.

Joesting, H. R., and Fautschy, J. D., 1948, Reconnaissance gravity map of part of Gulf of Mexico: U. S. Geol. Survey. Prepared in cooperation with the Office of Naval Research.

A map covering an area of the Gulf Coast between Sabine Pass and Grand Cheniere, La., and extending out 75 miles from shore, records the gravity variations made within depths of 20 fathoms (120 feet). Within the area mapped, numerous salt domes have been discovered and the presence of others are suggested by anomalous gravity variations.

Johnson, O. B., Jr., 1951, Underground storage of propane in a salt water sand: Jour. Petroleum Technology, v. 3, no. 1, sec. 1, p. 14–15.

Outlines the technical factors and cost advantages for underground storage of propane in a salt-water sand as an alternative to reservoirs formed in rock salt or in steel tanks.

Jones, C. L., 1954, Occurrence and distribution of the potassium minerals in southeastern New Mexico: N. Mex. Geol. Soc., Guidebook, Southeastern N. Mex., 5th Field Conf., p. 107–112.

Presents a cross section of the Ochoa series in a part of the New Mexico Permian salt basin, the stratigraphic succession of beds, and their relation to potash accumulation.

Jones, F. A., 1904, Salt, *in* N. Mex. Mines and Minerals: Sante Fe, N. Mex. Printing Co., p. 223–230.

Describes sources of salt supply in the early days, with analyses and production figures. Contains a picture of Crater Salt Lake.

Jones, G. E., Starkey, R. L., Feely, H. W., Kulp, J. L., 1956, Biological origin of native sulfur in salt domes of Texas and Louisiana. Science, v. 123, no. 3208, p. 1124.

The composition and environmental conditions of the salt-dome formations and the results of laboratory investigations of the S^{32} and S^{34} ratios of sulfate reduction to sulfide indicate that sulfate-reducing bacteria played an important part in the formation of sulfur. The bacteria probably reduced dissolved sulfate to hydrogen sulfide. The subsequent formation of sulfur was most likely due to a nonbiological process, such as a reaction between sulfide and sulfate.

Jones, T. S., 1953, Stratigraphy of the Permian basin of West Texas: West Tex. Geol. Soc., 57 p.

Lists and describes the rocks of the Permian basin occurring in West Texas by systems and formations from the Precambrian to the Quaternary, including the salt-bearing formations of the Permian. An ample bibliography is given.

Keller, R. M., and Quirke, T. T., 1939, Mineral resources of the chemical industries: Econ. Geology, v. 34, p. 287–296.

Lists 150 chemicals essential to industry. For the manufacture of these chemicals, 34 raw materials are required. Salt is fifth in importance, being preceded by water, air, coal, and sulfur. Salt is essential to the production of 75 percent of the chemical products listed.

Kelly, P. K., 1926, The sulphur salt dome, Louisiana, *in* Geology of the salt dome oil fields: Am. Assoc. Petroleum Geologists, p. 452–469.

This article is of interest for its description of a salt dome of the typical small sulphur-bearing type, with a thick cap rock of the anhydrite-sulfur-limestone succession. It is also the place where the Frasch process was developed for the extraction of sulfur. A brief historical note, cross sections of the cap rock, and an outline of the Frasch process are included.

Kindle, E. M., 1904, Salt and other resources of the Watkins Glen district, New York: U. S. Geol. Survey Bull. 260, p. 567–572.

Rock salt was first found at Ithaca in 1885. The salt occurs in beds in the Salina from 5 to 50 feet thick and at depths of from 1,800 to 2,100 feet. The Cayuga Lake depression offers a 400-foot topographic advantage, with from 100 to 400 feet of easy drilling in the overlying glacial fill from Watkins Glen to Ithaca. Logs of wells drilled through the Salina at Watkins Glen and Ithaca are recorded; a brief sketch of the early salt development is given.

Knight, S. H., 1939, The Rock Creek lakes, Albany County, Wyo., part 2, *in* The saline lake deposits of Wyoming: Wyo. Geol. Survey Rept. Inv. 2, 8 p.

Gives an outline map of the saline lakes and descriptions and analyses of the salts in Brooklyn and Philadelphia lakes. The dominant salts are mirabilite and epsomite. Sodium chloride is present in negligible amount.

Kroenlein, G. A., 1939, Salt, potash and anhydrite in the Castile formation of southeast New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 23, p. 1682–1693.

Attributes the close of Capitan reef building to excess of evaporation over inflow to the basin. Confines the lower Castile to the Delaware Basin, with a total thickness of 2,000 feet of banded and white anhydrite, white halite, without potash. The top of the lower Castile has a depositional relief of hundreds of feet which makes correlation from this base inaccurate. Potash is the important mineral of the upper part of the Castile (Salado) and is present in amounts sufficient to satisfy the future requirements of the country.

Krumbein, W. C., 1951, Occurrence and lithologic associations of evaporities in the United States: Jour. Sed. Petrology, v. 21, p. 63–81.

Presents by maps the geographic distribution of evaporite deposits in the systems of rocks from the Ordovician to the Tertiary and gives a discussion of the lithologic relations of the evaporites to other sediments and to the structural basins in which they are formed.

Laizure, C. M., 1925 [Salines in Monterey County, Calif.]: Calif. State Min. Bur., Mining in California, v. 21, no. 1, p. 53–54.

Salt is extracted from sea water by solar evaporation at Moss Landing for local use in fish curing, ice cream, dairy and cattle markets. It requires 2 months of evaporation for initial salt crystallization, ultimately producing a layer of salt 4 to 6 inches thick. The salt is said to be more uniform in composition than that from San Francisco Bay.

——— 1927 [Salines in Solano County, Calif.]: Calif. State Min. Bur., Mining in California, v. 23, p. 211-212.

A well drilled by the Rochester Oil Co. in sec. 24, T. 5. N., R. 1. W., encountered a flow of natural gas and salt water. Salt was obtained by solar evaporation and marketed for many years as stock salt. There has been no production for about 10 years.

——— 1929 [Salines in Alameda County, Calif.]: Calif. Dept. Nat. Res., Div. Mines and Mining, Mining in California, v. 25, p. 441–447.

Salt, the chief mineral product of Alameda County, is obtained by solar evaporation of San Francisco Bay water. The Indians made periodic trips to the marsh lands for salt which had accumulated to a thickness of 8 inches. These natural deposits were worked by the early settlers from 1848 to 1860, when earthen evaporation vats were constructed, and by 1868, 17,000 tons of salt were produced annually. The new salt industry then extended from San Leandro Creek to Centerville, with 17 companies operating. When the Comstock lode was discovered a scarcity of salt developed and its cost rose to $35 a ton. The operations of the Arden Salt Co., California Chemical Corp., Leslie-California Salt Co., and Morton Salt Co. are described.

Lamar, J. E., 1938, Brines, *in* Unexploited or little known industrial minerals of Illinois: Ill. State Geol. Survey Circ. 23, 5th Ann. Mineral industries Conf., p. 222–224.

Illinois was at one time an important salt-producing State. Formerly, salt works were in operation at Equality, Central City, Murphysboro, St. John, Danville, and probably elsewhere. All were in central or southern Illinois. Ultimately these works were closed because of salt production from other sources. The St. Peter sandstone seems to yield the strongest brines. A table of 13 analyses accompanies the article.

Landes, K. K., 1951, Detroit River group in the Michigan basin: U. S. Geol. Survey Circ. 133, 23 p.

Reviews the stratigraphy of Devonian rocks of the Detroit River group in the southern peninsula of Michigan. Contains a series of structure contour maps that are helpful in saline investigations.

Landes, K. K., Ehlers, G. M., and Stanley, G. M., 1945, Geology of the Mackinac Straits region and subsurface geology of the northern part of the southern peninsula: Mich. Dept. Conserv., Geol. Survey Div., Pub. 44, Geol. Ser. 37, p. 155–176.

Gives a description of the Salina formation and its stratigraphic position in the northern part of the southern peninsula. Near Saginaw Bay the Salina is 3,000 feet thick and the top of the section is at a depth of 5,000 feet. It is composed of dolomite, salt, and shale; 36 percent of the section is salt. The salt does not crop out; instead, breccia resulting from solution and collapse is found near the outcrop.

Lang, W. B., 1937, The Permian formations of the Pecos Valley of New Mexico and Texas: Am. Assoc. Petroleum Geologists Bull., v. 21, p. 833–898.

Contains an outline of the stratigraphic position and distribution of the salines of the Permian basin and a discussion of the factors controlling Permian sedimentation.

La Vigne, E. F., 1938, Mining and preparation of rock salt at the Retsof mine: Am. Inst. Min. Metall. Eng. Trans., v. 129, p. 381–403.

The economic depression in salt mining in 1895 brought most of the New York salt mining companies together under the Retsof Mining Co. banner. Retsof later became a subsidary of the International Salt Co. Salt is mined by shaft at a depth of 1,063 feet. In 1926 a core test was drilled 784 feet below the mined salt bed. Logs of both mine shaft and core test are given, also a full description of the methods of mining and preparation of salt.

Le Grand, H. E., 1955, Brackish water in great Carolina ridge: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 2020–2037.

Brackish water of moderate salinity occurs in Bladen County, N. C. This salinity is apparently related to faulting associated with the great Carolina ridge. It is believed that the water entering Salt Marsh Creek is artesian and not invading sea water, which is likely true in Florida (Salt Spring and Warm Salt Spring, 86°F).

Lloyd, S. J., 1947, The world's greatest mine: Jour. Chem. Education, v. 24, p. 273–277.

Refers briefly to the various mineral products recoverable from sea water, the world's greatest mine. Gives a table in pounds of the minerals in sea water and paragraphs on salt and on gold, bromine, magnesium, and other elements.

Longwell, C. R., 1928, Geology of the Muddy Mountains, Nev., with a section through the Virginia Range to the Grand Wash Cliffs, Ariz.: U. S. Geol. Survey Bull. 798, p. 18–19, 93–94.

Lenses or beds of salt from 85 to 100 feet thick crop out in washes of Virgin Valley near St. Thomas.

Looker, C. D., 1938, Some recent developments in the use of sodium chloride (common salt): Am. Inst. Min. Metall. Eng. Trans. v. 129, p. 423–431.

Describes in general the uses of salt, with special reference to the Lixate solution process, the making and use of eutectic salt ice, and the stabilization of clay roads by the application of salt.

———1941, Salt as a chemical raw material: Chem. Industry, v. 49, pt. 1, p. 594–601; pt. 2, p. 790–799.

Reviews the salt industry in the United States, covering briefly the early uses and history of salt, production and refining methods, and the products and present uses of salt. Contains density tables for sodium chloride brines at 60°F, and diagrams of the relations of the alkalis to one another, byproducts and their uses, and the electrolytic products derived from fused salt.

Lotze, Franz, 1938, Steinsaltz and kalisalze geologie: Berlin, Verlag von Gebruder Borntraeger, Band 3, Teil 1, 936 p. (Otto Stutzer, Die wichtigsten lagerstätten der nicht-erze ser.)

Summarizes the geologic occurrences of salt and potash in the world, including many maps and diagrams.

McGrain, Preston, 1953, Miscellaneous analyses of Kentucky brines: Ky. Geol. Survey, ser. 9, Rept. Inv. 7, 16 p.

Lists analyses of brines from oil wells in eastern and western Kentucky.

McGrain, Preston, and Thomas, G. R., 1951, Preliminary report on the natural brines of eastern Kentucky: Ky. Geol. Survey Rept. Inv. 3, p. 1–22.

Lists analyses of brines from oil wells in eastern Kentucky.

McLellan, H. J., Wendlandt, E. A., Murchison, E. A., 1932, Boggy Creek salt dome, Anderson and Cherokee Counties, Tex.: Am. Assoc. Petroleum Geologists Bull., v. 16, p. 584–600.

Boggy Creek salt dome is near the axis of the East Texas geosyncline. Its large size and shape are uncommon for salt domes, for it has a low central area on top. Faulting has occurred in the south end of the uplift. Oil is produced from the southeast flank of the dome.

Manning, P. D. V., 1941, Chemicals from California's desert: Chem. Metall. Eng. v. 48, p. 96–99.

Describes briefly the economic extraction of salts from the brines of three California desert lakes: the American Potash and Chemical Co. and West End Chemical Co. at Searles Lake: the Natural Soda Products Co. of Keeler, and Pacific Alkali, both at Owens Lake: and the Desert Chemical Co. producing sodium sulphate and sodium chloride at Dale Lake, discovered by Irwin Bush in 1920 to be a source of salts. The Pacific Coast Borax Co. operations at Mojave and Death Valley Junction are mentioned.

Mansfield, G. R., 1927, Geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey Prof. Paper 152, p. 98–99, 338–340.

In 1922 the Wallace-Wyoming Oil Co. drilled a well in Tygee Valley. Six beds of salt from 6 to 29 feet thick were penetrated in a section of 456 feet, from a depth of from 123 to 579 feet. The salt is in the Preuss sandstone of the Jurassic.

Mansfield, G. R., and Lang, W. B., 1934, The Texas-New Mexico potash deposits: Tex. Univ. Bull. 3401, p. 641–832 [1935].

Briefly reviews occurrences of potash contained in salt deposits of the world. Gives an account of the search for potash in the United States with special reference to the Permian salt basin of the Southwest. Analyses of salt samples from Government and oil-well tests in percentages of potash present are given.

Martens, J. H. C., 1943, Rock salt deposits of West Virginia: W. Va. Geol. Survey Bull. 7, p. 1–58.

Reviews stratigraphy of the Ohio basin in West Virginia, Pennsylvania, Ohio, New York, and includes logs of salt sections of many important wells. Gives analyses of the salt, estimates of reserves, and considers the possibility of salt in eastern West Virginia. Outlines salt production and uses.

Matheny, Frank, 1951, Underground storage for liquified petroleum gases: Petroleum Eng. Ref. Annual. v. 23, no. 8, p. C–49–52.

Outlines the problem of petroleum byproducts in seasonal demand the search for suitable storage in off-season periods. After a review of the situation, the conclusion is reached that a dissolved-out reservoir in salt is the most satisfactory and economical solution to the problem. Salt domes and salt beds are advantageously situated in or near many large oil-producing areas.

Matheny, W. F., and Billue, G. H., 1950, Underground storage tanks: Chem. Eng. v. 57, no. 12, p. 115.

Describes a test of underground storage of petroleum where, by dissolving the salt, a reservoir of 50,000 barrel capacity was formed between the depths of 1,167 to 1,750 feet. Five tests were made by filling and removing the petroleum from the reservoir. The first test recovered 95 percent of oil: the last 4 tests returned 99 percent of it to the tanks. The only noticeable effect on the oil was a slight enclusion of moisture. The maximum cost of storage per barrel is $2.50 or about one-seventh that of steel-tank storage on the surface. The test was made in Winkler County, Tex.

Meinzer, O. E., 1911, Geology and water resources of Estancia Valley, N. Mex., with notes on ground-water conditions in adjacent parts of central New Mexico: U. S. Geol. Survey Water-Supply Paper 275, p. 7–86.

Describes the geologic setting for the saline lakes of central New Mexico, from which salt has been produced over the centuries.

Meinzer, O. E., and Hare, R. F., 1915, Geology and water resources of Tularosa Basin, N. Mex.: U. S. Geol. Survey Water-Supply Paper 343, p. 72.

Deposits of sodium chloride and sodium sulphate occur in certain low places. Thin crusts of sodium chloride occur on small northern alkali flats along Salt Creek and in arroyos and small flats east of the White Sands. Sodium sulphate in considerable quantities underlies Lake Lucero in the southern part.

Mendenhall, W. C., 1909, Ground waters of the Indio region, California, with a sketch of the Colorado Desert: U. S. Geol. Survey Water-Supply Paper 225, p. 27–28.

States that the Salton depression was covered by a salt marsh with salt crusts 6 inches to 1 foot thick before flooding by the Colorado River in 1904. The New Liverpool Salt Co. had developed a profitable salt industry before 1904. As much as nine-sixteenths of an inch of water was reported to have evaporated from salt pans in 24 hours when temperatures reached a maximum of 140°F.

Moise, T. S., and Haddock, G. B., 1936, The salt producing industry: Manufacturer's control of distribution; a study of Trade Practice Provisions in selected N. R. A. Codes, work materials No. 62. Trade Practice Studies Section, p. 2, 20–24, 67–159.

Reviews the salt industry with respect to its trade practices, sales, marketing, price maintenance, discounts, price discriminations, and freight equalization as it affects customer classification. Lists members of the Salt Producers Assoc. and their division of sales territory.

Murray, G. E., 1953, Résumé of salt and sulphur in Louisiana, *in* Proceedings of the southeastern mineral symposium, 1950: Ky. Geol. Survey, ser. 9, Special Pub. 1, p. 48–68.

A brief review of the geology of the Gulf Coast salt domes, with maps and diagrams.

National Petroleum Council, Committee on underground storage for petroleum, 1952, Report of the technical sub-committee: Washington, app. 1, 10 p.; app. 2, 8 p.; app. 3, 6 p.

Appendix 1 presents data on salt deposits suitable for the storage of petroleum products in various areas in the United States as a means of saving steel for

storage tanks. Appendix 2 deals with some chemical aspects of underground storage and appendix 3 with the engineering aspects of underground storage. Comparative costs are presented.

Nettleton, L. L., 1934, Fluid mechanics of salt domes: Am. Assoc. Petroleum Geologists Bull., v. 18, p. 1175–1204.

The prime cause for salt dome formation is ascribed to density difference and plasticity of the sediments. The peripheral sink formed about the base of a salt stock may cut off the supply of salt. Expressions for volume relations and relative dimensions are given in terms of thickness of salt and radius of peripheral sink. The differential behavior of two liquids of different viscosities and densities is given by experiments. Diagrams are presented to show the effects of contemporaneous sedimentation and salt doming as an explanation for many of the geologic features of salt domes. A list of related references is included.

——— 1943, Recent experimental and geophysical evidence of mechanics of salt dome formation: Am. Assoc. Petroleum Geologists Bull., v. 27, p. 51–63.

Gives a comparison of the factual data to experimental evidence in formulating a concept of salt dome evolution. It is concluded that salt domes are the consequence of fluid-mechanics where pressure and plasticity are the motivating factors. Recent evidence for the existence of rim synclines favor this postulation.

——— 1947, Geophysical history of typical Mississippi piercement salt domes: Geophysics, v. 12, no. 1, p. 30–42.

Describes the discovery and exploration of the New Home and D'Lo salt domes by geophysical methods. They were indicated by gravity surveys, checked by the refraction seismograph, and their depth and position confirmed by drilling. Gives examples of how strong, but local gravity expressions, may be missed by reconnaissance surveys.

——— 1955, History of concepts of Gulf Coast salt-dome formation: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 2373–2383.

A comparison is made of the earlier concepts of salt-dome formation with those of today. It seems evident that salt domes are due to a fluid adjustment of salt to density differences. A study of the quantitative relations involved in salt doming and of increasing evidence of the occurrence of rim synclines are impressive assurances of a displacement origin for the domes.

Nettleton, L. L., and Elkins, T. A., 1947, Geologic models made from granular materials: Am. Geophys. Union Trans., v. 28, p. 451–466.

In part presents some results of experiments with dry powders as model materials to simulate salt-dome formation.

New Mexico Geological Society, 1954, Guidebook of southeastern New Mexico, 5th field conference: Socorro, N. Mex., 209 p.

A symposium of 19 papers which describes the geologic setting of the Permian salt basin in southeastern New Mexico.

New York State Department of Commerce, 1950, Mineral industries of New York: p. 54–60.

Gives a brief review of the salt industry in the State, a block diagram, a map of the salt area and a list of companies producing salt in the State.

Newland, D. H., 1919, Salt, *in* Mineral resources of the State of New York: N. Y. State Mus. Bulls. 223–224, p. 221–235.

Presents a comprehensive review of early history and development of the salt industry of New York State; also the mining, manufacture, and production of salt. Lists the plants, producers, and grades of salt marketed.

——— 1928, Recent progress in the study of the Salina formation: Natl. Research Council Repr. and Circ. Ser. 85, p. 36–43.

Reviews the information accumulated on the Salina formation. Compares the sedimentary characteristics of the Vernon, Camillus, and Bertie beds. States the Camillus problem and concludes that the Salina sea was of marine origin, that the volume of salt present could not have been derived from erosional leachings, and that the cause of saline accumulation varied from place to place. Because there is no trustworthy evidence, concedes the point that the Silurian sea may not have had the same composition as the sea today has.

O'Donnell, Lawrence, 1935, Jefferson Island salt dome, Iberia Parish, La.: Am. Assoc. Petroleum Geologists Bull., v. 19, p. 1602–1644.

Jefferson Island is the only one of the Five Islands in southern Louisiana from which sulfur is produced. It is a flat-topped dome, capped by sulfur-bearing limestone and anhydrite. A salt spine rises 850 feet above the cap on the east side. Salt was discovered in 1894. Sulfur was accidentally drilled into in the late twenties. By 1935 more than 2,225,000 long tons of salt had been produced and 500,000 long tons of sulfur. The author believes that the spine and cap were initially formed and were later thrust up from the source of the salt. Salt is produced by conventional mining and sulfur by the Frasch process. The sulfur wells are in Lake Peigneur and are connected by pipeline to the plant on shore.

Osterwald, F. W., and Osterwald, D. B., 1952, Wyoming mineral resources: Wyo. Geol. Survey Bull. 45, p. 131–141.

Most of the saline deposits of Wyoming are of the sodium sulphate-sodium carbonate types. Sodium chloride occurrences in brines or in deposits associated with other salines are given by counties.

Parker, T. J., and McDowell, A. N., 1955, Model studies of salt-dome tectonics: Am. Assoc. Petroleum Geologists Bull. v. 39, p. 2384–2470.

Describes various experiments using asphalt and semifluid muds of greater density to simulate salt-dome formation.

Pepper, J. F., 1947, Areal extent and thickness of the salt deposits of Ohio: Ohio Jour. Sci., v. 47, p. 225–239.

From a study of the records of 3,555 wells, contour maps of the total thickness of salt, position of the top of the salt, and the variation in thickness of rocks between the top of the Big Lime and the top of the uppermost salt bed were constructed. The first salts were deposited in local basins; subsequent deposition occupied enlarged basins which later coalesced to form continuous beds of salt. Salt beds, 100 feet thick, approach to within 1,300 feet of the surface southwest of Cleveland (Lorain and Cuyahoga Counties) and descend southeastward to 6,734 feet (Monroe County) below surface. The western limit of the salt is defined.

Phalen, W. C., 1912, Description of the Kenova quadrangle [Kentucky-West Virginia-Ohio]: U. S. Geol. Survey Geol. Atlas, folio 184, p. 16.

"Many years ago salt was obtained from wells sunk on Big Sandy River near Zelda. The old salt works have long since disappeared. South of Zelda, near Catalpa, some of the wells drilled for oil and gas have struck salt water, which is still running."

——— 1919, Salt resources of the United States: U. S. Geol. Survey Bull. 669, 284 p.

This comprehensive study includes descriptions of salt deposits by States. History of production, extent of deposits, geology of the deposits, and a bibliography of literature available for each State are included. Maps indicate locations of deposits. The origin and formation of saline deposits, chemical composition of saline materials, and tables on production are also given.

——— 1949, Salt, *in* Industrial minerals and rocks: New York, Am. Inst. Min. Metall. Eng., 2d ed., p. 807–843.

Summarizes most of the essential factors of salt: its properties, composition, mode of occurrence, origin, and world distribution. Operations relating to production, consumption, processing, marketing, with tests and specifications of salt for human consumption, uses and prices are described. A bibliography is given.

Poindexter, O. F., Martin, H. M., and Bergquist, S. G., 1951, Rocks and minerals of Michigan: Mich. Dept. Conserv., Geol. Survey Div. Pub. 42, 3d ed. revised, p. 101.

Gives data on the salt beds of Michigan. In Ogemaw County a well was drilled through 1,066 feet of the Detroit River formation containing 300 feet of rock salt in 12 beds from 6 to 78 feet thick. Also in this well, 3,144 feet of Salina was penetrated, which contained 38 rock salt beds from 2 to 463 feet thick, totaling 1,260 feet of rock salt. A deep well in Bay County penetrated 2,790 feet of Salina with 1,700 feet of rock salt in beds of from 30 to more than 400 feet thick. The top of the Salina formation varies from 5,393 to 8,547 feet below the surface in Ogemaw County; from 5,480 to 8,270 feet in Bay County; and from 1,000 to 2,000 feet below the surface in Wayne County where 550 feet of salt occurs in 17 beds 20 to 90 feet thick.

Rock salt is mined from a depth of 1,100 feet below Detroit. Elsewhere at Midland, Taganau, Bay City, St. Clair, Port Huron, and also in Detroit, salt is manufactured from natural and artificial brines.

Powers, Sidney, 1926, Interior salt domes of Texas, *in* Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, p. 209–268.

Discusses the characteristic features of six salt domes located in the interior of eastern Texas—Grand Saline, Steen, Brooks, Keechi, Palestine, and Butler—and compares them with the interior domes of Louisiana. Contains an introductory outline of the history, exploitation, and stratigraphy of the salt-dome area.

Powers, Sidney, and Hopkins, O. B., 1922, The Brooks, Steen, and Grand Saline salt domes, Smith and Van Zandt Counties, Tex.: U. S. Geol. Survey Bull. 736–G, p. 179–239.

Gives geologic descriptions of the salt domes with logs of wells, maps, and gas analyses. Also gives a general description of the origin of salt domes.

Pray, L. C., 1954, Outline of the stratigraphy and structure of the Sacramento Mountain escarpment: N. Mex. Geol. Soc., Guidebook southeastern N. Mex., 5th Field Conf., p. 92–107.

Outlines the stratigraphy of the Sacramento Mountains, covering the complete section of rocks of Paleozoic age which include or are related to the salt beds of the Permian salt basin to the east of the mountains. Maps, illustrations, and a bibliography are included.

Price, P. H., 1952, Geologic field conference in Wayne, Cabell, and Lincoln Counties [W. Va.]: W. Va. Geol. Econ. Survey, p. 5.

At present there are no salt brine industries in Wayne, Cabell, or Lincoln Counties. Brines from the Salt Sand of Pottsville age and the Big Injun of Mississippian age have a specific gravity of 1.08 or more. The Big Injun sand always yields large flows of salt water when penetrated by drill holes.

Price, P. H., Hare, C. E., McClue, J. B., Hoskins, H. A., 1937, Salt brines of West Virginia: W. Va. Geol. Surv., v. 8, 203 p.

Gives a descriptive and historic sketch of the brine industry, the geology and chemistry of production, and many tables of analyses of brine samples from wells.

Price, P. H., and Nolting, J. P., 1949, Salt resources of West Virginia: Am. Inst. Min. Metall. Eng. Trans. 184, p. 259–263.

Reviews history of salt production from brines that are believed to be connate waters in marine sediments. The Middle and Lower Pennsylvanian and the Mississippi rocks are the most important containers of brine. The Salt Sand yielded a heavy brine of 1.1243 specific gravity; Big Lime, 1.1299; Big Injun, 1.1449; Brown Shale, 1.1617, and the Oriskany a brine of 1.2246 specific gravity. Calcium saturates the lower horizons. The brine section is calculated to contain 800 million tons of salt. Rock salt is available only from the Salina (Silurian). The northern part of the State is underlain by a bed of salt about 100 feet thick. Production is by solution only. A table of depths to the Salina salt is given.

Prommel, H. W. C., and Crum, H. E., 1927, Salt domes of Permian and Pennsylvanian age in southeastern Utah and their influence on oil accumulation: Am. Assoc. Petroleum Geologists Bull., v. 11, p. 373–393.

Presents explanations of the relation of subsurface saline formations to anticlinal structures and the stratigraphy of the region. Maps, cross sections, and other illustrations accompany the article.

Rall, C. G., and Wright, Jack, 1953, Analyses of formation brines in Kansas: U. S. Bur. Mines Rept. Inv. 4974.

Contains a list of 600 analyses of oilfield waters in which, with other elements, the amounts of sodium and chlorine are given.

Rankama, Kalervo, and Sahama, T. G., 1950, Geochemistry: Chicago, Ill., Chicago Univ. Press, 912 p.

This is a voluminous compilation of data on geochemistry containing many items having particular reference to both sodium and chlorine and to their combined form, salt. Subjects such as sea water, evaporation, chemical differentiation during sedimentation, the alkali metals and the halogens which are of importance in problems concerning salt are discussed.

Reidel, J. C., 1951, Ninety percent propane recovery from 50,000-bbl salt reservoir: Oil and Gas Jour. v. 49, p. 167–168, 236–237.

Describes a reservoir dissolved out of salt for the storage of propane at the Texas Gasoline Corp. plant in the Benedum field, Upton County, Tex. The top of the 1,000-foot section of salt is at a depth of 1,290 feet. The first test showed a recovery of 93.79 percent of the propane stored in the reservoir.

Richardson, G. B., 1904, Salt, gypsum, and petroleum in trans-Pecos, Tex.: U. S. Geol. Survey Bull. 260, p. 573–585 [1905].

Presents data on the salt lakes in Salt Basin west of the Guadalupe Mountains, with analyses of some of the salts. Traces of strontium, lithium, and potassium have been identified, also borax. Mexicans for centuries have come from as far as Chihuahua to gather salt from these lake flats. Denial of their use without payment caused the Salt War of 1877.

——— 1907, Underground waters in Sanpete and central Sevier Valleys, Utah: U. S. Geol. Survey Water-Supply Paper 199, p. 8–9.

The Jurassic rocks exposed in Sevier Valley contain lenses of salt and gypsum.

Ries, Heinrich, 1938, Use of sodium chloride in road stabilization: Am. Inst. Min. Metall. Eng. Trans., v. 129, p. 432–438.

Presents data and explanations for the behavior of salt as a road binder for clay and soil surfaces.

Rogers, G. S., 1918, Intrusive origin of Gulf Coast salt domes: Econ. Geology, v. 13, p. 447–485.

Gives a critical review of the mechanics of salt-dome formation as evident from data known at the time. It assumes that salt from unknown depth is pressed through the overloading sediments toward the surface as opposed to a contemporary view held by most geologists that the salt was deposited by ascending waters.

Root, Bradley, 1953, The largest salt mine in the Western Hemisphere: Explosives Engineer, v. 31, no. 1, p. 49–52, 59.

Describes briefly the mining method and equipment used in the Retsof salt mine of the International Salt Co., Retsof, N. Y. The article is well illustrated.

Ross, C. P., 1941, The metal and coal mining districts of Idaho, with notes on the nonmetallic minerals resources of the State; annotated bibliography by C. P. Ross and M. S. Carr: Idaho Bur. Mines Geology Pamph. 57, 2 v., p. 109–110.

Describes briefly the occurrence of salt in the Preuss sandstone in southern Caribou County. Gives citations to salt, items 110, 406, 457, 565, 625, 726 in part 2, the Bibliography, volume 2 of this report. Also lists U. S. Geological Survey Mineral Resources 1882 to 1915 as references to information on salt.

Runnels, R. T., Reed, A. C., Schleicher, J. A., 1952, Minor elements in Kansas salts: Kans. Geol. Survey Bull. 96, p. 185–200.

Spectrochemical examination of mined salts, brines, and processed salts from Kansas revealed the presence of celestite, iron, and possibly polyhalite. Elements identified as present in minute quantity are Si, Al, V, Ti, Mn, Cr, Ca, Sn, Pb, Zn, and Ag.

Schaller, W. T., and Henderson, E. P., 1932, Mineralogy of drill cores from the potash field of New Mexico and Texas: U. S. Geol. Survey Bull. 833, 124 p.

Contains a descriptive list of the minerals found in an examination of the salt cores obtained in wells drilled into the Permian salt beds of western Texas and southeastern New Mexico.

Schrader, F. S., Stone, R. W., and Sanford, Samuel, 1917, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, 412 p.

A revised edition of U. S. Geological Survey Bulletin 585 on the same subject. Lists and describes mineral occurrences including salt by States.

Senior, S. P., Jr., 1929, San Mateo County [Calif.]: Calif. Dept. Nat.Res.,Div. Mines and Mining., Mining in California, v. 25, p. 253–254.

Describes the San Mateo plant of the Leslie-California Salt Refining Co. on the west side of San Francisco Bay where salt is produced from sea water by solar evaporation. The San Francisco Salt Refining Co. also produces salt on the marsh flats east of Redwood City.

Shoewe, W. H., 1943, Kansas oil field brines and their magnesium content, with chemical analyses by R. Q. Brewster and Calvin Vander Werf: Kans. Geol. Survey Bull. 47, p. 37–76.

Gives geographic distribution of oilfield brines and their analyses by stratigraphic position. Although the emphasis is on magnesium, data on sodium chloride are adequately presented.

Shrewsbury, R. D., 1946, A theory of the occurrence of salt domes: Oil Weekly, v. 122, no. 1, p. 36–39.

Presents largely a speculative view of an origin of salt domes with particular reference to their possible mode of occurrence in offshore locations.

Silsbee, J. L., 1925, Saline deposits of western Utah: Mining and Metallurgy, v. 6, p. 425–429.

Describes the operations and developments at Salduro for the extraction of potash from brines drained from the marsh. Gives representative analyses of the brine and a review of the economic factors involved. The very superabundance of salt in the intermountain region where industrial requirements are small makes production of sodium chloride for other than immediate local use uneconomic.

Sloss, L. L., 1950, Paleozoic sedimentation in Montana area: Am. Assoc. Petroleum Geologists Bull. v. 34, p. 423–451.

The Middle Devonian in western Montana is reported to contain large deposits of anhydrite and salt.

Smith, J. A., 1881, Biennial report of the Colorado State Geologist: Salt, p. 34.

"Several large salt springs exist in South Park, some 15 miles southeast of Fairplay, and some years since works were erected there capable of turning out 10,000 pounds of salt per day. Saline springs of various degrees of strength also exist at several other points in the State, some of which could be made profitable, but none of them have been improved, and many are not even claimed. Among the best of these are springs near the head of Salt Creek, a tributary of the Rio Dolores, which are so strongly saline as to render the waters of the creek quite briny."

Smith, R. A., 1914, Nonmetallic minerals; Mineral resources of Michigan: Mich. Geol. Survey Pub. 19, Geol. Ser. 16, pt. 2, p. 284–289.

Outlines the salt industry of the time. The record shows that most of the salt-producing areas of the present were then known. Along the shores of Lake Huron and Saginaw Bay, lumber mills in the early days engaged in salt production by burning waste sawdust to evaporate the brine obtained from wells. The decline in lumbering curtailed much of this production.

Snider, L. C., 1913, Gypsum and salt of Oklahoma: Okla. Geol. Survey Bull. 11, p. 202–214.

Describes the Alfalfa County salt plain, the salt plains of the Cimarron, known as Big and Little salt plains in Harper, Woods, and Woodward Counties; also those in Blaine, Beckham, Harmon, and Jackson Counties. The salt plains of the Cimarron are of historic interest because their salt was widely drawn upon by explorers and early settlers.

Spooner, W. C., 1926, Interior salt domes of Louisiana, *in* Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, p. 269–344.

Gives a general survey of the geology of northwestern Louisiana, including a note on exploitation of salt, and a comprehensive description of the Vacherie, Prothro, Bistineau, King's, Rayburn's, Price's, Drake's, Winnfield, Cedar Creek, and Coochee Beake salt domes.

——— 1932, Salt in Smackover field, Union County, Ark.: Am. Assoc. Petroleum Geologists Bull., v. 16, p. 601–610.

Salt was discovered at a depth of 5,974 feet in the Hayes well A–9, sec. 4, T. 16 S., R. 15 W., Union County, Ark., and the drill continued in salt and thin lenses of anhydrite to 7,255 feet. On the basis of this and other data it is believed that the Smackover oilfield is on a salt-dome structure.

Stafford, O. F., 1939, Preliminary report upon Oregon saline lakes: Oreg. Dept. Geology and Mineral Industries Short Paper 1, 4 p.

The Abert, Summer, and Alkali dry lakes of south-central Oregon contain sodium chloride, sodium sulphate, sodium carbonate, potassium chloride, and borax. Production and delivery of salt from these lakes to markets along the Columbia River in competition with imports of solar salt from San Francisco is not considered likely. The economic production of sodium carbonate and the other salts from these lakes depends on successful research and better facilities to meet the competitive market.

Stone, R. W., 1937, Rock salt in Pennsylvania [abs.]: Econ. Geology, v. 32, p. 1072.

Although salt is not produced from deposits in Pennsylvania, large quantities are available. Fifteen deep wells drilled in 9 counties of western and northwestern Pennsylvania penetrated beds of salt in the Salina formation at depths of from 2,300 to 7,000 feet. Single salt beds are from 5 to 70 feet thick; one bed in Erie County is 15 feet thick; 4 beds in Washington County total 100 feet. Another test penetrated 22 beds from 6 to 55 feet thick which, with intercalated shale, represents a 407-foot section.

Stose, G. W., 1911, Geology of the salt and gypsum deposits of southwestern Virginia: U. S. Geol. Survey Bull. 530, p. 232–255.

Describes the Holston River valley, giving an outline of the stratigraphy and structure of the rocks. The Maccrady formation, of the Mississippian, contains salt and gypsum. The gypsum occurs irregularly along an overthrust fault; the

salt is produced by solution from a depth of 2,000 feet on the east side of valley; it is shallower on the west. Natural brine seeps indicated the presence of salt below, which formed the only source of salt for the South during the Civil War. The author considers the salt and gypsum to be replacement deposits in relation to the fault.

Stout, Wilber, Lamborn, R. E., and Schaaf, Downs, 1932, Brines of Ohio: Ohio Geol. Survey, 4th ser., Bull. 37, 123 p.

Covers the history, origin, and stratigraphic succession of the occurrences of brines and their utilization and distribution by county and formation.

Stow, M. H. 1951, The mineral resources and mineral industry of Virginia: Advisory Council on Va. Economy, Comm. on Mining Rept., p. 43–44.

Rock salt occurs in association with gypsum in the valley of the North Fork of the Holston River. The valley extends 30 miles northeastward. No rock salt is mined in Virginia, but brine is produced by the Olin Mathieson Chemical Corp. at Saltville. It is believed that exploratory drilling might uncover additional deposits of salt.

Taft, Robert, 1946, Kansas and the nation's salt: Kans. Acad. Sci. Trans., v. 49, no. 3, p. 223–272.

Presents a general review of the occurrence of salt, its production and marketing, with special reference to Kansas.

Taylor, R. E., 1938, Origin of the cap rock of Louisiana salt domes: La. Dept. Conserv. Geol. Bull. 11, p. 1–183.

Gives a review of the geology, mineralogy, and literature of Louisiana salt domes. Describes the form and structure of cap rocks. Rejuvenated movement of the salt core in places may bypass the old cap, giving the impression, on insufficient exploration, that no cap rock is present. Concludes that the anhydrite of a cap is the same anhydrite as that found in the salt. Considers that ground water plays an important part in determining the size and composition of the cap rock.

——— 1955, Field trip to south Louisiana salt domes, *in* Russell, R. J., ed. Guides to southeastern geology: New York, Geol. Soc. America. p. 538–548.

Notes that 83 salt domes have been found in southern Louisiana: 27 in the northern part of the State, 50 in Mississippi, 1 in Alabama, 21 in east Texas, 51 along the Gulf Coast, and 5 in southwest Texas, making a total of 238 for the Gulf Coast region. Describes the general characteristics of salt domes, their size, depth, and mineral content, with more detailed data on Avery Island, Jefferson Island, and Weeks Island salt domes. Contains references and a map that shows the distribution of salt domes, both inland and offshore.

Teeple, J. E., 1929, The industrial development of Searles Lake brines, with equilibrium data: New York, The Chemical Catalog Co., Inc., 182 p.

Gives a brief historical outline and the operational development of the chemical plant for the successful production of the various salts from the Searles Lake brine. The presentation of equilibria diagrams constitutes two-thirds of the book.

Todd, J. E., 1909, Description of Aberdeen-Redfield district, South Dakota: U.S. Geol. Survey Geol. Atlas, folio 165, p. 9.

Saline waters and crusts are found in Salt Lake, Lord Lakes, and their vicinities. Some shallow wells also yield water too saline for domestic use. The salt is believed to be leachings from the Pierre shale.

Trump, E. M., 1947, Mining soluble salines by wells: Am. Inst. Min. Metall. Eng. Trans., v. 173, p. 223–229.

Outlines the Tully and Detroit methods previously developed to dissolve bedded salt from depth by solution and shows by description and diagram the advantages gained in using the Trump plan. In the Trump plan air is forced down with the water which forms a protective blanket between the salt above and the water, thus forcing solution of the salt to advance radially from the base of the well along the floor of the salt bed. By periodically raising the water level more salt is dissolved, and any impurities contained in the salt falls to the floor where it is eliminated from subsequent mining and refining operations.

Tucker, W. B., and Sampson, R. J., 1929 [Salines in Riverside County, Calif.]: Dept. Nat. Res., Div. Mines, Mining in California, v. 25, p. 524–526.

Before the flooding of Salton Sink in 1903 by the Colorado River, salt was produced from the dry bed by the New Liverpool Salt Co. The salt layer was reported to range from 10 to 20 inches thick. Salt is now produced by solar evaporation at the north end of Salton Sea, 6 miles southeast of Mecca. The present concentration of salt in the water is from 12 to 22 per cent: annual rainfall 1.48 inches, and an evaporation of 87 to 129 inches per year.

Tucker, W. B., Sampson, R. J., and Oakeshott, G. B., 1949, Mineral resources of Kern County [Calif.]: Calif. Jour. Mines and Geology, v. 45, p. 250.

A brief note indicates that the Long Beach Salt Co. is producing salt from Dry Salt Lake, 6 miles northeast of Cantil. Industrial salt is recovered from lake brine by solar evaporation.

Tustin, E. B., Jr., 1946, Salt, the most useful of mineral substances: Calif. Jour. Mines and Geology, v. 42, no. 1, p. 379–383.

Relates some of the early beliefs, superstitions, and biblical customs of ancient times regarding salt and its place in war and peace. Describes briefly the present vacuum process of salt production and mentions some of the uses of salt.

United States Bureau of Mines, 1924–31: Mineral Resources of the United States.

These annual reports are a continuation of those formerly issued by the Geological Survey and contain a chapter on salt, giving statistics on production, consumption, prices, uses, imports, exports, and any notable changes in the industry during the year.

——— 1932–52: Minerals yearbook.

These annual reports are a continuation of those previously appearing under the title of Mineral Resources of the United States. Each annual report contains statistics on the production, consumption, uses, prices, imports, and exports of salt. New developments in the industry are also noted.

United States Geological Survey, 1882–1923: Mineral Resources of the United States.

These annual publications contain reports on the geology of salt production with special reference to statistics of consumption, uses, prices, imports, exports, and current developments in the industry.

Vaughn, F. E., 1926, The Five Islands, La., *in* Geology of salt dome oil fields: Am. Assoc. Petroleum Geologists, p. 356–397.

Includes lucid descriptions and contour maps of each of the Five Islands, giving a general review of its history, geology, physiography, and paleontology.

A final summation gives opinions on the age, formation, and lineal orientation of the five salt domes—Jefferson Island, Avery Island, Weeks Island, Cote Blanche, and Belle Isle. The domes have long been a major source of salt in Louisiana.

Veatch, A. C., 1899, The Five Islands: La. Geol. Survey, Geol. and Agr., pt. 5, Special Rept. 3, p. 209–262.

The article is of value as an historical review of the geology of the Five Islands and the various interpretations of their origin before the salt-dome concept. Rock salt was first discovered here in the United States in 1862 (Avery Island). The salt masses were postulated to be upturned salt blocks.

Names by which the Five Islands have been known are as follows:

Early name	*Later Names*
Belle	Iberia dome
Cote Blanche	Cote Blanche Island dome
Cote Carline	Jefferson Island (Depuys, Millers, Orange)
Grande Cote	Weeks Island
Petite Anse	Avery Island (Thomas, Salt, Marsh)

Veitch, W. M., 1943, Mining salt beneath the Kansas prairies: Explosives Engineer, v. 21, p. 180–182, 198.

Four companies mine salt in Kansas: Morton Salt Co., American Salt Co., Carey Salt Co., Independent Salt Co. Salt is produced by both solution and mining from a bed 8½ feet thick and at a depth of 600 feet. Mining is done by the room-and-pillar method. A brief description is given of the solution process and vacuum refining.

Ver Plank, W. E., 1951, Salines in the Bay area, *in* Geologic guide book of the San Francisco Bay Counties: Calif. Div. Mines Bull. 154, p. 219–222.

The major production of salt in California is by solar evaporation. Favored by climate and natural facilities this method remains economically competitive. By modernization of refining methods salt of high purity is produced along with bromine, potassium, and magnesium chlorides from the bittern, when the market will permit. The raw water is drawn from San Francisco Bay which is only slightly less salty than the open-sea water (3.40 in comparison with 3.72 percent).

Voskuil, W. H., 1955, Salt, *in* Minerals in world industry: New York, McGraw-Hill, Inc. p. 286.

Briefly mentions salt as one of the primary necessities of life as well as of industry, and broadly states the areas of salt production in the United States and the uses for salt.

Wagner, N. S., 1947, Sodium chloride occurrence near Vale, Oreg.: Oreg. Dept. Geology and Mineral Industries, Ore.-Bin, v. 9, no. 9, p. 67–73.

Brines were early reported near Vale, Malheur County. To determine the facts, 9 hand-auger tests were drilled in the clay sediments of the area to a depth of 31 feet or less. Water samples taken in the wells gave salinities as much as 51,500 parts per million. Wells in the northwest sector of the group were strong in sulphates, those to the southeast high in sodium chloride. The origin of the brines remains uncertain. No bromine or iodine was found.

Weigel, W. M., 1938, The salt industry of Louisiana and Texas: Am. Inst. Min. Metall. Eng. Trans., v. 129, p. 405–422.

Gives a general review of the salt industry in Louisiana and southeastern Texas.

Wharton, J. B., Jr., 1953, Jefferson Island salt dome, Iberia and Vermilion Parishes, La.: Am. Assoc. Petroleum Geologists Bull., v. 37, p. 433–443.

Reports on results of exploration in the last 20 years. Drilling on the south and southeast sides of the dome has revealed small individual accumulations of oil in sand with possibilities of finding many more on opposite sides of the dome. This drilling has made it possible to define the shape of the salt stock to a depth of 12,000 feet and has disclosed sharply upturned marginal sediments and radial faulting. The positions of the calcite-anhydrite cap and the sulfur pocket have been outlined.

Whitlatch, G. I., 1945, Minerals, *in* Industrial resources of Tennessee; forests, agriculture, and minerals: Tenn. State Plan. Comm., v. 2, revised ed., p. 90–91.

Although some occurrences of rock salt have been reported, no economically important bed has been found. Drilled wells have encountered brines from the Ordovician to Mississippian. Counties from which brines have been produced are mentioned. Hawkins County, contiguous to Virginia, is suggested as the most likely place to prospect for salt in Tennessee.

Willard, D. E., 1907, Salt and alkaline waters in lakes, *in* Story of the Prairies: Chicago, Ill., Rand McNally & Co., p. 154–156, 165.

Explains in simple terms that the mineralized lake waters of North Dakota are derived from leachings of Cretaceous rocks. The shallow wells generally yield hard, or alkali-bearing waters; the deep or artesian wells yield soft, or sodium waters.

Willis, Bailey, 1948, Artesian salt formations: Am. Assoc. Petroleum Geologists, v. 32, p. 1227–64.

Presents a lengthy discussion of what the author calls an artesian process of salt-dome formation in which it is postulated that saturated warm water rising from salt beds through fissures deposit salt and other minerals on cooling, and by the force of crystal growth enlarge the mass of the salt body.

Wilson, E. D., 1944, Salt—nonmetallics of Arizona: Ariz. Univ. Bull., v. 15, no. 4, p. 43; Ariz. Bur. Mines Bull. 152, Min. Tech. Ser. 41, p. 42.

A small tonnage of salt has been mined from the Camp Verde sulphate deposits in Yavapai County. Salt also is found in dry marshes along the Salt River, particularly in the brine seeps at Salt Banks. It is dispersed in the muds of dry lakes and playas.

Winchell, N. H., 1885, The Humboldt salt well in Kittson County [Minn.]: Minn. Geol. and Natural History Survey 13th Ann. Rept., p. 41–47.

There are salt springs in the Red River valley in the northwest corner of Minnesota and adjacent North Dakota and Manitoba. This fact was known as early as 1823. Wells drilled in the area for stock water gave an overflow of brine. It is suggested that the source of the salt is in the Devonian, although it may be in older rocks, or even the younger Carboniferous. The salt springs issue through openings in the covering sheet of clay.

Wright, A. J., 1953, Economic geography of Ohio: Ohio Geol. Survey, 4th ser., Bull. 50, p. 43–44.

Briefly mentions the salt and brine industry in Ohio, stating that salt production is both the oldest and newest mineral activity because of the rise in chemical

industries. Anticipates increased production of salt as a companion to abundant local sources of limestone and fuel which are required for the production of numerous chemicals.

Zimmerman, E. W., 1951, World resources and industries: New York, Harper & Bros., revised ed., p. 784–785.

Comments in general on the production and economic use of salt in the chemical industry.

Anonymous, 1929, Open pit salt mining in Utah: Eng. Min. Jour. v. 128, p. 814.

Salt crops out over an area 1.5 miles by 0.5 mile, east of Salina, Utah. The method of mining by the Great Western Salt Co. is described, also the procedure followed in recovering salt from a strong brine (27 percent) formed by solution of exposed salt by rain water.

——— 1951, Cities Service's Lowell project storing propane, Michigan: Oil and Gas Jour., v. 50, p. 101.

A cavern was formed in a 250-foot bed of salt at a depth of 3,798 feet by dissolving out the salt, requiring 6 barrels of water for each barrel of underground space formed. Propane from the Pampa, Tex., plant was injected at 1,200 pounds per square inch gage. Withdrawal of the propane will be made by water displacement at 200 gallons per minute.

INDEX