Selected Annotated Bibliography of Gypsum and Anhydrite in the United States and Puerto Rico

GEOLOGICAL SURVEY BULLETIN 1105

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By CHARLES F. WITHINGTON *and* MARION C. JASTER

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Contains more than 400 annotated references, to January 1959, on the geology, geographic occurrences, origin, technology, and uses of gypsum and anhydrite

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SELECTED ANNOTATED BIBLIOGRAPHY OF GYPSUM AND ANHYDRITE IN THE UNITED STATES AND PUERTO RICO

By Charles F. Withington and Marion C. Jaster

ABSTRACT

This bibliography contains more than 400 annotated references that are concerned with the geologic occurrence of gypsum and anhydrite in the United States; the description of specific deposits; the mining, processing, and uses of gypsum and anhydrite; and the origin and properties of the calcium sulfate minerals. The annotations are arranged alphabetically by author. The data in the annotations are indexed according to geographic area and subject.

INTRODUCTION

This bibliography of gypsum and anhydrite consists of annotated references to the literature that is available in the libraries of the U.S. Geological Survey and the Department of the Interior in Washington, D.C. Although this is not a complete compendium of all the literature on gypsum and anhydrite, it is an attempt to include enough pertinent material to constitute a ready reference on the occurrences in the United States and provide a starting point for further research.

The references are listed alphabetically by author. In selecting them, emphasis was placed on the geologic occurrence of gypsum and anhydrite in the United States and on the location and origin of the economic deposits. Some references that concern the physical and chemical properties, uses, and mining and milling of gypsum and anhydrite are included. References that concern occurrences of gypsum and anhydrite crystals are also included for the use of mineral collectors.

The geologic names used in the annotations are those of the various authors and do not necessarily follow usage of the U.S. Geological Survey.

GYPSUM AND ANHYDRITE

Gypsum and anhydrite occur in considerable quantities in many parts of the United States. The resources of both minerals are great, though many of the despoits are in areas too far from consuming centers to be worked profitably. Gypsum is the more useful of the two; more than 9.6 million tons of it was mined in the United States in 1958. No comparable figures are available for anhydrite production, but probably less than 200,000 tons was mined in 1958.

COMPOSITION, PROPERTIES, AND OCCURRENCE

Gypsum is hydrous calcium sulfate ($CaSO_4 \cdot 2H_2O$); when pure, it contains 32.5 percent lime (CaO), 46.6 percent sulfur trioxide (SO_3), and 20.9 percent water. It is one of the softest minerals, having a hardness of 1.5 to 2.0 on the Mohs scale, and may be easily scratched with the fingernail. It has a specific gravity of 2.3. Gypsum resembles both calcite and talc; however, it does not effervesce in hydrochloric acid as calcite does, and it does not have the greasy feel of talc.

Several varieties of gypsum are found in nature: selenite and satin spar are the crystalline varieties, rock gypsum is the coarse-grained massive variety, alabaster is the fine-grained compact variety, and gypsite and gypsum sands are the unconsolidated varieties. Selenite is found as colorless transparent crystals which can be split into thin sheets or plates much as mica can, but, unlike mica, the selenite plates break down under heat and are not elastic. Selenite occurs either scattered through massive gypsum or in a clay matrix. Individual crystals are generally less than 2 inches long, although some are as much as 4 feet long. In places, selenite occurs as an aggregate of crystals so intergrown that they have lost their individual outlines.

Satin spar is composed of needlelike crystals that occur in narrow veinlets, mostly in mudstone and shale. The mineral is generally white and displays the silky luster for which it is named. Impure satin spar is pink and has a dull luster. The fibers are compact and perpendicular to the walls of the fracture in which they occur. Satin spar crystals are generally no more than 2 inches long, but some may reach a length of more than 1 foot. Satin spar is formed by precipitation of calcium sulfate from solutions that are derived from nearby gypsum beds. The forces exerted by the growing crystals of satin spar are so strong that the fractures may become enlarged to many times their original width.

Massive rock gypsum is a compact aggregate of crystals which range from less than 0.1 mm to more than 2.0 mm in diameter. The rock is generally white or light to dark gray. Impurities may color the gypsum pink, black, green, and yellow. White gypsum is most apt to be pure, though it may contain some calcite which is not readily visible.

Massive gypsum is the most common form and comprises the most important of the economic deposits. This type is found interbedded with sedimentary rocks as beds or broad lenses which may be a few inches to as much as 30 feet thick. Stringers and lenses of limestone, shale, and sandstone are generally associated with gypsum. Commercial gypsum deposits range from 90 to 98 percent pure gypsum and average about 96 percent.

Alabaster is compact gypsum in which the crystals average 0.05 mm or less in diameter. It is generally white, though pink and gray varieties that are due to impurities are common. These impurities include stringers and fragments of mudstone and limestone. The compact and soft nature of alabaster makes it easy to carve into vases and other ornaments.

Unconsolidated gypsum deposits include gypsite and gypsum sands. Gypsite consists of isolated crystals of gypsum scattered through alluvium. These deposits are generally less than 1 foot to more than 6 feet thick and consist of material that averages less than 70 percent gypsum. Gypsum sands are made up of crystals that have been transported by wind and deposited in dunes of remarkable purity. An outstanding example of a deposit of this type is the White Sands near Alamogordo, N. Mex.

Anhydrite is calcium sulfate and when pure contains 41.19 percent CaO and 58.81 percent SO_3. It has a hardness of 3 to 3.5 on the Mohs scale and a specific gravity of 2.9. It is closely related to gypsum but is slightly heavier and harder and lacks water of crystallization. Anhydrite may be gray, bluish gray, or white. It may occur as fine- to coarse-grained masses that comprise an entire body, or as lenses or beds within a gypsum deposit.

USES

Most of the gypsum mined in the United States is used for plaster. In general practice, ground gypsum is placed in large steel kettles and heated. At a temperature of about 120°C (248°F), the mass of gypsum begins to "boil"; the apparent boiling is caused by the release of the water of crystallization in the form of steam. When three-quarters of this water has been driven off hemihydrate of calcium sulfate ($CaSO_4 \cdot \frac{1}{2}H_2O$) or "stucco" is formed. This occurs at a temperature of about 170°C (338°F). Plaster is made by adding water to the hemihydrate. Upon the addition of water, the material crystallizes into an interlacing network of long fibrous gypsum crystals. By far the most important use of plaster today is in the manufacture of wallboard, lath, and other prefabricated gypsum products. Other applications include wall plaster, dental and orthopedic plasters, roof deck and insulating plasters, and other specialty plasters.

Uncalcined or raw gypsum is used primarily as a retarder for portland cement and as an agricultural mineral. Gypsum improves soil texture and increases the permeability of soils. Alkali soils, which contain sodium carbonate, are reclaimed by adding gypsum; the gypsum reacts with the sodium carbonate and forms calcium carbonate and sodium sulfate which are not harmful to plants. Gypsum is also used for soils that are deficient in sulfur and for crops, such as alfalfa and clover, that require sulfur. In India, raw gypsum is used in manufacturing ammonium sulfate fertilizers, which are made by combining the acid radical of the gypsum with synthetic ammonia that is derived from nitrogen in the atmosphere. Among other uses, uncalcined gypsum is used as a filler in paint and paper manufacturing and as a carrier for insecticides.

When gypsum is heated to about 500°C (932°F) all the water of crystallization is driven off and anhydrite is formed. This material resembles the natural anhydrite. The major use of anhydrite in the United States is as an agricultural mineral and, to a lesser extent, as a retarder in portland cement. In Europe, anhydrite is roasted with coke, sand, and aluminum-bearing shales to produce sulfuric acid and cement clinker; it is also used in making ammonium sulfate. These processes are too expensive to be economic in the United States at present.

ANNOTATED BIBLIOGRAPHY

Ackers, A. L., DeChicchis, R., and Smith, R. H., 1930, Hendrick field, Winkler County, Texas: Am. Assoc. Petroleum Geologists Bull., v. 14, no. 7, p. 923–946.

Hendrick oil field in central Winkler County, Tex. is 10 miles long and 4 miles wide. It contains beds of Permian age, which are divided into two parts, an upper red bed and evaporite series and a lower dolomitic limestone. The evaporite series, in turn, is divided into two parts, an upper anhydrite-dolomitic limestone series and a lower anhydrite-salt series. In the anhydrite-dolomitic limestone series, 100 feet of anhydrite and gypsum occurs at least 1,000 feet below the surface. A large-scale east-west cross section through the Hendrick field is included.

Adams, G. I., 1901, Oil and gas fields of the upper Cretaceous and Tertiary formations of the western Gulf Coast: U.S. Geol. Survey Bull. 184, p. 49–53.

The paper suggests that gypsum may be formed by chemical reaction between limestone, hydrogen sulfide, and atmospheric oxygen: hydrogen sulfide is oxidized to form sulfur and water, sulfur is oxidized to form sulfuric acid, and the acid reacts with limestone to produce gypsum. Various methods are presented that may be responsible for reducing gypsum to sulfur. Among these methods are the reduction of gypsum by algae and by hydrogen sulfide that is derived from the decomposition of organic matter.

——— 1904, Geology, technology, and statistics of gypsum *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 12–32.

The physical and chemical characteristics of gypsum and anhydrite are discussed, and the theories of the origin of gypsum are briefly described. Gypsum deposits occur in rocks of nearly every geologic age. The oldest deposits of economic value are found in rocks of Silurian, Mississippian, and Permian age.

The report describes the technology of processing gypsum and the theory and practice of manufacturing gypsum products. A section listing the production statistics of gypsum by States; and a map of the United States, 1 inch=250 miles, showing producing localities of gypsum are included.

Adams, J. E., 1944, Upper Permian Ochoa series of Delaware basin, west Texas and southeastern New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 28, no. 11, p. 1596–1625.

The Ochoa series of the Upper Permian is a nonfossiliferous poorly exposed series of evaporites that crop out in the Delaware basin in west Texas and southeast New Mexico. The series is divided into the Castile (oldest), Salado, Rustler, and Dewey Lake formations. At the start of Ochoa time, the Delaware basin was a geosynclinal bowl that was 1,700 feet deep and encircled by cliff-like reefs. These reefs were eroded only slightly before they were covered in middle Ochoa time.

The Castile formation, which has an average thickness of about 1,600 feet, is composed of gypsum and anhydrite, calcite-banded anhydrite, salt, and limestone. The gypsum extends from the surface to a depth of 500 feet, below which anhydrite occurs. The Salado formation is a thick sequence of evaporites that contains more salt than anhydrite. The anhydrite is blue white and thin bedded. The Rustler formation consists of sandstone, shale, dolomite, gypsum, and anhydrite. Exposures in Eddy County, N. Mex., show 4 beds of gypsum which range from 20 to 130 feet in thickness. The Dewey Lake formation consists predominantly of red beds in which gypsum occurs as cement, secondary crystals, and veins.

The Castile formation was apparently deposited in a basin which was connected intermittently with the ocean. A barrier, formed perhaps by a sand dune ridge that separated the Castile Sea from the ocean, was breached periodically, permitting fresh sea water to enter the basin. The incoming fresh sea water was lighter than the partially evaporated water, or brine, that was present in the basin and the fresh water tended to override the brine. Evaporation increased the concentration of salts in the top waters, and the first salt to be precipitated was calcium carbonate. Further evaporation increased the density of the top waters and caused them to settle. There would be no tendency for resolution of the precipitated salts, because the descending waters would be supersaturated. The sodium chloride-rich brine would settle into the deepest parts of the basin. Ideally, the stratigraphic sequence of the brine would be: a bottom that consisted only of sodium chloride, an intermediate part that consisted of a mixture of sodium chloride and calcium sulfate, and the same mixture with calcium carbonate at the top.

The calcite-anhydrite laminae probably were formed through an annual refreshening of the waters, which increased the supply of $CaCO_3$. Although some salt is scattered throughout the formation, the amount of salt in the Castile formation is less than it theoretically should be, considering the ratio of NaCl to $CaSO_4$ in sea water. The brines, which were heavily concentrated with salt and from which the calcium sulfate had been removed, probably escaped through the slightly permeable barrier to the sea. The Castile Sea seldom, if ever, completely dried up; the Salado and Rustler Seas were mostly shallow and, though nearly continuously connected with the sea, dried up periodically when the entrances were sealed. When the water evaporated, soluble salts were formed on the surface. These evaporites all contain clastic material which was transported to the basin by wind or stream action.

The laminae in the gypsum in the Ochoa series appear to be as thick as those in the anhydrite section. This suggests that hydration of anhydrite to gypsum is not accompanied by any great change in volume.

Albritton, C. C., Jr., 1938, Stratigraphy and structure of the Malone Mountains, Texas: Geol. Soc. America Bull., v. 49, no. 12, p. 1747–1806.

The report describes the geology of the Malone Mountains and the Malone Hills, which are located in south-central Hudspeth County, Tex. They are just east of Finlay, which is on the Southern Pacific railroad. The Briggs formation of Permian age is the oldest exposed in the area; it crops out extensively in both the Malone Mountains and the Malone Hills. The Briggs is at least 650 feet thick, and consists of gypsum and anhydrite interbedded with limestone. The gypsum, which is mostly white and granular, is being quarried near Briggs Switch for use in portland cement.

American Society for Testing Materials, 1955, Gypsum, *in* 1955 book of ASTM Standards: Philadelphia, Pa., pt. 3, p. 267–308.

Standards of specifications are listed for gypsum and for gypsum concrete, plasters, molding plasters, formboard, wallboard, lath, sheathing board, partition tile or block, and keene's cement. Standard methods of chemical analysis and physical testing of gypsum and gypsum products are given.

American Society for Testing Materials, 1958, ASTM Standards for gypsum products, plaster aggregates, and related standards: Philadelphia, Pa., 148 p.

The standards for 29 gypsum products and plaster aggregates are described. A compilation of definitions, specifications, and test methods are included.

Andrews, D. A., and Hunt, C. B., 1948, Geologic map of eastern and southern Utah: U.S. Geol. Survey Oil and Gas Inv. (Prelim.) Map 70, scale 1:500,000.

The map shows the geologic formations of eastern and southern Utah.

Anthony, J. W., Du Bois, R. L., and Krumlauf, H. E., 1955, Nonmetallic minerals—geology, evaluation, and uses, *of* Mineral resources, Navajo-Hopi Indian reservations, Arizona-Utah: Tucson, Arizona Univ. Press, v. 2, p. 78–83.

Gypsum occurs in the Navajo-Hopi Indian reservations of Arizona and Utah, in both the Moenkopi formation of Triassic age and the Cedar Mesa sandstone of the Cutler formation of Permian age. The best deposit, at Black Falls on the Little Colorado River in Navajo County, Ariz., consists of 2 beds of gypsum in the Moenkopi formation, each of which is about 18 inches thick. It is estimated that there are about 382,000 short tons of material that averages more than 97 percent gypsum. About 15 miles of road would have to be built, and the gypsum would have to be hauled about 50 miles to the nearest railroad.

In Utah about 20 miles southeast of Mexican Hat, gypsum occurs as lenses and beds in the Cedar Mesa sandstone. The beds generally range from about 1 to 7 feet in thickness. The thicker beds consist of gypsiferous mudstone or gypsite that contains about 50 percent gypsum, and the thinner ones contain 80 to 90 percent gypsum. No tonnage estimates are given.

Argall, G. O., Jr., 1949, Industrial minerals of Colorado: Colorado School Mines Quart., v. 44, no. 2, p. 226–238.

Gypsum has been found in at least 35 counties in Colorado. There are 5 major gypsum areas as follows:

1. A long narrow belt that is parallel to the eastern side of the Front Range and extends from Larimer County southward to Pueblo County. The gypsum here is found mostly in the top part of the Lykins formation of Permian age, though some is found in the Morrison formation of Jurassic age.
2. A belt of gypsum follows along both sides of the Arkansas River between Salida, Chaffee County, and Parkdale, Fremont County, and from there turns southeast along the west side of the Wet Mountain Valley through Custer, Huerfano, and Las Animas Counties.
3. Beds of gypsum of Permian and Pennsylvanian age crop out in Rio Blanco, Eagle, Garfield, and Pitkin Counties.
4. Gypsum is found in the western parts of Mesa, Montrose, and San Miguel Counties in Paradox, Gypsum, and Sinbad Valleys.
5. In Montrose and Delta Counties, gypsum crops out along the Gunnison River for a distance of 20 miles.

In addition to the above areas, gypsum is known in Dolores, Douglas, Jefferson, La Plata, Ouray, Otero, Park, and Pueblo Counties. Alabaster has been mined for ornamental material in Larimer, Mesa, and Otero Counties.

The report gives logs of wells throughout the State in which gypsum has been found.

Baker, A. A., Dane, C. H., and Reeside, J. B., Jr., 1933, Paradox formation of eastern Utah and western Colorado: Am. Assoc. Petroleum Geologists Bull., v. 17, no. 8, p. 963–980.

The Paradox formation of Pennsylvanian age is described in detail. This formation is restricted to the Paradox basin in southwestern Colorado and southeastern Utah. It consists predominantly of gypsum but also contains beds and chunks of black shale, sandstone, and limestone. Below the surface great thicknesses of salt alternate with beds of anhydrite. The report defines the limits of the formation and suggests that the "Webber shales," which occur northeast of the Uncompahgre uplift, also occupy a basin of contemporaneous age with the Paradox basin.

An outline map of southwestern Colorado and southeastern Utah, scale 1 inch=100 miles, shows the approximate extent of the Paradox basin.

Baker, C. L., 1927, Exploratory geology of a part of southwestern Trans-Pecos Texas: Texas Univ. Bull. 2745, p. 11.

Limestone and gypsum beds of the Malone Mountains which were long considered to be Jurassic are now proved to be Permian in age. Gypsum is being quarried at Gypsum (Briggs) Switch. It also occurs half a mile northeast of Torcer, a siding on the Southern Pacific railroad, and also along the valley southwest of the main northeast ridge of the Malone Mountains and at the southeast foot of the mountain.

———— 1929, Depositional history of the red beds and saline residues of the Texas Permian: Texas Univ. Bull. 2901, 72 p.

The distribution of the Permian rocks in the United States is described briefly and the Permian rocks of Kansas, New Mexico, and Texas are correlated. The author believes that an arid climate is not necessary for the deposition of saline residues, pointing out that salt and gypsum are now being deposited in lagoons along the Gulf of Mexico where strong winds and high temperatures cause excessive evaporation, though the annual rainfall varies from 20 to 36 inches. Analysis of water from one of the gulf coast lagoons shows a salinity of 9.14 percent and a density of 1.062. This is 6 times the total salinity of the Gulf of Mexico.

The report compares this salinity with that of the Caspian Sea, which becomes more saline from north to south. The Caspian has an overall salinity of only one-third that of the ocean, but the Karabugas Gulf on the east side of the Caspian has a salinity of 22 times that of the Caspian and 8 times that of the ocean. A current flows from the Caspian into the Karabugas and there is no compensating return current.

The report describes the succession of saline residues in the Permian rocks of Texas and New Mexico and points out that salinity differs within a given body of water, such as within the Caspian, Baltic, Black, and Mediterranean Seas.

The report concludes that the Permian rocks of the Southwest were deposited under nonarid conditions, and that the saline residues could also have been deposited under nonarid conditions. These saline residues were deposited in an elliptical embayment which was connected by a strait with an open normal sea on the southwest. The floor of the embayment was depressed about 9,000 feet before deposition ceased. The $CaSO_4$ was originally deposited as anhydrite and was later altered to gypsum by ground water.

The author also believes that the amount of salts in the ocean could have been greater in Permian time than at present because of the presence of extensive glaciers that probably removed some of the water from the ocean.

Baker, C. L., 1941, Tectonics of Sierra San Andrés of New Mexico: Pan-Am. Geologist, v. 75, no. 1, p. 55–56.

This report describes the deposition of the White Sands of the Tularosa (Otero) basin at the east foot of the San Andrés Range in New Mexico. The basin once contained an arm of Lake Cabeza de Vaca, a Pleistocene lake. The Tularosa arm of the lake was evidently more saline than the rest of the lake, and flesh-colored silt, which contained a high percentage of disseminated gypsum, was deposited here. When the lake silt dried, it was carried away by wind action, leaving the denser gypsum as a residue at the surface. The gypsum was heaped into dunes which now cover about 300 square miles and form the White Sands.

Banner, G. C., 1927, Outlines of Arkansas' mineral resources: Little Rock, Arkansas Bur Mines, Manufactures and Agriculture, p. 143–144.

Gypsum occurs in the southwestern part of Arkansas in Pike and Howard Counties. The deposits occur in the De Queen limestone of the Upper Trinity formation of Lower Cretaceous age. At Plaster Bluff, Pike County, 12 feet of gypsum overlain by about 60 feet of limestone and overburden, is exposed in a riverbank for a distance of 450 feet. At Highland, Pike County, the gypsum bed is 2 to 4 feet thick.

Crystalline, fibrous, and earthy gypsum occur in small amounts in the lead-zinc district in the northern part of the State. In many places the gypsum forms broad crystals.

Barnes, V. E., 1943, Gypsum in the Edwards limestone of central Texas, *in* Texas mineral resources, Texas Univ., Bur. Econ. Geology, Pub. 4301, p. 35–46 [1946].

In Gillespie County known deposits of gypsum follow about 10 miles of a west-trending ridge that is northwest of Fredricksburg. The report describes 12 gypsum exposures that occur along this ridge. Gypsum has been quarried intermittently from these deposits since 1932. About 50,000 tons is estimated to have come from this area, and a reserve of about 7.5 million tons remains. The gypsum generally ranges from 94 to 100 percent pure. The report also includes a map of gypsum occurrences in Gillespie County, scale 1 inch=3½ miles. In Menard County, gypsum is exposed in one place south of Menard, but no estimate of the amount of gypsum that may be present is given.

Barton, D. C., 1922, Occurrence of gypsum in the Gulf Coast salt domes: Econ. Geology, v. 17, p. 141–143.

Although most of the $CaSO_4$ that is found at depth in the caprocks of salt domes is anhydrite, gypsum has been found in caprocks below 1,000 feet. In Texas, gypsum has been found in caprocks at the following localities: At Bryan Hill, where cores of massive selenite were found between the depths of 750 and 850 feet; at Stanton Ridge, where gypsum was found between 960 and 1,300 feet; at Blue Ridge, where selenite and anhydrite were found at 3,500 feet. It is not proved that the deposition of anhydrite is associated with limestone, for anhydrite occurs with salt only in some domes.

________ 1926, The salt domes of south Texas, *in* Moore, R. C., ed., Geology of salt dome oil fields; Am. Assoc. Petroleum Geologists, 718–771.

The Falfurrias salt dome, also called Las Cuevas, Gyp Hill, and Loma Blanca, is about 7 miles south-southeast of Falfurrias, Brooks County, Tex. The caprock of the salt dome is exposed in a roughly circular hill that is less than 1 mile in diameter. A salt lake called Laguna Salada lies on the north side of the hill. The caprock is composed of clear selenite in crystals 1 to 8 inches in diameter and 6 to 18 inches in length. The long axes of these crystals are vertical. Wells drilled on the southwest slope of Gyp Hill cut gypsum from the surface to depths which range from 630 to 3,084 feet below the surface.

The report includes a topographic map of the Falfurrias salt dome, scale 1 inch=about ¾ mile.

Bauer, W. H., 1952, Fundamentals of gypsum calcination: Pit and Quarry, v. 44, no. 10, p. 113–114, 118–119, 122–123.

In the system $CaSO_4 \pm H_2O$, three basic types of compounds are recognized: dihydrite (gypsum), $CaSO_4 \cdot 2H_2O$; hemihydrate, $CaSO_4 \cdot \frac{1}{2}H_2O$; and anhydrite, $CaSO_4$.

Gypsum is made up of monoclinic prismatic crystals. Hemihydrate occurs as two forms, alpha and beta, which are also monoclinic. Alpha-hemihydrate is produced by heating gypsum in water or steam. It has large compact prismatic densely packed crystals, and is more stable and less active toward water than beta-hemihydrate. Thus, with less crystal surface, less water is required and greater setting strength is obtained. Beta-hemihydrate is produced under faster heating rates and dryer calcining conditions than alpha-hemihydrate. The beta variety is characterized by small crystals more heterogeneously arranged than the alpha variety. More water is needed to work beta-hemihydrate and, consequently, it is of lower strength than the alpha variety.

Anhydrite occurs as two varieties, soluble and insoluble. The soluble variety is divided into alpha and beta, which are formed by heating hemihydrate to temperatures of about 1,000°C for an hour or more. Both the alpha- and beta-anhydrites have less than 1 percent water, the beta having slightly more water than alpha. Insoluble anhydrite is the stable form. It is dense, orthorhombic, and contains no water of crystallization. It is found in nature or can be made by heating gypsum to temperatures above 1,600°F to remove all the water of crystallization.

In calcining, gypsum ground to minus 100-mesh is fed to a kettle. Heat is applied and steam is produced that makes the gypsum a boiling "fluid." This mixture is stirred with paddles to distribute the heat evenly throughout the mass. The mass leaving the kettle after calcination is a mixture of alpha- and beta-hemihydrate. In the hot pit, the mass is cooled from the outside toward the center. The hot mass will continue giving off water, which will alter any soluble anhydrite present to hemihydrate, and, along the cool edges of the hot pit, some of the hemihydrate is altered to gypsum. This gypsum has to be kept from the finished "stucco" because it will drastically change the setting time of the plaster.

Beede, J. W., and Bently, W. P., 1918, The geology of Coke County [Texas]: Texas Univ. Bull. 1850, 85 p.

The report describes the geology of Coke County, Tex. The Greer formation of Permian age which crops out within the county contains impure gypsum in lenses, as much as 12 feet thick in shale. The gypsum crops out mainly in bluffs along the river. Considerable amounts of gypsum have been removed in solution. The main gypsum reserves are in the western part of the county. The resources are large, but no figures are given.

Bell, G. L., 1953, Diapirite metamorphism of gypsum, Sevier County, Utah [abs.]: Geol. Soc. America Bull., v. 64, no. 12, pt. 2, p. 1540–1541.

Extensive lenses of commercial-grade gypsum are well exposed along the east margin of Sevier Valley, between Salina and Sigurd, Utah. The gypsum beds are typical members of the Arapien shale of Upper Jurassic age which crops out in a belt that trends N. 35° E. The Arapien shale consists predominantly of blue-gray paper-thin shale with interbedded siltstone, calcareous sandstone, masses of salt, and lenses of gypsum. The salt and gypsum are exposed in northeast-trending echelon folds.

The gypsum-bearing shale is in one of the most significant orogenic zones of Utah, and the effects of diapirite metamorphism are described as resulting from stresses that were initiated during Laramide thrust faulting. Décollement of the mobile Arapien shale lying on competent Navajo sandstone is postulated, and dislocation of the massive lenses of gypsum is described in relation to diapiric movements of mobile halite and incompetent "paper" shale. The resulting extreme examples of disharmonic folds (piercement folds), zig-zag or V folds with consequent repetition of the section, are described.

Only minor gypsification of anhydrite is attributed to circulating ground water. The Sigurd-Salina gypsum occurs as primary central beds with less hydrous margins that contain anhydrite. The ratio of anhydrite to gypsum is a function of the structural complexity, and the least deformed areas contain the most extensive deposits of pure gypsum.

Birkheimer, L. B., 1938, Selenite near Charlestown, Ohio: Rocks and Minerals, v. 13, no. 11, p. 331.

Selenite crystals interbedded in clay have been found 2 miles southeast of Charlestown, Portage County, Ohio.

Bixby, F. S., 1941, Gypsum quarry in a desert: Rock Products, v. 44, no. 6, p. 41–42.

The Quatal Canyon gypsum deposit is 15 miles west of Maricopa, Kern County, Calif. The gypsum is silica free and occurs in beds 40 to 45 feet thick. Material containing at least 90 percent gypsum, 4 percent lime, and 6 percent solubles is shipped for use as retarder for portland cement.

The report describes the quarrying of the deposit.

Blake, W. P., 1904, Gypsum deposits in Arizona, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 100–101.

The report mentions several localities in southern Arizona where gypsum occurs. These include—

1. On the Santa Rita Hills, Pima County, where gypsum deposits of great thickness have been reported.

2. In the low hills along the San Pedro River, in Cochise and Pinal Counties where gypsum, interstratified with diatomite and volcanic ash, occurs in beds of Pliocene or post Pliocene age.

3. In the Sierrita Mountains south of Tucson, Pima County, where the gypsum is associated with copper deposits in massive limestone.

4. In the foothills of the Santa Catalina Mountains north of Tucson, Pima County, where the gypsum is probably of Triassic age.

5. In the Fort Apache Reservation, Navajo County, where gypsum is found as large plates of selenite.

Borden, J. L. [1952], Paradox member of the Hermosa formation [Utah and Colorado], *in* Four Corners Geol. Soc., [1st] Geological symposium of the Four Corners region: p. 27–30.

The Paradox member of the Hermosa formation, which contains considerable quantities of gypsum, crops out in the northern part of the Paradox basin in both Utah and Colorado along breached anticlinal structures. In Colorado these structures include Gypsum, Paradox, and Sinbad Valleys and in Utah, Moab-Spanish Valley, Onion Creek, and Salt Valley-Cashe Valleys. Minor exposures of the Paradox member occur in the Animas River Canyon north of Durango, Colo.; in the Rico Mountains of Colorado; along the San Juan River, where it transects the Raplee anticline; along the Colorado River near its junction with the Green River; and in Castle Valley, Utah.

The Paradox member consists of irregular beds of gypsum, limestone, dark shales, and fine sandstone. The beds are frequently contorted, as in the breached anticlines. The gypsum is a dirty gray porous to cavernous mass. The shales are highly carboniferous. In the breached anticlines, limestone is rare. Drill holes away from the anticlines show that several hundred feet of limestone lies above 30 feet of undisturbed gypsum.

A map of the Paradox basin showing the location of drill holes is included.

Boutwell, J. M., 1904a, Utah, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 102–110.

In Utah the more important deposits of gypsum occur at Nephi, Juab County; near Salina, in Sanpete and Sevier Counties; near Fillmore, Millard County; and in Wayne County.

The Nephi gypsum deposit, which is the largest known in Utah, is probably of Jurassic age. The exposed parts of the gypsum are from 275 to 300 feet thick and more than 700 feet long. Shale and marl are interbedded with the gypsum. The gypsum is massive, dense, lusterless, and light gray brown. Some anhydrite occurs with the gypsum.

The deposits near Salina are probably of Jurassic age. They are reported to contain very pure gypsum.

In Millard County, there are extensive deposits of secondary gypsum, both as gypsite and gypsum sand. In Wayne County, extensive deposits of rock gypsum are present. In addition, there are large crystals of selenite. These deposits are thought to be Jurassic or Triassic in age.

———— 1904b, Rock gypsum at Nephi, Utah: U.S. Geol. Survey Bull. 225, p. 483–487.

The more important gypsum deposits in Utah occur in the central and southern parts of the State; in Juab County, east of Nephi; in San Pete and Sevier Counties near Salina; in Millard County, near Fillmore; and in Wayne County. These deposits are all rock gypsum except the unconsolidated dune sand that occurs near Fillmore. Deposits are also known in Emery, Kane, Grand, San Pete, Washington, and Iron Counties.

The deposit near Nephi, Juab County, is located 1 mile east of town on the south side of Salt Creek Valley. The first rock was quarried in 1887. The exposed part of the body is 275 to 300 feet thick and at least 700 feet long along the strike. The deposit consists of a thick bed of massive, dense, lusterless, and light grayish-brown to white gypsum with interbedded gypsum and shale at both its top and bottom. Analyses of 2 samples of the thick gypsum bed indicate that the lower part of it contains about 22 percent anhydrite and as much as 17 percent calcium carbonate. The upper part contains as much as 97 percent gypsum.

Several other occurrences of pure gypsum are known in Salt Creek Valley east of the main body. The largest of these bodies is located about 1½ miles east of Nephi, on the north side of Salt Creek.

The geology of the area is complex; the main gypsum deposit lies near a zone of folding and faulting and the beds are deformed. The rocks have been indicated as Jurassic by the Wheeler survey.

Bowles, Oliver, and Farnsworth, Marie, 1925, Physical chemistry of calcium sulphates and gypsum reserves: Econ. Geology, v. 20, no. 8, p. 738–745.

Gypsum deposits are formed as follows: (a) Direct deposition by evaporation of sea water, (b) concentration of disseminated gypsum by moving water, (c) alteration of limestone beds by acid sulfate waters, and (d) alteration of anhydrite.

When sea water evaporates, gypsum is precipitated at temperatures below 25°C, and anhydrite at temperatures above. Most of the calcium sulfate beds were probably deposited as anhydrite.

Gypsum is soluble in water in the proportion of about 1 part in 386 at temperatures of 18°C. Therefore, disseminated gypsum may be readily dissolved and later redeposited.

Experimental data indicate that the reaction $CaSO_4 + 2H_2O \rightleftharpoons CaSO_4 \cdot 2H_2O$ is reversible, very slowly to the right. Temperature is more important than pressure in this reaction. The change from gypsum at the surface to anhydrite at greater depth is because anhydrite is the original form of the $CaSO_4$, and not because the gypsum is changed to anhydrite with increasing pressure.

Bownocker, J. A., 1920, Ohio, *in* Stone, R. W., and others, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 218–223.

Gypsum in the Monroe formation of Silurian age underlies a broad area of Ohio, but it has been mined successfully only north of Sandusky Bay in Ottawa County, where the beds crop out. The gypsum is in at least 7 beds which range in thickness from less than 1 foot to as much as 17 feet, and which are separated from each other by beds of limestone as much as 7 feet thick. South of Sandusky Bay, gypsum occurs near the town of Castalia, Erie County. This deposit was developed by a shaft 73 feet deep, which passed through more than 30 feet of gypsum.

The report discusses the history of the gypsum industry in Ohio and describes the mills that were in operation in 1918. A map of the Sandusky Bay area, scale about 1:250,000, shows the location of the gypsum deposits.

Bownocker, J. A., compiler [1947], Geologic map of Ohio: Ohio Geol. Survey, scale 1:500,000; repr. with revisions.

The map shows the geologic formations of Ohio.

Bowyer, Ben, Pampeyan, E. H., and Longwell, C. R., 1958, Geologic map of Clark County, Nevada: U.S. Geol. Survey Mineral Inv. Field Studies Map MF–138, scale 1:200,000.

The map shows the outcrop of the gypsum-bearing formations of Clark County, Nev.

Branson, E. B., 1915a, Origin of the red beds of western Wyoming: Geol. Soc. America Bull., v. 26, p. 61–62; [abs.], p. 221–228.

The red beds of western Wyoming are about 1,400 feet thick in the western part of the State and thin eastward. The red beds on the east flank of the Wind River Mountains, Wyo., in the region of thickest exposure of the formation, crop out over an area of at least 20,000 square miles. Probably half of this area is underlain by gypsum averaging 1 foot thick. One-tenth of the total area (2,000 square miles) is underlain by gypsum beds 10 feet or more thick. The gypsum beds are discontinuous in many places, thinning in short distances from 40 feet to a few inches.

The gypsum occurs in many horizons within the Chugwater formation, but the thicker beds are commonly found near the top. The gypsum is remark-

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ably pure and contains no salt. The red beds were deposited mostly under marine conditions, though there is evidence of some aeolian deposition.

Branson E. B., 1915b, Origin of thick gypsum and salt deposits: Geol. Soc. America Bull., v. 26, p. 231–242; abs., with discussion, p. 103–104.

The author develops a modified bar theory to explain the phenomena of thick gypsum deposits. The hypothesis accounts for—

1. The evaporation of the volume of water containing calcium sulfate that is necessary to form a thick gypsum deposit without having to postulate a basin of a depth in excess of any known continental depression.
2. The fact that other salts are rare in deposits of gypsum and anhydrite.
3. The absence of clastic sediments within a gypsum deposit.
4. The absence of fossils within a gypsum deposit.

The modified bar hypothesis assumes that, when a large interior sea dried up, the remaining water became isolated in several small basins. The smaller basins on the margins received both the drainage from the land and the ocean water that formerly came into the larger interior sea. Most of the sediment was deposited and some of the water was evaporated in these marginal basins. The denser waters were transferred by overflow to inner basins and again partially evaporated, each time becoming denser and more concentrated, until the waters reached a salinity that sea life could not tolerate. The concentrated waters finally arrived at the innermost basin and were evaporated completely, causing rapid deposition of salt or gypsum. The absence of interbedding of salt and gypsum may be due to precipitation of the gypsum in an intermediate basin before the waters, which contained only sodium chloride, entered into the innermost basin.

Brill, K. G., Jr., 1944, Late Paleozoic stratigraphy, west-central and northwestern Colorado: Geol. Soc. America Bull., v. 55, p. 627–632, 639–640.

Gypsum occurs in the Maroon formation of Pennsylvanian age in the central part of Colorado. The Maroon formation is correlated with the Hermosa formation in southwestern Colorado, the Weber grit, Coffman conglomerate, and the Battle Mountain formation in central Colorado, and the McCoy formation in northwestern Colorado. The Maroon formation consists of red, yellow, and brown shale, sandstone and conglomerate with intercalated gypsum, and thin beds of limestone. The formation was deposited in a trough that extended over the central part of the State. Gypsum is found only in west-central Colorado in the northern basin of the trough, and wedges out toward the east into normal marine sediments. Most of the gypsum beds have been affected by tectonic movements and occur as domes or irregular anticlines. The greatest thickness of gypsum is at Deep Creek, 15 miles northeast of Glenwood Springs, where the gypsum is in 6 beds which total nearly 1,000 feet in thickness. Large deposits are found north and south of the Eagle River between Avon and Dotsero. The masses of gypsum do not seem to be found in any particular stratigraphic horizon, but occur irregularly in the lower part of the Maroon formation. The report contains geologic sections of the Maroon formation showing the thickness of the gypsum beds, and an index map of part of western Colorado, scale 1 inch=about 50 miles, showing the outcrops of gypsum.

——— 1952, Stratigraphy in the Permo-Pennsylvanian Zeugogeosyncline of Colorado and northern New Mexico: Geol. Soc. America Bull., v. 63, p. 809–880.

The structural troughs that developed in Permian and Pennsylvanian times in Colorado and New Mexico, are described. Gypsum occurs in rocks of Penn-

sylvanian age that include (a) the Hermosa formation in southwestern Colorado and (b) the Minturn formation in central Colorado. The Minturn formation is correlated with the lower part of the Maroon formation. It crops out in a belt that extends from Meeker, Rio Blanco County, southward to Coaldale, Fremont County. The gypsum that occurs in the western part of the outcrop belt probably occurs at the same stratigraphic horizon as the Swissvale gypsum bed at Coaldale, which lies about 2,000 feet above the base of the Minturn formation. The gypsum crops out sporadically in an area that is estimated to cover 5,000 square miles. The thickest beds of gypsum have been compressed and domed by folding and have an aggregate thickness of 100 feet.

The gypsum was deposited either in lagoons formed by calcareous reefs or offshore bars or in temporary saline lakes formed between deltas.

The report contains a map, scale 1 inch = about 32 miles, showing the location of gypsum in central Colorado.

Bromehead, C. E. N., 1943, The forgotten uses of selenite: Mineralog. Mag., v. 26, no. 182, p. 325–333.

This article is an account of the early uses of selenite for windowpanes, as described in the writings of Pliny, Seneca, Agricola, and others. Selenite and glass panes were both introduced about the same time. Selenite was used in Europe as late as the 17th century and in South America until the early part of the 19th century.

Bromfield, C. S., and Shride, A. F., 1956, Mineral resources of the San Carlos Indian Reservation, Arizona: U.S. Geol. Survey Bull. 1027–N, p. 681–683.

Gypsum on the San Carlos Indian Reservation crops out 3 miles west of San Carlos, Gila County, Ariz. The gypsum was deposited in late Tertiary or Pleistocene lakes, and occurs in 3 to 5 beds which can be traced for a distance of 2,500 feet along the outcrop. The beds dip 15° to 25° SW. The gypsum is interbedded with as much as 50 feet of tan mudstone. The top gypsum bed ranges in thickness from 3 to 10 feet and averages 6 feet. It is estimated that there are about 100,000 tons of gypsum underlying overburden that is less than 30 feet thick. The nearest railroad is about half a mile north of the deposit. Included in the report is a geologic map and sections of the gypsum area, scale 1:4,800.

Brown, J. S., 1932, Natural gas, salt, and gypsum in pre-Cambrian rocks at Edwards, New York: Am. Assoc. Petroleum Geologists Bull., v. 16, no. 8, p. 734.

Gypsum occurs in the Grenville limestone of Precambrian age, as a common fracture filling in and near ore bodies. It could have been formed by the chemical action on limestone of waters that were charged with sulfuric acid.

Brown, J. S., and Engel, A. E. J., 1956, Revision of Grenville stratigraphy and structure in the Balmat-Edwards district, northwest Adirondacks, New York: Geol. Soc. America Bull., v. 67, no. 12, p. 1599–1622.

Subsurface and surface data in the Balmat-Edwards district, New York, show two major metasedimentary units of Precambrian age: marble and the underlying migmatitic paragneiss. The marble beds are divided into 16 units. Unit 10 is divided into 3 subunits, the third of which is composed of anhydrite and gypsiferous schist, which is closely associated with green diopsidic marble and a discontinuous schistose marble. Anhydrite appears as "scattered relicts in the schist." The gypsum that is present probably altered from the anhydrite. The relations of the gypsum-anhydrite to the associated units suggest

a sedimentary origin for the calcium sulfate beds. The gypsum and anhydrite-bearing subunit thins and thickens abruptly along the strike. The maximum thickening of the gypsiferous schist is in the apex area of the Sylvia Lake fold, where the gypsum and anhydrite, mixed with marble from enclosing units, are 200 feet or more thick. Little gypsum appears on the surface because of its soluble nature.

The report includes a geologic map of the Balmat area, scale 1 inch=1,000 feet, which shows the outcrop of the gypsiferous anhydrite.

Brown, L. S., 1931, Cap-rock petrography [with discussion]: Am. Assoc. Petroleum Geologists Bull., v. 15, no. 5, p. 509–529.

Study of thin sections of caprocks of several domes resulted in the following conclusions:

1. Salt structure is caused by a vertical intrusion of the salt stock and true cap, under enormous pressures from an unknown depth.
2. The anhydrite is of normal, primary marine crystallization.
3. The anhydrite caprocks of the gulf coastal salt domes represent parts of the same sedimentary formation which is the Glen Rose limestone of Cretaceous age.
4. The calcite in the caprock is secondary and was derived through direct alteration of the underlying anhydrite by carbonate meteoric waters.
5. The gypsum of the gypsum caprock is also secondary and derived through alteration of anhydrites by circulating meteoric waters that were low in carbonates.
6. An important part of the sulfur is syngenetic with the anhydrite.
7. Commercial sulfur deposits of salt domes are at least partly secondary accumulations of primary sulfur.
8. Evidence of reduction of anhydrite by contiguous or penetrating hydrocarbons is obscure or lacking.

Comments:

E. L. DeGolyer took exception to the Glen Rose age of the caprock and mentions that the caprock more probably originated by accumulation of residual grains of anhydrite after removal of salt.

M. I. Goldman agrees with DeGolyer on the origin of anhydrite in the caprock and also believes that the sulfur in caprocks was formed by reduction of anhydrite and gypsum by hydrocarbons.

D. C. Barton objected to the assumption that the age of the caprock is Glen Rose.

Bundy, W. M., 1956, Petrology of gypsum-anhydrite deposits in southwestern Indiana: Jour. Sed. Petrology, v. 26, no. 3, p. 240–252.

In southwestern Indiana the evaporite deposits occur in the lower part of the St. Louis limestone of Mississippian age, at depths below the surface of 500 feet. The uppermost beds consist almost entirely of gypsum, which is as much as 25 feet thick. Anhydrite increases in proportion to the gypsum with increasing depth. Generally three evaporite beds are present, each of which is separated by 40 to 50 feet of limestone.

The Indiana evaporite deposits have passed through three stages of diagenesis: many of the evaporite beds were originally deposited as gypsum, converted to anhydrite, and then reconverted to gypsum.

Two stages of crystalloblastic anhydrite have been found: Stage 1, gneissic porphyroblastic anhydrite, which includes the extensive massive beds; and stage 2, porphyroblasts and veins in dolomite. Stage 1 is characterized by a texture consisting of elongate, parallel or nearly parallel crystals with included porphyroblasts. The orientation of the anhydrite is ascribed to directed pressure, which was caused by differences in rock strength, and to stresses, which were exerted by minor postdepositional adjustments of the earth's crust. Orientation probably is due to recrystallization flow. The porphyroblasts, perhaps, were formed by the removal of stress on the evaporites, much like that which takes place in some metals when stress is removed; in such cases, a rebound or growth phenomenon has been noted.

In the second stage, the anhydrite porphyroblasts in the dolomite were also probably formed by the relief of stress. Grains of dolomite occur within and adjacent to anhydrite veins and porphyroblasts, indicating that magnesium ions were present.

The gypsum deposits were formed from the hydration of anhydrite. Alteration of anhydrite to gypsum involves an increase in volume of 30 to 50 percent. The removal of calcium sulfate in solution accounts for the lack of volume change in the alteration of anhydrite to gypsum. The excess calcium sulfate is commonly found in veins of satin spar that occur in surrounding rocks. In satin spar veins, growth has occurred by spreading apart the vein walls by the force of crystallization.

Hemihydrate is present but is rare within the Indiana gypsum.

Buranek, A. M., and Needham, C. E., 1949, Directory of Utah mineral resources and consumers guide: Utah Geol. Mineralog. Survey Bull. 36.

The directory includes a mineral resource map, scale 1:1,000,000, that shows gypsum deposits in Utah.

Burbank, W. S., Lovering, T. S., Goddard, E. N., and Eckel, E. B., 1935, Geologic map of Colorado: U.S. Geol. Survey, scale 1: 500,000.

The map shows the outcrop of the gypsum-bearing formations of Colorado.

Burchard, E. F., 1911, Gypsum deposits in Eagle County, Colorado: U.S. Geol. Survey Bull. 470–G, p. 354–365.

Gypsum in Eagle County, Colo., occurs in the upper part of the Carboniferous system. The thickness of the gypsiferous series is about 800 feet. The gypsum, which is associated with gray gypsiferous shales and sandstones, is ash gray and can be recognized from many miles away. The gypsiferous series is contorted and folded, which makes it difficult to reduce the beds to any order. The gypsum beds are eroded and weathered into low hills and are covered with from 1 to 10 feet of soft weathered gypsum. The gypsum masses appear to be lenses of various dimensions that occur interbedded with shale but at no definite horizon. Weathering makes it difficult to determine the true thickness or condition of the unweathered rock. The lenses are generally from a few feet up to 200 feet or more thick, and generally contain shale bands or beds mixed with the gypsum. The report describes the outcrops along the Grand (Colorado) River; along the Eagle River, from the town of Gypsum eastward to Eagle and in the vicinity of Avon and Edwards; and along Frying Pan Creek, in the southern part of the County.

The only place that gypsum was being quarried in Eagle County before 1911 was along Frying Pan Creek at the town of Ruedi. The Roaring Fork Plaster Co. worked a deposit of massive gypsum that is interbedded with shale and limestone. The gypsum is light to dark gray and white, fine grained, and hard. Faint traces of sulfur show on the surface of some of the darker beds in the quarry.

Representative analyses of gypsum throughout the county are given; these show that the gypsum ranges from about 92 to 98 percent pure. Some of the analyses indicate that anhydrite occurs near the surface. A locality map, scale 1 inch=about 12 miles, is included.

Burchard, E. F., 1920, Alaska, *in* Stone, R. W., and others, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 47–48.

The only known extensive deposit of gypsum in southeastern Alaska is situated in the eastern part of Chichagof Island, about a mile from Iyoukeen Cove. Rocks of Carboniferous age are exposed along the southeast shore of the cove. The gypsum beds, which apparently overlie these rocks, are assigned to the Permian. The extent of the gypsum is not known because the deposit is covered by gravel. Drilling, which has been carried on to a depth of 300 feet, penetrated several gravel-filled channels that are as deep as the 160-foot level.

Thin basaltic dikes cut the gypsum. The gypsum, which is mostly light blue, has a high degree of purity although some anhydrite is present.

Burwell, A. L., 1955, An investigation of industrial possibilities of Oklahoma gypsum and anhydrite: Oklahoma Geol. Survey Mineral Rept. 29, 21 p.

The gypsum deposits of Oklahoma occur as part of the Permian red bed sequence and are in two geologic formations, the Blaine and the Cloud Chief. These deposits are grouped into three regions:

1. A region called the first line of gypsum hills that are situated along the Cimarron River.
2. A region called the second line of gypsum hills that run approximately parallel to, and 30 to 50 miles west of, the first line.
3. The southwestern region, in the southwestern part of the State.

The gypsum in the first line of hills is made up of the three gypsum members that occur in the Blaine formation; these are called the Ferguson, Medicine Lodge, and Shimer beds. The gypsum in the second line of hills occurs in the Cloud Chief formation, and the gypsum of the southwestern region occurs in both the Blaine and Cloud Chief formations.

The report lists seven areas in which gypsum could be economically quarried.

Gypsum and anhydrite are being used in Great Britain as raw materials for making sulfur dioxide, sulfuric acid, ammonium, and magnesium sulfate. Experiments by the Oklahoma Geological Survey in the conversion of gypsum and anhydrite to ammonium sulfate and in the thermal reduction of calcium sulfate are described.

Butler, B. S., 1918, Reconnaissance geologic map of Utah, *in* Butler, B. S., Loughlin, G. F., Heikes, V. C., and others, The ore deposits of Utah: U.S. Geol. Survey Prof. Paper 111, scale 1:750,000.

The map shows that outcrop of the geologic formations, including those that are gypsum bearing, in Utah.

Butters, R. M., 1913, Permian or "Permo-Carboniferous" of the eastern foothills of the Rocky Mountains in Colorado: Colorado Geol. Survey Bull 5, pt. 2, p. 61–94.

Gypsum occurs in eastern Colorado in the red-bed sequence of the Lykins formation of probable Permian or Triassic age. The gypsum crops out in the lower part of the formation in Box Elder Canyon and South Table Mountain; here the gypsum occurs in several bands that are 2 to 12 feet thick and that are separated by thin red shales.

West of Loveland, Colo., good-quality gypsum is present in beds 25 to 30 feet thick. At Perry Park, southwest of Denver, gypsum occurs in the top

part of the Lykins formation in a bed that is 40 to 50 feet thick, which is overlain by limestone. Stratigraphic relations and correlation of the Lykins formation are given.

California Division of Mines Mineral Information Service, 1953, Anhydrite: v. 6, no. 1, p. 1–2.

Abundant amounts of anhydrite associated with gypsum deposits have been found in the Fish Creek Mountains, Imperial County, and in the Little Maria Mountains of eastern Riverside County. It may also be found with the gypsum deposits in the Palen and Riverside Mountains, Riverside County; with the deposits in the Clark Mountains, San Bernardino County; and with the Quatal Canyon deposit, Ventura County.

Anhydrite is used largely as an agricultural mineral and also as a retarder for portland cement.

California Journal Mines and Geology, 1952, Map of California showing distribution of principal mineral resources: v. 48, no. 1, p. 4–5.

The map, scale 1 inch=80 miles, shows the location of gypsum deposits in California.

California State Mining Bureau, 1906, The structural and industrial minerals of California: Bull. 38, p. 281–288.

The report discusses the physical and chemical properties of gypsum and the uses and methods of manufacturer of plaster. A general description of the gypsum deposits in California by counties is given.

Carpenter, A. C., 1941, New mineral localities in Kansas: Kansas Acad. Sci. Trans., v. 44, p. 264.

Excellent crystals of selenite occur along the east side of Smoky Hill River, about 4 miles southeast of Kanopolis, Ellsworth County, Kans., and in a clay bank that is one-fourth of a mile south of the west edge of Brookville, Saline County, Kans.

Cater, F. W., 1955, Gypsum Gap, Colorado: U.S. Geol. Survey Geol. Quad. Map GQ–59, scale 1:24,000.

The map is accompanied by a text that describes the geology of the Gypsum Gap quadrangle, San Miguel County, Colo. The area covered includes part of Gypsum Valley, which is an elongate collapsed salt anticline. The floor of the valley consists of the caprock which is made up of 400 to 600 feet of gypsum and anhydrite, shale, and carbonaceous limestone.

Christiansen, F. W., 1952, Geology of Henry gypsum deposits, Juab County, Utah [abs.]: Utah Acad. Sci. Proc. for 1949–50, v. 27, p. 87.

The Twelvemile Canyon member of the Arapien shale of Upper Jurassic(?) age is exposed in a narrow belt along the western foothills of the Gunnison Plateau. Gypsum has been produced from several localities. The Henry Gypsum deposits are 5 miles south of Levan, Juab County, Utah. They are near the base of a sequence of marine Jurassic strata. Early Laramide stresses folded the strata and caused the gypsum beds to thicken and thin locally, depending upon their position in relation to the axes of the folds. The thick lenticular gypsum body of the Henry mining district occurs along the axial zone of a steeply plunging anticline. Evidence points to a flowage of gypsum from the limbs toward the axis of the structure at the time of folding, or later. The gypsum flowed from depth toward the surface, in a direction parallel to the axis of the fold. The force of the intruding gypsum locally broke the continuity of the fold. Assay of samples taken across the deposit shows that the gypsum varies from about 90 to about 96 percent pure. About 500,000 tons of gypsum is exposed on the surface.

Clabaugh, S. E., Larrabee, D. M., Griffitts, W. R., and others, 1946, Map showing construction materials and nonmetallic mineral resources of Wyoming: U.S. Geol. Survey Missouri Basin Studies Map 9, scale 1:500,000.

The map shows the location of gypsum deposits in Wyoming.

Clarke, W. C., 1893, The gypsum industry of New York State, *in* Salt and gypsum industries of New York: New York State Mus. Bull. 11, p. 70–89.

The report describes the gypsum deposits of New York. Included are a list of producers, production figures, and a locality map, scale 1 inch=15 miles, showing the gypsum deposits of the State.

Coats, D. R., and Cushman, R. L., 1955, Geology and ground-water resources of the Douglas basin, Arizona: U.S. Geol. Survey Water-Supply Papers 1354, p. 18.

East of Douglas, Ariz., in T. 24 S., R. 28 E., are 4 small areas of gypsum that consist of white earthy gypsum, with almost a complete lack of grit and crystals. The largest deposit is in strata that are 25 feet thick in the center, and taper to featheredges on the sides. Intermittent mining has been carried on for several years. Fossils indicate that these deposits were formed in a lake during the middle or late Pleistocene.

North of Douglas in the Turkey Creek area (T. 18 S., R. 28 E.), gypsum occurs in crudely bedded deposits, largely as crystalline and fibrous forms. The thickest section measured was 6½ feet. The gypsum is white to brownish red, very gritty, and nonfossiliferous.

Gypsum is found at depth in wells that are drilled in the Douglas basin. The ground water is affected by these deposits, though the gypsum itself does not carry water.

Collier, A. J., 1920a, Anticlines near Maverick Springs, Fremont County, Wyoming: U.S. Geol. Survey Bull. 711–H, p. 149–166.

The Maverick Springs region is in the northwestern part of Fremont County, Wyo. Gypsum, which occurs in the Chugwater formation (Triassic) in a bed that is 123 feet thick, is pure and forms prominent white cliffs. A map, scale 1:62,500, that shows the topography and geologic structure of the Maverick Springs region and a photograph of an exposed bed of gypsum in the Chugwater formation are included.

———— 1920b, Oil in the Warm Springs and Hamilton domes near Thermopolis, Wyoming: U.S. Geol. Survey Bull. 711–D, p. 62, 65–67.

The Chugwater formation of Triassic age is 1,200 feet thick where it is exposed near Thermopolis, Hot Springs County, Wyo. Beds of gypsum occur near the top and middle of the formation. In the Dinwoody formation, lower Triassic gypsum occurs interbeddeed with calcareous shale and sandstone. A detailed section of the Chugwater formation shows the gypsum to be as much as 60 feet thick; in the Dinwoody formation, impure yellowish gypsum is 17 feet thick. Geologic sections of the formations in the Thermopolis area are included.

Connolly, J. P., and O'Harra, C. C., 1929, The mineral wealth of the Black Hills [South Dakota-Wyoming]: South Dakota School Mines Bull. 16, p. 277–284.

The outcrop of the Spearfish formation of Triassic(?) age completely circles the Black Hills and forms the floor of Red Valley. Gypsum occurs in

the Spearfish in beds that are as much as 30 feeet thick. Two continuous beds of gypsum extend from Spearfish eastward and southward to Centennial, through Whitewood, Sturgis, Tilford, Piedmont, and Black Hawk, to Rapid City, S. Dak. The upper bed, which is near the top of the formation, ranges in thickness from 8 to 25 feet; it thins and disappears south of Rapid City. The lower bed, which lies about 100 feet above the base of the formation, and constitutes the principal deposit from Black Hawk southward, averages about 6 feet thick but thickens to 15 feet west of Hermosa; it then thins and is missing until it reappear near Hot Springs, S. Dak.

At Hot Springs, 2 prominent beds aggregate about 33 feet in thickness. These beds are separated from each other by about 10 feet of shale. Gypsum is also extensively exposed in Red Valley, which is in the vicinity of Minnekahta, Fall River County. The principal bed, which is about 25 feet thick, lies about 80 feet above the base of the formation.

Thick gypsum beds extend northwest from Fall River County, through New Castle, Wyo., to Sundance, Wyo., and thence eastward to Spearfish, S. Dak.

Gypsum plants have been located at Spearfish, Crook City, Sturgis, Hot Springs, Rapid City, Piedmont, and Black Hawk, all in South Dakota. The mills at the last three localities were in operation in 1929.

Chemical analyses of gypsum from South Dakota deposits indicate that the material averages more than 95 percent gypsum.

Cook, E. F., 1957, Geology of the Pine Valley Mountains, Utah: Utah Geol. Mineralog. Survey Bull. 58, p. 31, 34, 40–41, 46.

The Pine Valley Mountains are located in the southwestern part of Utah. Gypsum occurs in two formations within the area mapped: The Kaibab formation of Early Permian age and the lower part of the Carmel formation of Late Jurassic age. The gypsum member of the Kaibab formation is in the middle of the formation between 2 massive limestone beds and consists of about 150 feeet of gypsum and anhydrite.

The Carmel formation, which crops out on the east flank of the Pine Valley Mountain, can be divided into 3 units: the lowest unit contains soft red sandstone, gypsiferous shale, and about 225 feet of bedded gypsum; the middle unit is gray and brown limestone; and the upper unit is gray limestone. Geologic sections of the Carmel formation show that the beds of gypsum are each 20 feet or less thick and are intermixed with blue-gray shale.

Corpus Christi Geological Society, 1957 [Guidebook] Annual field trip, South Texas salt domes, 30 p.

The report describes the salt domes of South Texas. The Falfurrias dome in Brooks County is described in detail and an aerial photograph and a map of the dome are included.

Crane, W. R., 1901, The milling and mining of gypsum in Kansas: Eng. Mining Jour., v. 72, no. 19, p. 602–603.

The report describes the mining industry in Kansas in 1900. The mines in operation were: 3 at Blue Rapids, Marshall County; 2 near Solomon City, Dickinson County; and 1 each near Banner City, Marion County; at Longford, Clay County; near Peabody, Marion County; and near Mulvane, Sedgwick County.

Crocker, William, 1923?, The history of agricultural gypsum: Chicago, Ill., Gypsum Industries Assoc., 36 p.

The use of gypsum as a fertilizer was discovered simultaneously in Germany and France, in the last half of the 18th century. It was used in this country shortly thereafter.

The report describes the results of several experiments that were made to determine the value of gypsum as an agricultural mineral.

Gypsum contains two essential chemical elements which are beneficial to plants, calcium and sulfur. Phosphate and nitrogen are other important elements. The average soil contains relatively few years' supply of these elements, and it is necessary to replace them often to get the maximum use of soil. A mixture of rock phosphate and gypsum, or manure and gypsum, together with nitrogen fixing plants used in rotation, are the best methods of keeping soils fertile. Gypsum is also used in reclaiming lands bearing black alkali. It transforms the sodium carbonate to the less harmful sodium sulfate and calcium carbonate. Gypsum cannot be used in place of limestone to neutralize acid soils.

Cross, Whitman, and Spencer, A. C., 1900, Geology of the Rico Mountains, Colorado: U.S. Geol. Survey 21st Ann. Rept., pt. 2, p. 50–53, 111–112.

The Hermosa formation of Pennsylvanian age at Rico, Colo., is divided into three equal parts; the basal part contains rock gypsum. In most of the Rico area, gypsum has been removed by solution, but at Newman Hill, a maximum thickness of 30 feet is present. Gypsum beds associated with black shales and bituminous limestones are also present in the Animas region. A geologic section in the Silver Glance shaft, and a geologic map of the Rico Mountains, scale 1:23,600, are included.

Cushing, E. R., 1946a, Gypsum mine mechanization: Rock Products, v. 49, no. 7, p. 68–70, 106–107.

Gypsum mining is an old profession in the United States. Of the 30 gypsum mines in operation, 12 have been operating more than 40 years, and 18 of the remaining are more than 20 years old. The Grand Rapids Plaster Co. of Grand Rapids, Mich., is more than 90 years old. Only in the last 5 years has any progress been made in mine mechanization in the gypsum industry.

Types of improvement in drilling techniques in different mines are given, as well as factors to be considered in choosing the right drill for the gypsum deposit. In addition, the pros and cons of using undercutting machines are outlined.

——— 1946b, Gypsum mine mechanization: Rock Products, v. 49, no. 8, p. 92–97.

The report discusses loading gypsum underground. The caterpillar-mounted loading machines that are used in conjunction with rubber-tired shuttle cars are now widely used in gypsum mining. Briefly described in the report are other phases of mine operation where mechanization has improved the mining of gypsum. The use of auxiliary equipment, maintenance, safety, supervision, and methods of handling impurities are also discussed.

Dana, J. D., 1895, Manual of Geology: New York, American Book Co., 4th ed., p. 553–555.

The rocks of the Salina group consist predominantly of reddish shales with some dolomitic limestone, or alterations of shale with thick beds of limestone. Gypsum and rock salt are often present within the group. The beds crop out in northwestern New York from the Helderburg Mountains south of Albany, westward to Buffalo. The gypsum is sometimes in layers, but more often consists of parts of layers, or masses, interbedded with shale. Lines of stratification occur in the gypsum. In places, layers of shale are bulged up around the gypsum, indicating that the gypsum was formed after the beds were deposited. The gypsum probably originated by the action of sulfuric acid on a mass or bed of limestone, converting the $CaCO_3$ to $CaSO_4 \cdot 2H_2O$. The gypsum is generally of an earthy variety, dull gray, reddish and brownish, and sometimes black. That all the gypsum in the formation was derived from altered limestone is reasonably questioned; it is possible that some of it may have been deposited from the same sea water that supplied the salt.

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, 175–176.

Gypsum occurs in the Paradox formation of Pennsylvanian age in Salt and Onion Creek Valleys, Grand County, Utah. The outcrops of the Paradox formation show the beds to be so faulted and fractured that no section can be measured. The formation consists of black shale that alternates with gray sandstone, and limestone. Rock gypsum is abundant in thick beds and is typically dark blue, gray, crystalline and banded in lighter and darker gray.

Outcrops of the Paradox formation are so coated with gypsum powder and secondary selenite crystals that it appears as though much more gypsum is present than actually there is. The total thickness of the formation is probably greater than 1,000 feet, and it increases to at least 3,000 feet where the formation has been squeezed into the Salt Valley and Onion Valley anticlines.

A geologic map of the area, on a scale of 1:62,500, is included.

Dane, C. H., and Bachman, G. O., 1958, Preliminary geologic map of the southeastern part of New Mexico: U.S. Geol. Survey Misc. Geol. Inv. Map I–256, scale 1:380,160.

The map shows the location of the gypsum-bearing formations in southeastern New Mexico.

Darton, N. H., 1901, Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming: U.S. Geol. Survey 21st Ann. Rept., pt. 4, p. 516–519, 584–585.

The Spearfish formation of Triassic? age consists of 350 to 500 feet of red sandy clays with intercalated beds of gypsum which in places attain a thickness of 30 feet. The gypsum beds occur at various horizons within the formation, some extending laterally over wide areas. Some secondary deposits are found throughout the formation in small veins.

The only commercial operations, in the gypsum of the Spearfish formation, have been at Hot Springs, S. Dak. Operations were discontinued here because of high transportation rates to the markets.

A geologic section of the Spearfish formation, measured three-fourths of a mile northwest of Hot Springs, shows 5 beds of gypsum; the thickest bed is 15 feet. The beds are separated by red shale which is from 1 to 20 feet thick. An analysis of a typical sample of gypsum from Hot Springs indicates that the gypsum is about 95 percent pure.

________ 1902, Description of the Oelrichs quadrangle [South Dakota-Nebraska]: U.S. Geol. Survey Geol. Atlas, Folio 85, p. 1, 3, 6.

The Oelrichs quadrangle is located mostly in the eastern half of Fall River County, S. Dak., and in parts of Custer County, S. Dak., and Dawes County, Nebr. Gypsum occurs in the Spearfish formation of Triassic? age, which crops out in the northwestern part of the quadrangle. Near Hot Springs, S. Dak., it attains its greatest thickness. A section measured here shows 4 beds of gypsum, all of which occur near the top of the formation, and range from about 2 to 15 feet in thickness. An analysis of gypsum from this area indicates that it is about 98 percent pure. The report contains a geologic map, scale 1:125,000.

Darton, N. H., 1904a, Description of the Newcastle quadrangle [Wyoming-South Dakota]: U.S. Geol. Survey, Geol. Atlas, Folio 107, p. 3, 9.

In the Newcastle quadrangle, which lies mostly in Weston County, Wyo., gypsum occurs in the Spearfish formation of Triassic(?) age. The most extensive gypsum deposits are located about a mile southeast of Newcastle, Weston County, where the gypsum reaches a maximum thickness of 25 feet; and near Mount Pisgah, in the north-central part of the quadrangle in Weston County, where the gypsum occurs in the lower and middle parts of the formation.

A geologic map, scale 1:125,000, is included.

——— 1904b, South Dakota, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 76–78.

An elliptical outcrop of the gypsum-bearing Spearfish formation is exposed around the Black Hills uplift in the western part of South Dakota and eastern Wyoming. The outcrop belt is about 100 miles long and 50 miles wide, and has an average width of 3 miles. The thickness of the gypsum varies; in some parts of the area it is more than 30 feet. At Hot Springs, Fall River County, at the south edge of the outcrop belt, the principal gypsum beds are 33 feet thick and are about 60 feet above the base of the Spearfish.

North of Edgemont, Fall River County, the principal bed lies 80 feet above the base of the Spearfish and can be traced continuously for many miles. It has an average thickness of 25 feet. East of Newcastle, Weston County, Wyo., thick beds in both the lower and upper parts of the formation occur. At Sundance, Crook County, Wyo., in the northwestern part of the outcrop zone, gypsum occurs about 80 feet above the base of the Spearfish. At Rapid City, Pennington County, S. Dak., the gypsum bed is 10 feet thick and occurs about 80 feet above the base of the Spearfish.

Only two mills have been in operation in the outcrop belt, one at Hot Springs and one at Sturgis, Meade County, S. Dak. Lack of transportation limits the use that can be made of these deposits.

The report contains a map of the gypsum-bearing formations in the Black Hills, scale 1 inch=about 25 miles.

——— 1905a, Preliminary report on the geology and underground water resources of the central Great Plains: U.S. Geol. Survey Prof. Paper 32, p. 31, 32, 49–50, 58, 90, 94, 96, 99, 160, 163, 300, 392–396.

The area included in this report comprises the greater parts of South Dakota, Nebraska, and Kansas, the eastern parts of Colorado and Wyoming, and the southern part of Montana. In the Big Horn Mountains of Wyoming and Montana, gypsum occurs in the Chugwater formation of Triassic(?) or Permian age. The Chugwater formation is about 1,250 feet thick and consists of bright-red sandstones and sandy shales that contain deposit of gypsum. Thin beds of limestone are near the top and bottom of the gypsum beds. The gypsum occurs mainly in the lower 200 feet of the formation.

In the Black Hills of western South Dakota and eastern Wyoming, gypsum occurs in the Spearfish formation of Triassic(?) age. This formation encircles the Black Hills, and, as it is softer than the overlying and underlying formations, it has been eroded and has formed the wide Red Valley. The formation consists of red shales and beds of gypsum. The gypsum occurs below the middle of the formation in beds that range in thickness from less than 1 foot to more than 30 feet. It is thickest in the vicinity of Hot Springs, S. Dak., where the principal beds are about 33 feet. Near Rapid City, S. Dak., the beds are about 10 feet thick. In the region north of Edgemont, S. Dak., near Minnekahta, the principal bed of gypsum lies about 80 feet above the base of the Spearfish formation, and is about 25 feet thick. An analysis of this gypsum indicates that it is about 99 percent pure(?). East of Newcastle, Wyo., the gypsum beds in the lower part of the Spearfish formation attain a thickness of 40 feet and in the upper part, a thickness of 30 feet.

Around Sundance, Wyo., a continuous deposit of gypsum occurs about 50 feet above the base of the formation and extends around the northwestern part of the Black Hills and southward for many miles. In Wyoming on the east end of Casper Mountain in Converse County, gypsum occurs in the Spearfish formation of Triassic age. The gypsum here occurs in a bed that is 8 feet thick and overlies buff sandstones and shales.

Gypsum is present near the Garden of the Gods, west of Colorado Springs, Colo. A section measured here shows 30 feet of gypsum that is associated with red shales. These beds are probably Triassic in age. In Las Animas County, Colo., near the Purgatory River, a measured section shows that 25 feet of gypsum occurs with some shale in a sequence of red beds of Triassic(?) age. The gypsum in the red beds lies just below the Morrison formation of Cretaceous age.

A well drilled in Grant County, Kans., 6 miles southeast of Ulysses, passed through several beds of gypsum. The best bed was 14 feet thick and occurred at a depth of 21 feet below the surface. The major gypsum deposits in Kansas, however, occur in Permian rocks that are found in the east-central part of the State and that extend from the north border southward into Oklahoma. The gypsum deposits become successively younger from north to south. The main deposits lie in three areas: in Marshall County, in the northern part of the State; in Salina and Dickinson Counties, in the central part of the State; and in Barber, Comanche, and Kiowa Counties, in the southern part of the State.

Darton, N. H., 1905b, Description of the Sundance quadrangle [Wyoming-South Dakota]: U.S. Geol. Survey Geol. Atlas, Folio 127, p. 3, 12.

Gypsum occurs in the vicinity of Sundance in Crook County, Wyo., in the Spearfish formation. The outcrop of the formation extends southward from Rocky Ford and passes around the west side of Green Mountain. Thick beds of gypsum occur in the top part of the formation. The maximum thickness of a single gypsum bed within the quadrangle is 25 feet. Near Sundance, the gypsum occurs 8 feet below the top of the formation in a deposit that is 4 feet thick. Several caves and sinkholes are present within the gypsum.

A geologic map, scale 1:125,000, is included.

________ 1906a, Description of the Bald Mountain and Dayton quadrangles [Wyoming]: U.S. Geol. Survey Geol. Atlas, Folio 141, p. 14–15.

Gypsum beds, 3 to 5 feet thick, crop out near the base of the Chugwater formation of Triassic age in the Dayton quadrangle, Sheridan County, in a band around the edge of the Big Horn Mountains. The gypsum is pure enough to be of commercial interest.

A geologic map, scale 1:125,000, shows the outcrop of the Chugwater formation.

________ 1906b, Geology of the Bighorn Mountains [Wyoming]: U.S. Geol. Survey Prof. Paper 51, p. 114.

Gypsum occurs on both sides of the Bighorn Mountains in lenses that are scattered throughout the Chugwater formation (Triassic). The most persistent lens of gypsum is near the base. Several geologic sections of the formation are given; these show that the gypsum beds range from 6 to 50 feet in thickness and average 10 to 12 feet in thickness. The area covered includes parts of Bighorn, Sheridan, and Johnson Counties. A geologic map, scale 1 inch=4 miles, is included.

Darton, N. H., 1906c, Geology of the Owl Creek Mountains [Wyoming]: U.S. 59th Cong., 1st sess., 1. Doc. 219, 48 p.

The Owl Creek mountains are in Hot Springs and Fremont Counties, Wyo. The Chugwater formation of Triassic age that crops out along the south side of the mountains contains a bed of gypsum, which is 30 to 40 feet thick near the top.

The report includes a geologic map of the Owl Creek Mountains, scale 1 inch=4 miles, which shows the outcrop of the Chugwater formation.

——— 1909, Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming: U.S. Geol. Survey Prof. Paper 65, p. 27–31, 75, 94–95.

The Spearfish formation of Triassic(?) age is composed of red sandy shales with intercalated beds of gypsum. The gypsum beds vary in thickness from 30 feet to less than 1 inch. Most of the gypsum is pure white, but some is gray to dirty blue. The gypsum beds may occur anywhere within the formation, though there are two principal beds; one in the upper part and one in the lower part of the formation. The upper bed is the thicker in the eastern part of the district; the lower bed is the thicker in the western part of the district. In the vicinity of Sundance, Wyo., the lower gypsum bed lies about 120 feet above the base of the formation. It is 20 to 30 feet thick in most places, and thins eastward to 5 feet. East of Spearfish, S. Dak., the upper bed is 18 to 20 feet thick. This bed is only about 4 feet thick near Sundance, Wyo. The gypsum beds form ridges on many of the small divides, and many sinks or caves are present within the gypsum; 1 cave is 30 feet wide and 25 feet or more in depth.

Several geologic sections of the Spearfish formation are given; these show the stratigraphic locations and thicknesses of the gypsum beds. A locality map, scale 1 inch=80 miles, is included.

——— 1920, New Mexico, *in* Stone, R. W., and others, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 161–186.

Much of New Mexico is underlain by thick, beds of pure gypsum. In the south-central part of the State, the deposits are interbedded with red and gray sandstones and limestones of the Yeso formation and San Andreas limestone of the Manzano group upper Carboniferous age. In the north-central part of the State gypsum that is as much as 100 feet thick overlies the Wingate sandstone of Jurassic age. A large deposit of gypsum of Tertiary age constitutes the white sand dunes in south-central New Mexico.

The report gives brief descriptions of the stratigraphy of the gypsum deposits that occur throughout the State. An outline map of New Mexico, scale about 1 inch=55 miles, showing the distribution of the gypsum deposits, is included.

——— 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. 21–25, 27–28, 35, 59, 69–87, 96–97, 114, 118, 121, 145, 167, 190, 205, 227–252, 322 [1929].

Gypsum occurs in three different formations which are widely spread throughout the State: the Chupadera, the Castile, and the Todilto. The lowest is the Chupadera formation of Permian age which consists of two members: the upper, the San Andres limestone member and the lower, the Yeso member. The San Andres member contains limestone and gray sandstone and some beds of gypsum, anhydrite and salt in the southeastern part of the State. The Yeso member consists mainly of soft red sandstone that is interbedded with numerous beds of gypsum which thin and disappear in the northern part of the State. The report includes several stratigraphic sections that show the thickness of the gypsum and anhydrite. A section of the Chupadera formation, which was measured near Santa Rita, N. Mex., shows that there are 6 beds of gypsum, ranging from 20 to 80 feet in thickness, and that they are separated by beds of limestone and sandstone. In other measured sections, the gypsum and anhydrite are generally a few inches to more than 100 feet thick.

In the southeastern part of the State, gypsum occurs in the Castile formation of Permian(?) age. Gypsum is exposed along the valley of the Black River, along the Pecos River in Chaves and Eddy Counties, and near Carlsbad, N. Mex. Deep borings near Carlsbad reveal an alternation of anhydrite and salt that extends from 300 feet to below 2,380 feet from the surface.

In the northern part of the State, gypsum occurs in the Todilto formation of Jurassic age. The Todilto formation generally consists of limestone, but locally contains beds of pure white gypsum, which attain a thickness of about 60 feet. Conspicuous outcrops occur in cliffs along the Santa Fe railroad near El Rito and east of Laguna. It also occurs throughout the Nacimiento uplift and in the Chama basin.

Quaternary dune sands occur west of Alamogordo. These "white sands" occupy an irregular area that is about 27 miles long and 10 to 13 miles wide. The gypsum was brought to the surface by seepage of water, possibly from the underlying Chupadera beds, and deposited in crusts, which were then crumbled to sand and piled by wind into dunes.

The report describes local geology of several areas throughout the State. Geologic maps, scale 1 inch=4 miles, show outcrops of gypsum-bearing formations.

Darton, N. H., Blackwelder, Eliot, and Siebenthal, C. E., 1910, Description of the Laramie and Sherman quadrangles [Wyoming]: U.S. Geol. Survey Geol. Atlas, Folio 173, 18 p.

The area mapped includes the Laramie and Sherman quadrangles in Albany and Laramie Counties, Wyo. Gypsum occurs in the Satanka shale of Pennsylvanian age and in the Chugwater formation of Triassic age.

The gypsum in the Satanka shale occurs as local lenses that are 1 to 15 feet thick, and that crop out south of Laramie at Red Buttes. Chemical analysis indicates that this material is 99 percent pure gypsum. Some plaster has been made from the gypsum of this deposit.

The gypsum in the Chugwater is associated with red shale and sandstone and crops out in a broad zone along the west side of the Laramie Mountains. Three beds of gypsum, which range from 3 to 67 feet in thickness, are present in a geologic section of the Chugwater that was measured near Red Mountain, in the southwestern part of the Laramie quadrangle; the thickest of these beds lies at the base of the formation.

Numerous deposits of gypsite are present in the Laramie quadrangle; one deposit just south of Laramie is being worked. Chemical analysis of this material indicates that it is 93 percent pure gypsum.

A geologic map, scale 1:125,000, is included.

Darton, N. H., and O'Harra, C. C., 1905, Description of the Aladdin quadrangle [Wyoming]: U.S. Geol. Survey Geol. Atlas, Folio 128, p. 2, 8.

In the Aladdin quadrangle, Crook County, Wyo., gypsum occurs 100 feet above the base of the Spearfish formation of Triassic(?) age, in a bed that averages 15 feet in thickness. The gypsum crops out only in the southern part of the quadrangle in a continuous band that extends through Government and Redwater Valleys.

A geologic map, scale 1:125,000 is included.

Darton, N. H., and O'Harra, C. C., 1909, Description of Belle Fourche quadrangle [South Dakota]: U.S. Geol. Survey Geol. Atlas, Folio 164, p. 1, 3, 7.

The Belle Fourche quadrangle covers the southwest corner of Butte County, the northern part of Lawrence County, and a small part of Meade County, S. Dak. The gypsum occurs in the Spearfish formation of Triassic(?) age in 2 beds which are best exposed northeast of the town of Spearfish. One bed, near the top of the formation averages 12 feet in thickness; the other, 100 feet above the base of the formation, averages 5 feet in thickness. Stratigraphic sections of the Spearfish formation, measured in Red Valley and near Spearfish, are given. A geologic map, scale 1 inch=about 2 miles, is included.

Darton, N. H., and Paige, Sidney, 1925, Description of the central Black Hills [South Dakota]: U.S. Geol. Survey Geol. Atlas, Folio 219, p. 1, 10, 31.

The central Black Hills area includes the greater part of Lawrence, Custer, and Pennington Counties and the western part of Meade County, S. Dak. Gypsum occurs in thick beds in the Spearfish formation which crop out in the Red Valley, a valley which circumscribes the Black Hills uplift. The gypsum, which is in beds that range in thickness from less than 1 inch to 25 feet, is mostly white, but some is gray to dirty blue. From Spearfish, on the north side of the Black Hills uplift, to Rapid City on the east side, there are two continuous beds: one that is 100 to 120 feet above the base of the Spearfish and is 6 to 10 feet thick; the other that is near the top of the formation and is 6 to 8 feet thick, and thickens to 25 feet near Rapid City. The bed near the top of the formation disappears south of Rapid City, but the lower bed continues.

A geologic map, scale 1 inch=about 2 miles, is included.

Darton, N. H., and Smith, W. S. T., 1904, Description of the Edgemont quadrangle [South Dakota-Nebraska]: U.S. Geol. Survey Geol. Atlas, Folio 108, p. 1, 10.

The Edgemont quadrangle covers the western half of Fall River County, and parts of Custer County, S. Dak., and Sioux County, Nebr. Gypsum occurs scattered throughout the Spearfish formation of Triassic(?) age. The thickest and most continuous bed, however, is about 80 feet above the base of the formation. In many places, this bed reaches a thickness of 25 feet. In Fall River County it is exposed in the Red Valley to the northwest, north, and east of Minnekahta; in Alabaugh Canyon; and southeast of Cascade Springs. The gypsum is very pure.

A geologic map, scale 1:125,000, is included in the report.

Darton, N. H., Stephenson, L. W., and Gardner, Julia, 1937, Geologic map of Texas: U.S. Geol. Survey, scale 1:500,000, 4 sheets.

The map shows the geologic formations of the State, including those which are gypsum bearing.

Davis, F. F., and Carlson, D. W., 1952, Mines and mineral resources of Merced County [California]: California Jour. Mines and Geology, v. 48, no. 3, p. 227–228.

Gypsite is mined in the foothills of the Coast Ranges in the western part of Merced County. The gypsite, which is a mixture of gypsum, sand, clay, marl, and diatomaceous earth, is in deposits that are from 6 inches to 6 feet thick and are close to the surface. A geologic map, scale 1 inch=3 miles, is included.

Day, D. T., 1904, Florida, *in* Adams, G. I., and others, U.S. Geol. Survey Bull. 223, p. 48.

A deposit of claylike gypsum occurs near the surface at a locality that is 6 miles west of Panasoffkee, Sumter County, Fla. The gypsum deposit is 6 to 7 feet thick and can be mined easily. Water should not hinder mining.

Delwig, L. F., 1955, Origin of the Salina salt of Michigan: Jour. Sed. Petrology, v. 25, no. 2, p. 83–110.

The temperature at which the Salina salt in Michigan was precipitated was determined by examination of liquid inclusions. The temperature, which ranged from 32° to 48.4°C, represents those found at the surface of the brine. The temperatures below the surface were probably lower.

Anhydrite laminae and bands occur along with dolomite, pyrite, and organic material in association with halite. No evidence exists to indicate that the $CaSO_4$ was deposited as gypsum.

The report quotes Posnjak (1938, 1940) and Hill (1937) in stating that anhydrite will be precipitated at 42°C or above, regardless of the concentration of the sodium chloride brines in the water. If sea water is concentrated to 4.8 times its original composition, anhydrite will be deposited at a temperature of 30°C. At the temperatures that were determined in this study for the deposition of the salts, it is possible that gypsum could have been deposited originally, before the concentration of the brines became such that the anhydrite would have been deposited.

Detwiler, R. M., 1955, The story of gypsum: Frontiers, v. 20, no. 1, p. 17–21.

A popular account of gypsum, including a review of its properties, uses, and history, is given.

Deussen, Alexander, and Lane, L. L., 1925, Hockley salt dome, Harris County, Texas: Am. Assoc. Petroleum Geologists Bull., v. 9, no. 7, p. 1031–1060.

Hockley dome is located in the northwestern part of Harris County, Tex. The report describes the history of exploitation of the dome, the physiography, and the surface and subsurface geology. The dome is a typical salt dome with a caprock, lying within 100 feet of the surface, that is composed of an anhydrite sheet under an overlying sheet of limestone. The salt core rises to within 1,000 feet of the surface, and the limestone of the caprock lies within 100 feet of the surface. Several geologic sections that show the structure and shape of the dome and an outline map of the dome, scale 1 inch=about 1 mile, are included.

Dolbear, S. H., 1945, Economic mineral resources and production of California: California Div. Mines Bull. 130, p. 151–155.

Gypsite is found along the Coast Ranges in California, south of San Francisco, in Fresno, Kern, Kings, Merced, San Benito, Los Angeles, Riverside, and San Bernardino Counties. Gypsum is produced in Alameda County as a byproduct in the manufacture of magnesia, by evaporation of sea water. Large deposits of rock gypsum occur in Imperial, Ingo, Riverside, and San Bernardino Counties, and smaller deposits are found in Fresno, Orange, Santa Barbara, and Ventura Counties. Most of the gypsum produced in California is used in agriculture, and much of the remainder is made into plaster products or is used as a retarder for portland cement.

A map of California, dated 1944, scale of 1 inch=40 miles, shows the distribution of mineral deposits.

Dorheim, F. H., and Campbell, R. B., 1958, Recent gypsum exploration in Iowa: Iowa Acad. Sci. Proc., v. 65, p. 246–253.

Activity in exploring for gypsum in southern Iowa is centered in five areas: Bussey, Marion County; Albia, Monroe County; Centerville, Appanoose County; Ottumwa, Wapello County, and Burlington, Des Moines County. Evaporites in southern Iowa occur in rocks of both Mississippian and Devonian age. The cores taken at Albia show that the evaporites occur in St. Louis and the underlying Warsaw formations of Mississippian age, and in the Wapsipinicon formation of Devonian age. No pure gypsum occurs in the Devonian section. In the Warsaw, the upper 60 feet is almost all evaporite; the upper 5 feet is pure gypsum, and the basal 5 feet is 90 percent gypsum and 10 percent dolomite. The remaining 50 feet is mostly anhydrite.

At Ottumwa, the evaporites occur in the Davenport and Kenwood members of the Wapsipinicon formation. The cuttings show that most of the Davenport is anhydrite with about 2½ feet of gypsum near the top. In the Kenwood member, the evaporite occupies about half of the top 45 feet. A 2-foot bed of brown to gray gypsum occurs at the top of the formation.

The findings suggest that the evaporite deposits were originally anhydritic and have been altered to gypsum by movement of water along bedding or fracture surfaces.

Douglas, G. V., and Goodman, N. R., 1957, The deposition of gypsum and anhydrite: Econ. Geology, v. 52, p. 831–837.

Broadly speaking, a calcium sulfate deposit that is formed under lagoonal conditions is composed of a great number of extremely thin beds, which are generally interbedded with clay or limestone. The form of calcium sulfate that is originally deposited will be dependent on the existing physical-chemical conditions in the lagoonal waters and lagoonal floor.

The authors studied the effects of temperature, pressure after deposition of calcium sulfate, loss of heat through the bottom of a lagoon, and addition of fresh water, with or without accompanying silt, from land areas around the lagoon, to determine which of these affects the form of calcium sulfate found in nature. The results show that climatic temperature changes do not determine whether gypsum or anhydrite is precipitated. They also rule out pressure as a factor that is responsible for changing gypsum to anhydrite. Radiant heat has a more important part than conducted heat in determining whether gypsum or anhydrite will be deposited, since radiant heat can pass through a medium that is "transparent to that wave length and heat up a more saline solution due to its lower specific heat." In this way, lagoonal waters can accumulate more heat during the day than they lose at night, under the blanketing effect of less saline water. Therefore, if pure fresh water is added to a lagoon, flooding over the more dense salt water, the temperature of the salt water at depth will rise. If fine silt is included in this fresh water, it will act as an insulating blanket over the surface of the lagoon, and the salt water will not increase in temperature.

If brines of 70°C are in contact with a clay on the bottom of a lagoon, the heat will penetrate into the clay as much as 25 meters. The heat will also penetrate into an anhydrite or gypsum mud. It is conceivable that the heat from the brine could penetrate a gypsum bed containing interstitial water, raise the temperature of this bed above 40°C, and alter the already-deposited gypsum to anhydrite.

If the waters of a lagoon are at 40°C, anhydrite will be precipitated with the silt that is entering the lagoon, and the temperature will fall below 40°C as the silt absorbs the heat. Thus, gypsum will be deposited over the anhydrite. Regardless of which form of calcium sulfate is deposited, it is still subject to alteration to the other form (if interstitial water is present), with changed conditions in the body of accumulated sediments.

The example of the deposit at Amaranth, Manitoba, is given. A stratigraphic section of this deposit shows that there is, in sequence: 94 feet of overburden, 33 feet of gypsum, 4 to 6 feet of anhydrite, 9 feet of gypsum, and basement rocks. There are two explanations for this sequence:

1. If the lagoon had an initial temperature of less than 40°C, gypsum would be deposited. An influx of fresh water, combined with the insulating effect of the gypsum on the floor of the lagoon, would cause the temperature to rise above 40°C, and anhydrite to be deposited on the gypsum. If the fresh water then became silty, the temperature would fall and gypsum and silt would be deposited.
2. If the lagoon was initially at a temperature of 40°C or more, anhydrite would be deposited. Silty water then entered the lagoon, lowering the temperature enough so that gypsum would be deposited. At the same time, the temperature below the anhydrite would have been lowered by conduction into the floor and the lower part of the anhydrite horizon recrystallized into gypsum.

Dunbar, R. O., 1944, Como Bluff anticline, Albany and Carbon Counties, Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 28, no. 8, p. 1196–1216.

Como Bluff anticline is a westward plunging asymmetric fold that extends across the east-central part of the Laramie basin, in parts of Albany and Carbon Counties, Wyo. The Chugwater formation of Permian and Triassic age consists of red sandstone and shales, with some gray sandstone, limestone, and gypsum. Extensive gypsum deposits are found in N½ sec. 35 and in S½ sec. 26, T. 23 N., R. 77 W. The gypsum is white to red and occurs in nearly horizontal beds, throughout much of the area. No estimate of reserves was made. A geologic map, scale 1 inch=three-quarters of a mile, and a locality map, scale 1 inch=about 20 miles, are included.

Dunham, R. J., 1955, Uranium minerals in Oligocene gypsum near Chadron, Daws County, Nebraska: U.S. Geol. Survey Trace Elements Inv. Rept. 525, 31 p.

Secondary uranium minerals occur with gypsum and gypsiferous clays in the Brule formation of Oligocene age in Daws and Sheridan Counties, Nebr. The Brule formation is composed of a discontinuous bed of basal limestone and calcareous siltstone that is 15 feet thick and lies below 165 feet of siltstones and silty clay. The gypsum facies, which consists of a sequence of nonmarine gypsum and gypsiferous clay more than 270 feet thick, lies in the northern part of the area described, and interfingers with the clastic facies in the southern part of the area. The gypsum occurs in beds that are 2 to 8 feet thick, and are light yellow gray with some pink. It is granular and breaks readily into sand-size grains. A chemical analysis of a grab sample indicates that the gypsum is 94.5 percent pure. The lower 25 feet of the gypsum is interbedded with limestone and dolomite that corresponds with the basal limestone.

The gypsum was probably deposited by evaporation, in the center of a persistently renewed elongate valley lake. The calcium sulfate was derived either from the solution of the Upper Cretaceous shales, which contain considerable pyrite, or from the solution of the gypsum that occurs in the Permian and Triassic red beds of the Black Hills, and that was reprecipitated in the Chadron area.

Dunn, C. P., 1948, Quarrying Texas gypsum: Explosives Eng., v. 26, no. 6, p. 176–178.

National Gypsum Co. operates a plant that makes wallboard and plaster at Rotan, Fisher County. The quarry, which is 7 miles from the plant, contains 100 years' supply of gypsum. The overburden, which consists of 4 to 20 feet of shale with thin lenses of sandstone, is removed by bulldozers and carryalls. Individual blasts in the gypsum yield about 600 tons. The material is scooped into 15-ton dump trucks that transport the gypsum to the plant, where the gypsum is crushed to 2½ inches. After crushing, the mineral is conveyed to a rotary-type dryer. The crushed and dried gypsum is then sent through a pulverizer and raymond mill, and then into the calcining kettles.

Eardly, A. J., and Stringham, Bronson, 1952, Selenite crystals in the clays of Great Salt Lake [Utah]: Jour. Sed. Petrology, v. 22, no. 4, p. 234–238.

Selenite crystals that occur in the soft clays around the shores of the Great Salt Lake, Utah, suggest an origin for the selenite crystals that occur in various shale formations of the geologic past. The crystals occur in clusters, or "pockets," that lie from a few inches to as much as 18 inches below the surface. The largest of the crystals is as much as 6 inches in diameter. All the crystals are in a vertical or nearly vertical position.

Neither gypsum nor anhydrite has ever been found on the bottom of the Great Salt Lake, because the calcium is precipitated as $CaCO_3$ and the sulfate is precipitated as $Na_2SO_4 \cdot 10H_2O$. The selenite crystals probably originated in one of three ways:

1. By precipitation from spring or seep waters rich in calcium sulfate, which emerged from below and permeated into the clays.
2. By physical and chemical changes that occurred in the clays as they lost their water and became compacted.
3. By action of sulfate-producing bacteria, which are abundant throughout the clays of the Great Salt Lake, and which, under certain conditions, tended to dissolve the gypsum or anhydrite scattered throughout the mud, and then reprecipitated the calcium sulfate as selenite crystals.

Eberl, J. J., and Ingram, A. R., 1949, Process for making high-strength plaster of Paris: Indus. Eng. Chemistry, v. 41, no. 5, p. 1061–1065.

A high-strength low consistency plaster of paris was developed by autoclaving a gypsum slurry in the presence of a few tenths percent of certain dicarboxylic acid salts, including soluble succinate, malate, citrate, and maleate salts. The product was a plaster of paris compound of short rodlike crystals. The crystal shapes varied according to the method of autoclaving and the type and concentration of the added salt.

Eckel, E. C., 1904a, Virginia, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 36–37.

In Virginia, all workable deposits of gypsum occur in Washington and Smyth Counties in a narrow belt that is 16 miles long. The gypsum occurs interbedded with shales and shaly limestone of Carboniferous age. The beds of gypsum average 30 feet in thickness and dip at high angles. A thick bed of shale and thick beds of salt underlie the gypsum. At a short distance southeast of the line of gypsum outcrops, a fault has brought the Cambrian limestones up against the shaly limestones of the Carboniferous.

The report includes a geologic map, scale 1 inch=about 3½miles, which shows the location of the gypsum mines.

Eckel, E. C., 1940b, New York, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 33–35.

In New York, gypsum occurs interbedded with shale and shaly limestone in the Salina formation of Silurian age. The gypsum beds are lenticular and range from 4 to 10 feet in thickness. The area in which the gypsum deposits are located extends through the central part of the State, in parts of Madison, Onondaga, Cayuga, Ontario, Genessee, Monroe, Livingston, and Erie Counties. The deposits in Genessee are pure enough to be used in making the highest grade of plaster. Those to the east of Genessee County are less pure and have been used only for low-grade plaster and in agriculture.

In 1904, deposits of gypsum were being worked at Marcellus and Fayetteville, Onondaga County; Union Springs, Cayuga County; Phillipsport, Gibson, and Victor, Ontario County; Mumford, Monroe County; and Oakfield, Genessee County.

A map, scale about 1 inch=30 miles, showing the gypsum-producing localities and outcrops of the Salina formation, is included in the report.

———— 1922, Cements, limes, and plasters; their materials, manufacture, and properties: New York, John Wiley & Sons, pt. 1, p. 18–90.

This report describes the physical and chemical properties of gypsum and anhydrite, the distribution of gypsum in the United States and Canada, and the mining processes that are used.

Gypsum plasters are classed as follows:

A. Plaster that is produced by incomplete dehydration of gypsum; the calcination is carried on at a temperature not exceeding 400°F.

1. Calcination of pure gypsum, with no foreign materials added either during or after calcination, results in plaster of paris.
2. Calcination of gypsum that contains certain natural impurities, or of calcined pure gypsum to which certain materials that serve to retard the set of the product have been added, results in cement plaster.

B. Plaster that is produced by complete dehydration of gypsum; the calcination is carried on at temperatures exceeding 400°F.

1. Calcination of pure gypsum results in flooring plaster.
2. Calcination, at red heat or over, of gypsum to which certain substances have been added (usually alum or borax) results in hard-finish plaster.

Stucco is almost a synonym for **plaster of paris** except that plaster of paris is more finely ground.

Wall plasters are made by adding a retarder and some type of fiber or hair.

Keene's cement is a hard-finish plaster that is made by "dead burning" gypsum, adding a 10 percent alum solution and recalcining. On addition of water, keene's cement hardens, but more slowly than ordinary plasters.

The report describes the preparation of gypsum, from grinding through calcining, and gives the properties of calcined gypsum. In addition, production figures of gypsum in the United States and Canada are given, as well as a description of gypsum deposits in France, where there are two main areas of production, one in the Paris Basin and the second in southern France. The gypsum in the Paris Basin is in rocks of Oligocene age, which consist of alternating beds of gypsum and clay. Several analyses of gypsum that is produced in Canada, France, and the United States are given.

Crude gypsum is used for pigment filler, land fertilizer, and as a retarder for portland cement. Calcined gypsum is used mainly for wall and other types of plasters.

The report includes maps of the United States and Canada that show the location of the major gypsum deposits.

Eckel, E. C., 1935, Cement resources and lime, gypsum [Muscle Shoals District, Alabama] [abs.]: Alabama Acad. Sci. Jour. Proc., v. 7, p. 35.

Gypsum has been found in the Bangor limestone in small quantities along Estell's Fork, Jackson County, Ala. The deposit is not commercial, though other more extensive deposits might be found in the same horizon.

Eckhart, R. A., 1953, Gypsiferous deposits on Sheep Mountain, Alaska: U.S. Geol. Survey Bull. 989–C, p. 39–61.

Gypsiferous deposits, which are badly fractured and faulted, occur in the layered volcanics of Jurassic age on Sheep Mountain, 90 miles northwest of Anchorage, Alaska. The deposits crop out along the highway, about half way between Palmer and Glen Allen. The gypsum occurs with kaolin, alunite, and quartz as blebs and irregular stringers of soft massive material that cement fragments of the country rock. The gypsum probably was derived from the alteration of volcanic material. Sixty samples of gypsum were assayed that ranged from 2 to 65 percent gypsum. Material that averages 52.2 percent gypsum was obtained by concentration methods. An estimated 658,000 tons of indicated and inferred reserves, which average about 50 percent gypsum, is present.

Evans, G. L., 1946, The Rustler Springs sulphur deposits as a source of fertilizer: Texas Univ. Rept. Inv. 1, 13 p.

The Rustler Springs sulfur deposits occur on the outcrop surface of the Castile formation of Permian age, along the western flank of the Delaware synclinal basin, in eastern Culberson County, and the western part of Reeves County. The Castile formation consists of a thick series of gypsum beds that have weathered to gypsite on the surface. The sulfur occurs in the gypsite-alluvium mantle as acidic earth and as disseminated particles, crystals, or massive bodies associated with selenite, H_2S, and carbonaceous material in cracks and solution openings in the gypsum. The thickness of the gypsite mantle ranges from 2 to 15 feet and changes considerably in short lateral distances, because of the irregular weathering of the underlying gypsum. No sulfur has been found in the unaltered gypsum. The report describes the individual deposits and notes that the sulfur appears to be of considerable value for use as fertilizer. A geologic map of the Rustler Springs district, scale 1 inch=about 16 miles shows the deposits of acidic sulfur earth.

Fairbanks, H. W., 1904, California, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 119–123.

Gypsum is widely distributed in recent gypsiferous clays in the southern part of California. Many of the deposits that have been worked are so impure that the material is useful only in agriculture.

The report includes a map of southern California, scale 1 inch=about 65 miles, which shows the location of the gypsite deposits.

Finlay, G. I., 1916, Description of the Colorado Springs quadrangle [Colorado]: U.S. Geol. Survey Geol. Atlas, Folio 203, p. 1, 7, 15.

The Colorado Springs quadrangle is in the east-central part of Colorado, in parts of El Paso, Fremont, and Teller Counties. Gypsum occurs in the Lykins formation of Permian(?) age, which consists of less than 200 feet of thin-bedded red sandstone, with pinkish-white to white gypsum at the top. The formation crops out in a narrow belt from the north center to about the central part of the quadrangle, and in the south-central part. Gypsum is present along Fountain Creek, near Colorado City, where it is about 20 feet thick, and in Red Creek Valley, in the southwestern part of the quadrangle, where it reaches a maximum thickness of 90 feet.

A geologic map, scale 1:125,000, is included.

Flint, G. M., and Cobb, E. H., 1953, Gypsum deposits near Iyoukeen Cove, Chichagof Island, southeastern Alaska: U.S. Geol. Survey Bull. 989–B, p. 27–37.

Gypsum occurs at Iyoukeen Cove on Chichagof Island, which lies southwest of Juneau in southeastern Alaska. The gypsum was first developed by the Pacific Coast Gypsum Co. in 1902. A considerable amount of underground mining was done between then and 1923; it is estimated that 500,000 tons of gypsum has been produced. The Gypsum-Camel property, which is east of the Pacific Coast Gypsum Co. property, has had no record of production, though some development work has been done.

The gypsum where it can be seen is a translucent fine-grained white rock with included irregular narrow gray bands and is associated with limestone of probable Mississippian age. Several sinkholes and gravel-filled channels occur within the gypsum. Further development of the deposit would have to be done before any estimate of the resources can be made.

The report contains a map of the Iyoukeen Cove area, scale 1 inch=about 2,000 feet, which shows the location of the gypsum deposits.

Freeman, O. W., 1916, Gypsum and lime industry in central Montana: Mining and Eng. World, v. 45, no. 16, p. 663–665.

Gypsum occurs in central Montana in two forms: (a) as selenite crystals in the Bearpaw and Claggett shales of Cretaceous age, and (b) as rock gypsum of Permian, Triassic, and Jurassic age. The latter are the commercial deposits.

The Hanover Gypsum Co. operated a 400-ton mill at Hanover, Fergus County, which is about 7 miles west of Lewistown, on the south flank of the South Moccasin Mountains. The gypsum that crops out near the mill is in two beds: the top bed is 7 to 11 feet thick and is underlain by a thin bed of limestone; below the limestone the second bed of gypsum is 15 to 30 feet thick. A third gypsum bed underlies these two, but this bed has not been explored. The products of the mill are plaster, plaster board, gypsum tile, agricultural gypsum, and retarder for portland cement.

At least 7 million tons of rock gypsum is present at Heath, 10 miles east of Lewistown, Fergus County.

Gypsum crops out at Forest Grove, Fergus County, and in the foothills of the Big Snowy Mountains, in beds that are 20 to 30 feet thick, and exceptionally pure.

Thick beds of gypsum occur near Kibbey, Cascade County. Large deposits of gypsum also occur in eastern Montana and north of the Missouri River, near the Bear Paw Mountains.

Small mills have been operated in Montana at Bridger, Carbon County, and at Armington, southeast of Great Falls.

Frye, J. E., and Schoff, S. L., 1942, Deep-seated solution in the Meade basin and vicinity, Kansas and Oklahoma: Am. Geophys. Union Trans., v. 23, p. 35–39.

Several thousand feet of Permian strata underlie the Meade basin in Meade and Clark Counties, Kans., and Beaver County, Okla. Oil well logs show that considerable thicknesses of salt and anhydrite are interbedded with each other, as well as with shale, siltstones, and fine-grained sandstones, at depths of 500 to more than 1,000 feet below the surface. Sinkholes, in and adjacent to the Meade basin, have resulted from the solution of salt and anhydrite by deep-seated water circulation that was made possible by late Pliocene faults; the sinkholes, therefore, are Pleistocene and Recent in age.

Galbraith, F. W. [1940], Gypsum: Arizona Bur. Mines Circ. 5, 6 p.

Gypsum and gypsite deposits are widely distributed throughout Arizona, though only a few have been developed. The major occurrences of gypsum are as follows:

1. In Cochise County, 5 miles east of Douglas, where a gypsite deposit has been worked for many years. The gypsite contains between 90 and 95 percent gypsum.
2. In Maricopa County, 15 miles south of Gila Bend, where gypsum occurs with celestite.
3. In Navajo County, west of Winslow, two gypsum deposits are present which were worked for several years.
4. In Pima County, gypsum occurs in the Empire Mountains in 3 beds, in the Yeso formation: the upper bed is 20 to 30 feet thick; the middle, which is 275 feet below the upper, is 50 to 60 feet thick; and the lower, which is 395 feet below the middle bed, is about 15 feet thick.
5. Also in Pima County, gypsum occurs on the western slopes of the Santa Rita Mountains in rocks of Permian age. The gypsum is in 2 beds: the upper bed is 10 feet thick, and the lower is 50 to 60 feet thick. The gypsum averages about 95 percent pure.
6. On the northeast flank of the Sierrita Mountains, Pima County, gypsum of about 94 percent purity is in beds that are at least 40 feet thick.
7. About 8 miles northeast of Tucson, Pima County, and about a mile south of Alamo Springs, gypsum occurs in 3 thin beds, which are 1 to 2½ feet thick and are separated by thin layers of shale. Similar deposits have been found near Vail.
8. In Pinal County, along the San Pedro Valley near Feldman, where a bed of white, massive gypsum, 30 feet thick, extends for a distance of 2 or 3 miles along the river. Another and similar deposit of gypsum occurs in a high bluff along the San Pedro River near Redington in the extreme southeast corner of the county.

Gale, H. S., 1951, Geology of the Saline deposits, Bristol Dry Lake, San Bernardino County, California: California Div. Mines Spec. Rept. 13, p. 3, 5–6.

Gypsum occurs in Bristol Dry Lake, in the south-central part of San Bernardino County near Amboy. The deposit is in a bed that is at least 8 feet thick. In some places a thin layer of volcanic ash covers the deposit, and in other places dunelike gypsum has been blown into small drifts across tongues of lava. The cleanest and purest gypsum is a spongy white mass that is granular, coarsely crystalline, and easily broken. There are 1,800 acres of potential gypsum land along the northwest border of the playa.

Gallagher, R. T., 1940, Mineral content of the Bevier coal seam, Boone County, Missouri: Mines Mag., v. 30, no. 11, p. 586, 588, 611.

The Bevier coal seam underlies approximately the northern half of Boone County, Mo., where it occurs in the Cherokee formation of the Des Moines group of Pennsylvanian age. Fine-grained white opaque gypsum occurs in gash veins that are normal to the stratification of the coal. The gypsum probably was formed as the result of oxidation of pyrite, which formed sulfuric acid that acted on calcite to form calcium sulfate.

George, R. D., 1920, Colorado, *in* Stone, R. W., and others, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 87–94.

Gypsum in Colorado occurs mostly in rocks of Permian and Pennsylvanian age, although some workable deposits are found in rocks of Jurassic age. The most accessible deposits occur in Larimer, Jefferson, Douglas, El Paso, and Pueblo Counties. Other deposits are found in Fremont, Custer, Huerfano, and Chaffee Counties, east of the Rocky Mountains; in Rio Blanco, Garfield, Eagle, and Pitkin Counties, in the west-central part of the State; and in Gunnison, Delta, Montrose, San Miguel, and Dolores Counties, in the southwestern part of the State.

Gilbert, G. K., 1890, Lake Bonneville [Utah]: U.S. Geol. Survey Mon. 1, p. 222–223, 320.

In the southeastern part of the Sevier Desert, Utah, gypsum is found in several playas that are partially separated from the general plain by basaltic lava. The streams that flood the playas flow from strata of Jurassic and Triassic age that are highly gypsiferous and redeposit the gypsum in the playas. Part of the gypsum in the playas is amorphous and part is crystalline. One phase of the precipitation results in the formation of small crystals, which are carried by the wind from the surface of the playa and deposited in dunes. The dunes are checked by a low rhyolitic butte known as White Mountain. Estimated gypsum reserves of the dunes are 450,000 tons, and much larger amounts of less pure gypsum can be obtained from the playas. A map, scale about 1 inch = 1½ miles, shows the area of the playa deposits; a map, scale 1:800,000, of Lake Bonneville is also included.

Gildersleeve, Benjamin, 1931, The occurrence of gypsum crystals in the Virginia Eocene: Am. Mineralogist, v. 16, no. 3, p. 104–105.

Crystals of selenite are found between the Potomac and Rappahannock Rivers in the Nanjeonoy formation of Eocene age, which consists of green sand, sands, and clays. The gypsum appears to be restricted to the clays. The prevailing habit is a rosette form, with crystals that range from 1/10 to 1 inch in diameter. They were probably formed by permeating ground waters that contained sulfuric acid, which acted on limestone.

Giles, A. W., and Jones, A. M., 1931, Gypsum in the Fayetteville shale: Oklahoma Acad. Sci. Proc., v. 11, p. 53–60.

The Fayetteville shale of Upper Mississippian (Chester) age ranges from 10 to 400 feet in thickness, and is widely developed in northwestern Arkansas and northeastern Oklahoma. The gypsum is found chiefly in the lower part of the formation; as concentric layers and penetrations of clay ironstone concretions; as grains, stringers, and irregular aggregates in the shale beds; as isolated crystals, thin seams, and lenses of crystals and grains, between the layers of shale; and as white efflorescence on the surfaces of outcrop of the formation.

The origin of the gypsum is attributed to the alteration of calcareous beds and lenses by percolating water that carried in solution sulfuric acid and ferrous sulfate that were derived from the oxidation of pyrite.

Gilluly, James, 1929, Geology and oil and gas prospects of part of the San Rafael Swell, Utah: U.S. Geol. Survey Bull. 806–C, p. 83–86, 92–94, 99–102, 105–117.

The San Rafael Swell in Emery and northern Wayne Counties, Utah, is an area of irregular shape that covers about 1,480 square miles. Gypsum occurs in several formations throughout the swell in beds that range from 6 to 30 feet in thickness. The beds are in the Moenkopi formation of Lower Triassic

age, the lower part of the Carmel formation of Upper Jurassic age, and in the Summerville formation also of Upper Jurassic age. The thickest and most extensive beds are in the Carmel formation.

The report includes geologic sections of the different gypsum-bearing formations and a geologic and structure map, scale 1:126,720, which shows the outcrops of the gypsum-bearing rocks.

Goldman, M. I., 1952, Deformation, metamorphism, and mineralization in gypsum-anhydrite cap rock, Sulfur Salt Dome, Louisiana: Geol. Soc. America Mem. 50, 169 p.

The report is the result of a study of a diamond-drill core through the entire gypsum-anhydrite caprock of the Sulfur Salt Dome, in Louisiana. The anhydrite caprock forms on top of a salt stock by cementation of the anhydrite that was freed from the salt as a result of solution by ground water. The gypsum is formed from alteration of the anhydrite. The report describes, in detail, the minerals that are found in the caprock.

Gould, C. N., 1905, Geology and water resources of Oklahoma: U.S. Geol. Survey Water-Supply Paper 148, p. 17, 39–77, 87–88, 98.

The Gypsum Hills region includes part, or all, of Woods, Woodward, Blaine, Dewey, Day, Canadian, Caddo, Kiowa, Comanche, Greer, Washita, Custer, and Roger Mills Counties, in Oklahoma. Two types of gypsum topography occur: the wall canyon and the round mound. The wall canyon type is found mainly in Blaine, Woods, and Woodward Counties. It is characterized by steep bluffs of red clay that are capped by massive ledges of gypsum. The round-mound type is identified by low, white, and rounded gypsum hills or mounds, which stand on the plain, or by gentle slopes of gypsum along shallow streams. The Blaine and Greer formations of Permian age include massive beds of gypsum. The Blaine formation consists of red shales with interbedded strata of gypsum; the base of the formation is the bottom of the lowest massive gypsum member, the Ferguson gypsum. Above the Ferguson, and separated from it by red shales, is the Medicine Lodge gypsum. The Shimer gypsum, which overlies the Medicine Lodge, and is separated from it by red shales, forms the top of the Blaine formation. The thickness of the gypsum beds is less than 1 foot to about 25 feet. Chemical analyses indicate that the gypsum in these beds averages over 98 percent pure. In some places anhydrite is present within the gypsum bed in surface exposures.

The Greer formation is made up of red clays, shales, and sandstones with intercalated beds of gypsum that are irregular bedded and can rarely be traced as continuous or definite ledges. The beds of gypsum, from the base upward, are called: the Chaney, the Kiser, the Haystock, the Cedar Top, and the Collingsworth. The Haystack, the thickest of the gypsum beds and ledges, ranges in thickness from 18 to 25 feet. The Collingsworth and the Cedar Top have much the same lithology and are only a little thinner, ranging in thickness from 18 to 20 feet.

Reserves of gypsum in Oklahoma, from all beds that are more than 3 feet thick, are estimated to be 125.3 billion tons.

The water which comes from the Blaine and Greer formations is so strongly impregnated with calcium sulfate that in many places it is not palatable. Springs, rising from beneath the gypsum, have dissolved the gypsum in solution and have created many sinks and caves within the gypsum beds.

———— 1906, Geology and water resources of the eastern portion of the Panhandle of Texas: U.S. Geol. Survey Water-Supply Paper 154, 64 p.

The area described in this paper is the eastern part of the Panhandle of Texas, which includes Collingsworth, Wheeler, Donley, and Armstrong Counties. The basal formation exposed is the Greer formation of Permian age; it contains gypsum beds that crop out only in the river canyons. The Greer consists of brick-red shales with ledges of banded white, blue, or pink gypsum that range from 1 to 6 feet in thickness. Within the gypsum beds there are numerous caves and sinkholes, which vary in depth from a few inches to 20 feet and in diameter from 10 to 100 feet. In some places gypsum is missing, having been removed in solution. The report contains a geologic map of the area, scale 1 inch=15 miles.

Gould, C. N., 1907, The geology and water resources of the western portion of the Panhandle of Texas: U.S. Geol. Survey Water-Supply Paper 191, 70 p.

The geology and water resources of the western half of the Texas Panhandle are described. The Greer formation of Permian age, which is the lowest formation exposed, contains gypsum that crops out only in the river bottoms, in Oldham, Potter, and Randell Counties. In Armstrong County, a persistent ledge of gypsum crops out. This ledge is 20 to 50 feet thick, and lies 100 feet or more above the river where it forms the cap of an interriver canyon.

The report contains a geologic map, scale 1 inch=15 miles.

——— 1939, The great White Sands [New Mexico]: Mines Mag. [Colo.], v. 29, no. 7, p. 379–381.

The White Sands are located near the middle of the Tularosa basin, which is an elongated flat valley that is 100 miles long and about 30 miles wide, which extends north from El Paso, Tex., almost to the center of New Mexico. The Sacramento Mountains bound the basin on the east, and the San Andres Mountains bound it on the west. The White Sands occupy an area of about 280 square miles, as dunes, which range from 5 to 60 feet in height and consist almost entirely of grains of gypsum. Two theories are given as to the origin of the sands:

1. The gypsum has been brought to the surface by a seepage of water, which probably was derived from the underlying Chupadera beds and deposited on the surface in crusts. The crusts are crumbled to sand and the gypsum is blown into dunes.
2. The sands are derived from the disintegration of selenite crystals, which form along the shores of a lake that is located near the southwestern margin of the dunes.

Gould, C. N., and Herald, F. A., 1911, Gypsum, *in* Preliminary report on the the structural materials of Oklahoma: Oklahoma Geol. Survey Bull. 5, p. 98–113.

Gypsum or gypsite is found in four general areas in Oklahoma: the Kay County region, the main line of gypsum hills, the second line of gypsum hills, and the Greer County region.

In the central part of Kay County, a number of gypsite deposits occur. The deposits consist principally of soft clays and shales and disseminated gypsum.

The main line of gypsum hills is formed by 2 or 3 ledges of gypsum that are interbedded with red shales. The line of hills extends from Canadian County, northwest through Kingfisher, Blaine, Major, Woods, Harper, and Woodward Counties to the Kansas line. The upper bed, called the Shimer gypsum, is about 15 feet thick. Below it, and separated from it by red shales, is the Medicine Lodge gypsum, which is about 17 feet thick. The Ferguson gypsum is a 4-foot bed, which crops out only in the southern end of the hills, and is the lowest ledge.

The second line of gypsum hills lies parallel to the main line and 50 to 75 miles farther southwest; it extends from the Keechi Hills, in southeastern Caddo County, northwestward through Washita, Custer, Dewey, Roger Mills, and Ellis Counties. There are 2 beds of gypsum, which range from 8 to 18 feet in thickness.

The Greer County region is in the southwest corner of the State in Greer, Harmon, and Jackson Counties, and the southern part of Beckham County. These gypsum beds probably are the same as those that are exposed in the second line of gypsum hills. In the greater part of the area 5 exposed gypsum beds are present, which range in thickness from less than 3 to about 25 feet.

Gypsum mills in operation in 1911 were located at Bickford, Marlow, Okeene, Alva, Watonga (2), Southard, Okarche, Eldorado, Ferguson, and McAlester.

Analyses of gypsum from various ledges indicate that the gypsum is over 95 percent pure.

A geologic sketch map, scale 1 inch = 15 miles, is included.

Green, D. A., 1936, Permian and Pennsylvanian sediments exposed in central and west-central Oklahoma [with discussion]: Am. Assoc. Petroleum Geologists Bull., v. 20, no. 11, p. 1468–1475.

The Permian and Pennsylvanian rocks in central and west-central Oklahoma are described. All the gypsum deposits in this area occur in rocks of Permian age. Most of the gypsum occurs in the Blaine formation and consists generally of 4 beds, except in Canadian County where 5 beds are present. A section measured in Canadian County shows that these beds have a maximum thickness of 32 feet. The names and thicknesses of the beds, from the base upward are: Medicine Lodge, 4 to 7 feet; Alabaster, 3 feet; Shimer, 1 to 13 feet; Lovedale, 1 to 8 feet; Haskew, 0 to 4 feet.

The Marlow formation, which overlies the Blaine formation and is separated from it by the Dog Creek shale, is 120 feet thick and consists of brick-red shales and even-bedded brick-red sandstones with bands of fine white sand and sandy gypsum. A bed of almost pure gypsum, which is about 1 foot thick, occurs at the top of the formation. Gypsum beds are found throughout the Rush Springs sandstone formation (Whitehorse sandstone) and the Cloud Chief member of the Quartermaster formation. Detailed surface sections, which show gradations and relative stratigraphic positions of the sediments in central Oklahoma, are included.

Greene, G. U., 1937, Selenite crystals at Ellsworth, Ohio: Rocks and Minerals, v. 12, no. 9, p. 272–273.

Selenite crystals have been found in blue clay at Ellsworth, Mahoning County, Ohio.

Gregory, H. E., 1950, Geology of eastern Iron County, Utah: Utah Geol. Mineralog. Survey Bull. 37, p. 3, 26–27, 30–37, 40–41, 45–48.

The area covered by this report is in the eastern part of Iron County, Utah. The gypsum within the area occurs as gypsiferous beds in the upper part of the Shnabkaib member of the Moenkopi formation of Triassic age and as beds as much as 60 feet thick in the basal part of the Curtis formation of Jurassic age. The report includes a geologic map of eastern Iron County, scale 1 inch=1 mile.

Gregory, W. M., 1904a, The Alabaster area, *in* Grimsley, G. P., The gypsum of Michigan and the plaster industry: Michigan Geol. Survey, v. 9, pt. 2, p. 60–66.

The Alabaster gypsum area comprises about 600 square miles on Saginaw Bay, on the northwestern side of the Lower Peninsula of Michigan, in parts

of Arenac, Ogemaw, and Iosco Counties. The report discusses the topography and glacial geology of the area. A map of the Alabaster area, scale 1 inch =2 miles, shows the gypsum outcrops.

Gregory, W. M., 1904b, The Paleozoic geological formations of the Alabaster area, *in* Grimsley, G. P., The gypsum of Michigan and the plaster industry: Michigan Geol. Survey, v. 9, pt. 2, p. 66–77.

In the Alabaster area Michigan, gypsum occurs in the Michigan series of Mississippian age. The gypsum is poorly exposed, but probably extends under much of Iosco County and eastern Ogemaw County. It is not uniform in thickness, and in places, it is interstratified with limestone. About 4 miles south of Traverse City, Iosco County, the gypsum bed is 23 feet thick. Gypsum outcrops in Iosco County are found at Alabaster; north of Harmon City; 3 miles east of Prescott; and about 2 miles east of Whittemore. In addition, at Turner, Iosco County, a gypsum bed 15 feet thick has been found at depths of 25 to 50 feet below the surface.

——— 1912, Geological report on Arenac County [Michigan]: Michigan Geol. Survey Pub. 11, ser. 8, p. 16–19, 33–34, 38, 52–59, 132.

Gypsum that occurs in the lower Grand Rapids group of the Michigan series of Mississippian age is exposed only in a few places along the shore of Saginaw Bay, in Arenac County. Gypsum occurs in 2 beds, which are about 30 feet apart in the southern part of the county, and which become nearly 75 feet apart toward the north. Well records indicate that the upper bed of gypsum is covered by 51 feet or more of overburden, and is about 22 feet thick. The lower bed of gypsum is exposed at Alabaster, Iosco County, just north of Arenac County, and averages about 23 feet in thickness.

The gypsum in Arenac County would be difficult to mine because glacial material covers the deposits, though the report indicates that there are two areas where economic deposits of gypsum might be obtained. A geologic map of the county, scale 1 inch = about 1 mile, is included.

Grimsley, G. P., 1897, Gypsum deposits of Kansas: Geol. Soc. America Bull., v. 8, p. 227–240.

Gypsum deposits of Permian age lie in a belt that extends from the northeastern part of Kansas southwestward. The belt, which varies in width from 5 miles at the north end to 14 miles in the central part, and 36 miles near the southern end, is divided into three districts: the northern, or Blue Rapids area, in Marshall County; the central or Gypsum City area, in Dickinson and Saline Counties; and the southern or Medicine Lodge area, in Barber and Comanche Counties.

In the northern district, the gypsum occurs as a mottled gray rock of saccharoidal texture in a bed that is about 8½ feet thick and is underlain by limestone and overlain by blue shale.

Three well-marked beds occur in the central district; the lowest bed is about 3 feet thick, and extends over most of the district; the middle and top beds extend over the southern and central parts of the district. The rock is white with many dark lines. In places, the lower bed contains yellowish selenite crystals which are as much as an inch long and half an inch wide.

In the southern area, gypsum occurs in two beds. The lowest is the Medicine Lodge gypsum, which covers an extensive area in southern Kansas and extends southward into Oklahoma and Texas. Above the Medicine Lodge, and separated from it by 15 feet of red shale, is the Shimer gypsum bed, which is 15 feet thick, and appears to be a local deposit that is found only in the eastern part of Comanche County, Kans.

Several deposits of gypsite are being worked for plaster. A chemical analysis indicates that this material averages from 72.1 to 81.4 percent gypsum.

Grimsley, G. P., 1904a, The gypsum of Michigan and the plaster industry: Michigan Geol. Survey, v. 9, pt. 2, p. 1–60, 77–246.

The report is a general discussion of the gypsum industry that includes a brief description of the distribution of gypsum throughout the world. Gypsum in Michigan occurs in the Michigan group of Mississippian age, which is folded into a broad basin. These rocks consist of shales, thin-bedded limestones, and gypsum beds. Production has come both from Grand Rapids, on the southwest side of the basin, and from Alabaster, on the northeast side.

In St. Ignace, on the northern peninsula of Michigan, gypsum of about 98 percent purity occurs in the Salina formation of Silurian age, in beds that are as much as 60 feet thick. At Rabbits Back, 4 miles north of St. Ignace, gypsum occurs between limestone in beds that are as much as 21 feet thick. The gypsum crops out near and under the water of Lake Michigan.

The report discusses the mines and mills of Michigan and describes various theories of origin and uses of gypsum. Maps of the Grand Rapids and Alabaster areas, scale 1 inch=about 2 miles, show the extent of the gypsum-bearing rocks.

——— 1904b, Kansas, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 53–59.

The gypsum deposits of Kansas consist of extensive beds of rock gypsum and a number of gypsite deposits. The area, in which gypsum is found, is an irregular belt that extends northeast across the State. The belt is divided into 3 parts: the northern, or Blue Rapids area, in Marshall County; the central, or Gypsum City area, in Dickinson and Saline Counties; and the southern, or Medicine Lodge area, in Barber and Comanche Counties.

The report describes the gypsum in each of the three areas and discusses the economic development in the State. A map of Kansas, scale 1 inch=55 miles, shows the outcrops of gypsum rock and gypsite.

——— 1904c, Michigan, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 45–47.

Economic deposits of gypsum occur in two areas in Michigan: near Grand Rapids, Kent County, and at Alabaster, Iosco County. The gypsum occurs in the lower part of the Grand Rapids series, of lower Carboniferous age.

At Grand Rapids, there are 2 beds of gypsum; the upper bed is 6 feet thick and is separated by 1 foot of shale from the lower bed, which is 12 feet thick. Both beds are covered by 10 to 15 feet of shale and a thin cover of gravel. At Grandville, southwest of Grand Rapids, the gypsum that is quarried is 11 feet thick and is covered by 1 foot of shale and 20 feet of gravel. The floor of the quarry is limestone, under which is a 14-foot bed of gypsum.

At Alabaster, the gypsum is 16 to 22 feet thick and is covered by as much as 16 feet of glacial drift.

Gypsum of Silurian age occurs near St. Ignace, Mackinac County, on the Upper Peninsula.

Grimsley, G. P., and Bailey, E. H. S., 1899, Special report on gypsum and gypsum cement plasters: Kansas Univ. Geol. Survey, v. 5, 183 p.

The report is a definitive discussion of the gypsum occurrences in Kansas, which includes a geologic description of the gypsum-bearing rocks and a description of the mines and mills in Kansas.

The report contains an outline map of Kansas, which shows the location of the gypsum and gypsite deposits, and maps of the three main gypsum-producing areas, which show the outcrop pattern of the gypsum-bearing rocks.

Groves, A. W., 1958, Gypsum and anhydrite: London, Overseas Geol. Surveys, Mineral Resource Div., 108 p.

The report describes the properties and uses of gypsum and anhydrite and the occurrence of deposits throughout the world, with special emphasis on those found in the British Isles and Commonwealth Territories. A bibliography of gypsum, with emphasis on uses and world occurrences, is included.

Gutschick, K. A., 1956, Celotex Corporation doubles gypsum plant capacity at Port Clinton [Ohio]: Rock Products, v. 59, no. 11, p. 62–65, 82, 86, 128.

The gypsum that is mined by the Celotex Corp., Port Clinton, Ohio, is mixed with dolomite that must first be separated before the gypsum can be used. The report describes the heavy-media separation plant, in which a mixture of finely ground magnetite and ferrosilicon is used, and the gypsum products fabricating plant.

Ham, W. E., and Curtis, N. M., Jr., 1958, Gypsum in the Weatherford-Clinton district, Oklahoma: Oklahoma Geol. Survey Mineral Rept. 35, 32 p.

The Weatherford-Clinton district covers approximately 59 square miles in southeastern Custer County, Okla., between the town of Weatherford and Clinton. Gypsum and anhydrite occur as lenses and beds throughout the Cloud Chief formation of Permian age; the thickest and best bed is developed near the base of the formation. These evaporites have a maximum thickness of 92 feet; the thickest bed extends from the Weatherford-Clinton district southward to Cloud Chief in Washita County. The evaporites thin westward and northwestward, where they become more clastic. The gypsum, which crops out on the surface, is grayish pink, medium to fine granular, and massive. In places, it has been removed by solution, though it is generally eroded into low hills. The weathered upper surface, which is uneven and very irregular, extends down to a depth of 3 to 10 feet. A series of holes were drilled in the district in order to appraise the gypsum potential of the area. About 1.3 billion short tons of gypsum that ranges from 86.13 to 97.04 percent in purity and averages 91.28 percent is estimated to be available. The anhydrite within the gypsum averages 1.38 percent; the maximum amount is 2.52 percent. The calcium and magnesium carbonates within the gypsum average 5.34 percent, and the silica averages 1.55 percent.

The anhydrite, which underlies the gypsum, occurs over an area of about 10 square miles and averages 21.8 feet thick, at depths ranging from 33 to 68 feet below the surface. It is massive, medium to coarse crystalline, grayish purple, translucent, and compact. About 523 million short tons of anhydrite is estimated to be present within the district.

Proberite, a hydrous sodium-calcium borate mineral, which occurs as white compact nodules that are ¼ to ½ an inch in diameter, is sparsely distributed through the gypsum.

The report contains an areal map, which shows the thickness and purity of the gypsum in the district, scale 1 inch=three-fifths of a mile; a geologic map of the gypsum in the district, scale 1 inch=five-eighths of a mile; and geologic sections that were taken through holes that were drilled for gypsum.

Ham, W. E., Merritt, C. A., and Frederickson, E. A., 1957, Field conference on geology of the Wichita Mountain region in southwestern Oklahoma: Oklahoma Geol. Survey Guide Book, 5, 58 p.

The report describes the stratigraphy of the Precambrian, Cambrian, Ordovician, and Permian rocks of southwestern Oklahoma. According to the classification of the Permian rocks given in this paper, gypsum occurs in the Flowerpot shale, Blaine, and Cloud Chief formations of Permian age. The gypsum in the Flowerpot shale consists of two thin persistent beds near the top of the formation; these are known as the Kiser and the Chaney gypsum members, which were formerly included in the Blaine formation. The Blaine formation consists of four gypsum beds; the upper bed was formerly included in the Dog Creek shale. The gypsum in the Blaine formation becomes more clastic eastward, from southwestern Oklahoma.

The thickest evaporite bed is the gypsum that occurs at or near the base of the Cloud Chief formation of middle or upper Permian age, mostly as a massive white to pink layer with faint lines of stratification. It is best developed in eastern Washita County and southeastern Custer County. Scattered outliers of the Cloud Chief are found in Caddo and Grady Counties, where as much as 50 to 80 feet of gypsum are exposed. On both flanks of the Anadarko basin to the west, the thick gypsum grades into sandstone and shales that contain only a few lentils of gypsum.

Near Weatherford, Caddo County, vast reserves of gypsum occur in the Cloud Chief formation in a bed that is as much as 90 feet thick.

A geologic map of southwestern Oklahoma, scale 1:500,000, is included.

Hardenberg, H. J., and Rosenau, J. C., 1950, Michigan's mineral industries for 1948: Michigan Dept. Conserv. Geol. Survey Div. Pub., p. 9.

In 1948, Michigan ranked first in the production of gypsum in the United States. Iosco County, with 2 quarries, ranked first in the State, and Kent County, with 2 mines, ranked second. The gypsum was used for plaster, wallboard, building materials, and cement retarder. A map, scale 1 inch=50 miles, shows rock and mineral development and mineral industries.

Harder, E. C., 1910, The gypsum deposits of the Palen Mountains, Riverside County, California: U.S. Geol. Survey Bull. 430–F, p. 407–416.

Large gypsum deposits associated with limestone occur in the central part of the Palen Mountains, in an area that is 3 miles long and 1½ miles wide, in Riverside County, Calif. The gypsum consists of fine crystals of selenite, which are one-tenth inch or more in diameter. The individual flakes are colorless and transparent, but the mass is white or slightly cream colored. Some reddish gypsum is present. Included in the gypsum are fine grains of calcium carbonate and anhydrite. In places, the gypsum occurs in beds that are as much as 50 feet thick, which include little or no interbedded limestone; in other places there are thick limestone beds which do not include gypsum. Quartz diorite has intruded the gypsum in some places and has altered it to a white powdered anhydrite.

Chemical analysis of gypsum indicate that it is 80 percent or more pure, the impurities being calcium carbonate and anhydrite. A map, scale 1 inch=75 miles, which shows the location of the gypsum deposits in southeastern San Bernardino and Riverside Counties, is included.

Hartnagel, C. A., and Broughton, J. G., 1951, The mining and quarry industries of New York State, 1937 to 1948: New York State Mus. Bull. 343, p. 39–46.

The gypsum deposits of New York are located within the upper 100 feet of the Camillis formation of upper Silurian age. The outcrop of the gypsum occurs in a belt that extends from Madison County, in the eastern part of the State, to Erie County, in the western part. The higher grade material occurs in the western 50 miles of the outcrop belt in Monroe, Genessee, and

Erie Counties. The gypsum that has been produced in the eastern part of the belt was used mostly as an agricultural mineral and also as a retarder for portland cement. The gypsum that is produced in the western part is used mainly for making plaster and plaster products. About 66 million tons of reserves is estimated to be present in the deposits of Erie, Genessee, and Monroe Counties.

Havard, J. F., 1957, What makes a gypsum deposit economic?: Mining Cong. Jour., v. 43, no. 3, p. 56–58.

The economics of producing gypsum are described. Large companies that own their own mines are the rule; the small independent producer is rare. The cost of raw ground gypsum at the mine ranges from about $1 a ton for low-grade gypsite, which is used in agriculture, to about $12 a ton, for high-grade finely ground sacked gypsum. The average cost for gypsum sold in carload lots, is about $2.50 to $3.50 a ton.

The problems that must be considered in evaluating an economic gypsum deposit include (a) an available market, (b) low mining costs, (c) cheap transportation to point of use, (d) good competitive quality, and (e) adequate tonnage.

Some dangers that must be considered are (a) interstratified impurities, (b) presence of anhydrite, (c) structural problems, and (d) removal of gypsum by subsurface solution.

Haworth, Erasmus, 1920, Kansas, *in* Stone, R. W., and others, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 111–120.

The report briefly describes the three principal gypsum-producing areas in Kansas: Blue Rapids area, Marshall County; central Kansas, between Salina, Saline County, and Hope, Dickenson County, where gypsite also occurs; and south-central Kansas, west of Medicine Lodge in Barber and Comanche Counties. The gypsum in the Blue Rapids area is 8½ feet thick, and lies between 2½ feet of limestone at the base of the bed and red and blue shale at the top. In the central area are two well-marked horizons and possibly a third; the beds are separated by 40 to 100 feet of shale. The lowest bed is the most extensive. Near Medicine Lodge, the gypsum covers a large area. It is massive and compact at the base and sugary at the top. There are two beds of gypsum; the Medicine Lodge gypsum is as much as 30 feet thick and is separated from the overlying bed of the Shimer gypsum by 15 feet of red shale. Much of the gypsum in the south-central area has been removed in solution.

Gypsum crystals are found in the Pennsylvanian shales of southeastern Kansas, in the Cretaceous shale along the Smoky Hill River, and in the Tertiary beds in the southwestern part of the State.

The report contains a map of Kansas, scale 1 inch=52 miles, which shows the location of the gypsum and gypsite deposits.

Henderson, Junius, 1909, The foothills formations of north-central Colorado: Colorado Geol. Survey 1st Rept. for 1908, p. 168–170, 179.

The Lykins formation of Permian and Triassic(?) age is a series of variegated mostly thin-bedded deep-red sandstones and shales that include thin limestone beds. The upper part of the formation is commonly gypsiferous. A thick bed of gypsum is exposed in Owl Canyon, Larimer County; on Sand Creek, Adams County; and at Perry Park, Jefferson County, southwest of Denver. A geologic map, scale 1 inch=4 miles, is included in the report.

Herrick, C. L., 1900, The geology of the White Sands of New Mexico: New Mexico Univ. Bull., v. 2, pt. 3, p. 12–13.

Gypsum of the White Sands is derived from the gypsum beds that occur to the west in the Manzano group of Permian age, where the beds crop out in the San Andres Mountains. The gypsum is brought to the salt flats, at the east base of the mountains, by saline waters and is deposited in ribs. These ribs form successive low ridges that are broken up by the wind. The gypsum is then wind deposited in dunes to the south and east of the salt flats. The dunes consist mostly of pure gypsum, but some earthy impurities are present. The other salts in the flat are more soluble and thus are dissolved out of the dunes. The dunes cover an area about 35 miles long by 6 to 18 miles wide and encompass about 350 square miles.

A sketch map shows the location of the White Sands deposits.

Herrick, H. N., 1904, New Mexico, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 89–99.

Gypsum is widely distributed throughout New Mexico and is associated with red beds of both Permian and Jurassic-Triassic age.

In eastern New Mexico, the gypsum lies principally along the valley of the Pecos River; along the Canadian River; and on the plains west of the Upper Pecos River, in southern Mora County.

In central New Mexico, gypsum occurs along the Rio Grande, in the headwaters of the Puerco Jamez River; east of the Sandia Mountains; and east of the Manzana Mountains.

In northwestern New Mexico red beds containing gypsum occur in the vicinity of Fort Wingate and Gallup.

In Otero County, an area of about 350 square miles is covered by dunes of granular gypsum sands.

A map of New Mexico, scale 1 inch=about 85 miles, shows the outcrops of gypsum-bearing red beds.

Hershey, H. G., and others, 1947, Mineral resources map of Iowa: Iowa Geol. Survey, scale 1:500,000.

All gypsum that is produced in Iowa is in the vicinity of Fort Dodge, Webster County. A deeply buried deposit of undetermined extent was once worked near Centerville, Appanoose County. Other subsurface areas in central Iowa contain a large potential source of gypsum.

Hess, F. L., 1910a, A reconnaissance of the gypsum deposits of California: U.S. Geol. Survey Bull. 413, 33 p.

The report describes the gypsite and gypsum deposits of California. There are four types of deposits: (a) efflorescent deposits, (b) periodic lake deposits, (c) interbedded deposits, and (d) vein deposits. All except the last are considered to be of economic value.

Efflorescent deposits consist of gypsite that averages about 80 to 85 percent gypsum. These deposits are purer at the surface than at depth.

Periodic lake deposits are generally larger and less pure than efflorescent deposits. In California this type of deposit is found mainly in King and Kern Counties.

Interbedded deposits consist of both thick and thin beds of rock gypsum, which generally average 90 percent or more, though a few are composed of very thin stringers that are interbedded with shales. The report briefly describes the deposits and includes a map of southern California, scale 1 inch = about 70 miles, which shows the location of gypsum deposits.

Hess, F. L., 1910b, Gypsum deposits near Cane Springs, Kern County, California: U.S. Geol. Survey Bull. 430–F, p. 417–418.

The gypsite deposits in the vicinity of Cane Springs, Kern County, are as much as 10 feet thick. The material has formed in a closed valley, which receives water that contains calcium sulfate from intermediate streams and forms a periodic lake. The gypsite, which is buff and very fine grained, is located on the south side of the playa. Analysis indicates that it contains about 79 percent gypsum.

________ 1920, California, *in* Stone, R. W., and others, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 58–86.

The gypsum deposits of California are all located south of the San Francisco Bay area. Most of these deposits are gypsite that is associated with Tertiary strata. Rock gypsum occurs in the Palen, Maria, and Avawatz Mountains. This report describes the gypsite and gypsum deposits and lists them by counties.

A map, scale 1 inch = 70 miles, showing the distribution of the gypsum deposits, is included.

Higgins, W. C., 1913, The Nevada Douglas Copper Mining Co.: Salt Lake Mining Rev., v. 14, no. 24, p. 15–16.

Gypsum deposits lie west of the Ludwig copper mine in the Yerington mining district, Lyon County, Nev. The gypsum bed has been developed for a distance of 2,000 feet and a width of 200 feet and has been cut at a depth of 400 feet by a drift from the copper mine. The gypsum, which is used in the manufacture of portland cement, is 96 percent pure.

Higson, G. I., 1951, $CaSO_4$ as a raw material for cement manufacture: Chem. Eng. News, v. 29, no. 43, p. 4469–4474.

Gypsum and anhydrite have been used for many years in making ammonium sulfate, and, more recently, in making sulfuric acid that is accompanied by cement clinker as a byproduct The process used in making ammonium sulfate includes the double decomposition of calcium sulfate and ammonium carbonate, which results in ammonium sulfate and calcium carbonate. Plants that manufacture ammonium sulfate from calcium sulfate include 2 each in Germany and England, 1 each in France and Belgium, and 2 in India.

The manufacture of sulfuric acid with a cement byproduct entails the heating of a mixture of calcium sulfate and carbon in a rotary kiln with sand that contains alumina, silica, and iron oxide. The reaction is roughly represented as:

$$2CaSO_4 + C + xSiO_2, yAl_2O_3, z\,Fe_2O_3 \rightarrow$$
$$2(CaO \cdot xSiO_2 \cdot yAl_2O_3 \cdot zFe_2O_3) + 2SO_2 + CO_2.$$

The SO_2 is converted into sulfuric acid. For each ton of sulfuric acid that is made, 1 ton of cement clinker is produced. Plants that produce sulfuric acid from calcium sulfate include 2 each in Germany and England and 1 in France. One plant, which was scheduled to be built in India, was not completed. Tables that show the comparative costs of the different methods of manufacturing both ammonium sulfate and sulfuric acid are given.

Hill, A. E., 1937, The transition temperature of gypsum to anhydrite: Am Chem. Soc. Jour., v. 59, no. 11, p. 2242–2244.

The solubility of anhydrite was determined, and a solubility curve was developed between the temperatures 20° and 100°C. The curve was compared with a well-authenticated curve for gypsum, and it shows that the transition temperature of gypsum to anhydrite is 42°C.

Hill, B. F., 1904, Texas, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 68–73.

Gypsum was first mentioned in Texas in 1852, by Captain Marcy. In 1904 there were two plants that manufactured gypsum products; both were located at the northern border of the State. The largest area of gypsum lies east of the foot of the Staked Plains in northern Texas. The beds have a northeast strike and extend from the Red River to the Colorado River. These beds are a continuation of the Greer formation in Oklahoma.

In the eastern part of El Paso County, east of the Guadaloupe Mountains, there is an extensive area of gypsum that extends southward from New Mexico. These beds are from 300 to 500 feet thick and contain gypsum in all varieties and in varying degrees of purity. In the Malone Mountains in El Paso County, there are 2 beds of gypsum, which range from 45 to 110 feet in thickness and which are separated by about 175 feet of limestone.

Hill, R. T., 1899, Mineral resources of Porto Rico: U.S. Geol. Survey 20th Ann. Rept., pt. 6 (Continued), p. 774.

Gypsum occurs in yellowish marl, which is extensively exposed along the southern side of the Central Mountains, just north of the village of Juana Diaz; it also occurs in other localities, notably near Ponce. The deposits are impure because they are mixed with sand and clay, but they could be used for making low-grade plaster, for use as a fertilizer, and as stucco.

Holmes, G. H., Jr., 1950, Mining, milling and manufacturing methods at the Blue Diamond Corp.'s gypsum property, Clark County, Nev.: U.S. Bur. Mines Inf. Circ. 7555, 21 p.

The gypsum property of the Blue Diamond Corp. comprises about 4,000 acres near Arden, about 23 miles southwest of Las Vegas, Clark County, Nev. The deposits occur on top of a series of steeply rising hills, along the foothills of the Spring Mountain Range. The gypsum is in 4 beds which are separated by limestone and shale and dip gently westward. The top 2 beds of gypsum range from 4 to 8 feet in thickness and are too thin to be mined. The third gypsum bed ranges in thickness from 12 to 20 feet, and is separated from the bottom gypsum bed by 16 to 33 feet of limestone. The bottom gypsum bed averages 12 to 18 feet in thickness. Mining consists of both open-pit and underground methods; the beds are quarried until the overburden becomes too expensive to move, then underground methods are used until the point is reached where the anhydrite replaces the gypsum. This occurs at a depth of about 100 feet below the surface.

Methods of mining and processing the gypsum are described.

Hoppin, R. A., 1954, Geology of the Palen Mountains gypsum deposit, Riverside County, California: California Div. Mines Spec. Rept. 36, 25 p.

Gypsum occurs in an area of 5 square miles at the north end of the Palen Mountains, Riverside County, Calif. The gypsum is in east-trending bands, which are as much as 150 feet thick, and are interbedded with marble and quartzite of Precambrian or Paleozoic age, and metamorphosed intrusives. The rocks are badly folded and faulted. The gypsum deposits occur as massive beds of fine crystalline material or as thinly laminated gypsiferous and epidotic schist. Little anhydrite appears on the surface, but it probably occurs at depth. Reserves of several hundred million tons are estimated. An index map, scale three-fourths inch=10 miles, and a geologic map, scale 1 inch=800 feet, are included.

Hose, R. K., 1955, Geology of the Crazy Woman Creek area, Johnson County, Wyoming: U.S. Geol. Survey Bull. 1027–B, p. 35, 50–54, 106–108.

The Crazy Woman Creek area lies south of Buffalo, Johnson County, Wyo. The gypsum occurs in red shales of Permian age and the Gypsum Springs formation of Jurassic age. The gypsum that occurs in the beds of Permian age crop out along the eastern edge of the Big Horn Mountains. The upper 150 feet of this formation consists of interbedded gypsum and red siltstone. In places, the gypsum has been leached from the surface. The Chugwater formation of Triassic age overlies the gypsum and shale of Permian age and is, in turn, overlain by the Gypsum Spring formation, which contains as much as 50 feet of limy gypsum with interbedded reddish-brown siltstone and shale in the lower part. Much of the gypsum is leached out, and a thin section of limestone breccia and reddish-brown siltstone, or shale, is left in its place.

Measured stratigraphic sections of the Permian gypsum and shale sequence show that several beds of gypsum are present. These range from less than 1 foot to about 20 feet in thickness, and are separated by red shale, which is 1 foot or more thick. The soft weathered gypsum is predominantly pink with some beds of white.

Hull, W. Q., Schon, Frank, and Zirngibl, Hans, 1957, Sulfuric acid from anhydrite: Indus. Eng. Chemistry, v. 49, no. 8, p. 1204–1214.

The process of making sulfuric acid from calcium sulfate was developed in Germany in 1916. In Great Britain, the first plant of this type was completed in 1920. The known plants are listed:

Location	*Original raw material*	*Capacity*
Germany:		
Leverkusen	Gypsum, anhydrite	40 tons per day, dismantled 1931.
Wolfen	Anhydrite	200,000 tons annually.
France: Miramas	Gypsum	25,000 tons per year; operated until World War II; now shut down.
England:		
Billingham	Anhydrite	175,000 tons per year.
Widnes	do	150,000 tons per year.
Whitehaven	do	100,000 tons per year.
Poland:		
Breslew	do	(?).
Busko		(?).
Zdroi		(?).
Austria: Linz	Anhydrite	45,000 to 50,000 tons per year.

Although a plant for making sulfuric acid from anhydrite or gypsum is expensive, the process is competitive with other processes in countries that have limited sulfur or pyrite deposits.

Coke, anhydrite, and an aluminum-containing material, such as clay, are added together and heated to 1,450°C. The result is sulfuric acid and portland cement clinker.

Sulfuric acid consumption in the United Kingdom has increased 80 percent in the last 20 years to almost 2.5 million long tons of acid per year. The percentage of the acid made from $CaSO_4$ has increased from about 100,000 tons in 1951 to more than 400,000 tons in 1956.

The Solway Chemicals Ltd. in Whitehaven, England, began operations in 1955. The anhydrite deposit is 400 feet deep and 15 to 20 feet thick, and the purity ranges from 88 to 95 percent. The anhydrite is crushed; coke is added to it to reduce the calcium sulfate; then shale is added for cement clinker. The following ratios are used: Anhydrite, 78 to 80 percent; shale, 14 to 15 percent; coke, 6 to 7 percent.

Three reactions take place in the kiln:

1. Reduction of anhydrite by coke:

$$CaSO_4 + 2C \rightarrow 2CO_2 + CaS$$

2. Reaction of calcium sulfate and calcium sulfide, freeing sulfur dioxide gas and forming lime:

$$CaS + 3CaSO_4 \rightarrow 4CaO + 4SO_2$$

3. Direct reaction of calcium sulfate and acidic oxides to give clinker compounds.

The gas is cleaned and cooled and passed into absorbers, which are ceramic-packed towers where sulfuric acid, 98.5 percent pure, and oleum, fuming sulfuric acid, are produced.

The cost of producing a ton of sulfuric acid from anhydrite in a plant that produces 75,000 to 150,000 tons per year, is estimated to be between $84 and $106 at 1953 prices. The ratio between capital costs of anhydrite-sulfuric acid and that of acid from pyrites is about 1.5 to 1.

Imlay, R. W., 1940, Lower Cretaceous and Jurassic formations of southern Arkansas: Arkansas Geol. Survey Inf. Circ. 12, p. 35–36.

The Ferry Lake anhydrite member, which is a part of the Glen Rose limestone formation of the Trinity group of Early Cretaceous age, is found in the subsurface of southern Arkansas, northern Louisiana, and northern Texas. The outcrop of the Ferry Lake anhydrite is expressed by the gypsum in the De Queen limestone of lower Cretaceous age, in Howard and Pike Counties, Ark. The Ferry Lake anhydrite varies in thickness from 2 to 10 feet on the outcrop to about 500 feet in the subsurface. The thickest section is in the southwest corner of Arkansas. The anhydrite is white to dark gray, finely crystalline, thin to thick bedded, locally brecciated, and contains thin limestone lenses. At the base of the member is an anhydrite breccia, which is embedded in a matrix of anhydrite, limestone, and calcareous shale. R. T. Hazzard noted this as a "chicken wire lattice structure" in which individual masses of anhydrite are separated by thin films of calcareous mud. He suggests that this structure was formed by discrete, nearly gelatinous anhydrite masses that settled through muddy waters, at the same time that the mud was settling. Imlay suggests that the "chicken wire lattice structure" was formed by wave action in shallow muddy water before the solidification of the anhydrite. The Ferry Lake anhydrite was formed in a shallow sea that was surrounded by an arid landmass; no barrier to the sea has been found.

Included in the report is a table that shows the correlation of the Trinity group in southern Arkansas, northwest Louisiana, and northeastern Texas.

Inglesby, A. L., 1940, The Utah selenite find: Mineralogist, v. 8, no. 2, p. 50–51.

Several miles east of Fruita, Utah, selenite crystals occur in a mound that is 40 feet high. The crystals, some of which are 1 foot in diameter, are intergrown and piled together at all conceivable angles. The mound is probably in the Summerville formation of Jurassic age. No definite location is given in order to protect the deposit from damage.

Irving, J. D., 1904, Economic resources of the northern Black Hills [South Dakota]: U.S. Geol. Survey Prof. Paper 26, p. 139.

Irregular masses of gypsum, some of which are as much as an inch in diameter, occur in the ores from the Double Standard shoot, between Fantail and Nevada gulches, Lawrence County, S. Dak.

Jamison, C. E., 1911a, Geology and mineral resources of a portion of Fremont County, Wyoming: Wyoming Geol. Survey Bull. 2, Ser. B., p. 34–37, 84–85.

Extensive beds of excellent-quality gypsum are found near the top of the Chugwater formation of Triassic age. The formation consists mainly of red shales and sandstones, but it also contains several thin beds of limestone and, near the top, a thick bed of gypsum. The gypsum bed is 32 feet thick on the Big Popo Agie River; near the Lander Experiment farm the bed is more than 40 feet thick; in the Sage Creek district the bed ranges from 30 to 70 feet in thickness; and on the Little Wind River, an upturned bed of massive gypsum is 61 feet thick. Geologic sections of the formation are given for an area west of Lander, along the Big Popo Agie Canyon; along the Little Wind River, west of Fort Washakie; and on the Little Wind River, half a mile south of Tar Spring.

——— 1911b, Mineral resources of Wyoming: Wyoming Geol. Survey Bull. 1, Ser. B, p. 34–35.

Pure gypsum is found throughout Wyoming in beds that range in thickness from 10 to 100 feet. The deposits occur in the red beds of Triassic age. Plaster mills were in operation in 1911 in Red Buttes and Laramie, Albany County, and one, which had just been completed, at Wyopo, Fremont County. Annual production (1911) from the State was 40 thousand tons.

Jenkins, O. P., 1918, Spotted lakes of epsomite in Washington and British Columbia: Am. Jour. Sci., v. 46, 4th ser., p. 638–644.

Epsom salts ($MgSO_4 \cdot 7H_2O$) have been mined from two "spotted" or briny lakes, one in British Columbia and one in Washington. The lake west of Oroville, Okanogan County, Wash., covers an area of 4 acres; it is 30 feet deep, and lies in a glacial depression with no outlet. The rocks that surround the area are dolomites and shales, which contain some pyrite and pyrrhotite. The epsom salts that occur within the lakes are, in places, as much as 15 feet thick, and are underlain by layers of gypsum. The salts were formed by the oxidation of the pyrite and pyrrhotite, which formed sulfuric acid that acted upon the dolomite and formed magnesium and calcium sulfate.

——— 1938, Geologic map of California: California Dept. Nat. Resources, Div. Geology, scale 1:500,000, 6 sheets.

The map shows the geologic formations of the State.

Jensen, D. E., 1942, Minerals of the Lockport dolomite in the vicinity of Rochester, New York: Rocks and Minerals, v. 17, no. 6, p. 199–203.

Gypsum and anhydrite are found in the Lockport dolomite, in the vicinity of Rochester, Monroe County, N.Y. The calcium sulfate occurs in cavities as crystalline nodules, which are a foot or more in diameter and vary from gray to pale blue. Specimens have been found west of Rochester in dumps along the barge canal and in quarries near Gates. Snowy massive nodules of gypsum that sometime fill the cavities have an anhydrite core, which indicates that the gypsum is formed by alteration of anhydrite.

Selenite crystals are found in quarries east of Rochester in the town of Penfield.

Jermain, G. D., and Rutledge, F. A., 1952, Diamond drilling the Gypsum-Camel prospect, Iyoukeen Cove, Chichagof Island, southeastern Alaska; U.S. Bur. Mines Rept. Inv. 4852, 6 p.

In 1948, the U.S. Bureau of Mines drilled 2 holes in the Gypsum-Camel prospect at Iyoukeen Cove, Chichagof Island southeastern Alaska. The prospect has been developed by 5 adits. The gypsum lies unconformably on a brecciated limestone in a small synclinal basin. The first hole that was drilled cut 3 beds of gypsum which ranged from 2 to 4 feet in thickness; the second hole did not cut gypsum. An analysis of gypsum taken from the adits shows that the material ranges from less than 50 to about 90 percent gypsum and contains some anhydrite. The report includes location maps of the area, and a map of the Gypsum-Camel prospect, scale 1 inch = about 500 feet, which shows the location of the adits and drill holes. Maps and cross sections of the underground workings are also included.

Jewett, J. M., 1942, Gypsum, *in* Jewett, J. M., Schoewe, W. H., and others, Kansas resources for wartime industries: Kansas Geol. Survey Bull. 41, pt. 3, p. 138–144.

In Kansas, workable deposits of gypsum are located in (a) northern Kansas, in the Blue Rapids area, Marshall and eastern Washington Counties, (b) central Kansas, Dickinson, Saline, and Marion Counties, and (c) southern Kansas, Barber and Comanche Counties. Gypsum and gypsite deposits are known in Clay, Sedgwick, Sumner, and Harvey Counties.

Gypsum was first mined in Kansas in 1885 near Hope, Dickinson County. The first mill in southern Kansas was built in 1889.

In northern Kansas in the Blue Rapids area, the gypsum bed averages 8½ feet thick and occurs in the Badger formation of Permian age. The gypsum has a sugary texture and is nearly white. A layer of satin spar occurs above and below the deposit.

In central Kansas, several layers of gypsum occur. The thickest layer, which is about 14 feet, has been mined as much as 80 feet below the surface.

In southern Kansas, the gypsum underlies a considerable part of Barber and Comanche Counties. The Medicine Lodge gypsum member, the lowest of three gypsum beds that occur in the Blaine formation of Permian age, is also the thickest and is 30 feet thick at outcrop. All the beds grade to anhydrite downdip.

An index and a map show the distribution of the gypsum deposits and the location of mills and mines of the three gypsum areas.

Jicha, H. L., Jr., 1952, Gypsum, occurrence, properties, utilization: New Mexico Miner, v. 14, no. 8, p. 12–13, 21–22, 29.

The properties, origin, and uses of gypsum and anhydrite are described. Deposits of both gypsum sands and rock gypsum are found in New Mexico. The gypsum sands, which cover an area of 270 square miles in the Tularosa basin near Alamogordo, were formed by the disintegration of existing deposits of gypsum and anhydrite and were transported and concentrated by wind into dunes. The dunes contain at least 4½ billion tons of gypsum.

A large part of New Mexico is underlain by rock gypsum and anhydrite, which occur in beds that vary in thickness from a few inches to 100 feet. Selenite crystals of exceptional clarity occur in the Rio Puerco Valley near Carlsbad. Bedded gypsum deposits of Permian age are found in the Yeso formation and the San Andres limestone. In southern Otero County, gypsum occurs in the Abo formation of Permian age. Gypsum also occurs in the Todilto limestone of Jurassic age, which locally contains thick beds of gypsum in the northwestern part of the State.

Only a small amount of production of gypsum has been reported from New Mexico. The only mine that was operated in 1949 was near Las Cruces, Dona Ana County. Other areas, from which production has been reported in the past, are in the Pecos Valley, at Acme, Chaves County, and at Oriental, Eddy County. The report includes an index map that shows areal distribution of gypsum deposits in New Mexico.

Jones, D. J., 1953, Gypsum-oölite dunes, Great Salt Lake desert, Utah: Am. Assoc. Petroleum Geologists Bull., v. 37, no. 11, p. 2530–2538.

The report describes a series of dunes that occur on the eastern margin of the Great Salt Lake desert near the town of Knolls, Tooele County, Utah. An analysis of the material, which makes up the dunes, indicates that they consist predominantly of fine to very fine grains of gypsum crystals, calcareous oolites and lesser amounts of shell fragments, algal fragments, and quartz sand. The gypsum makes up about 65 percent of the sand, and the oolites make up about 30 percent.

The gypsum probably originated from selenite crystals, which were formed along the border of the Great Salt Lake, and which were transported by the wind to the present location.

Jones, J. C., 1920, Nevada, *in* Stone, R. W., and others, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 139–160.

In Nevada deposits of gypsum include (a) beds or lenses of rock gypsum that are interstratified with sedimentary rocks; (b) thin beds and seams that occur in lacustrine deposits of Tertiary age; (c) small seams and replacements that occur in mineralized areas, chiefly in altered andesites of Tertiary age; and (d) gypsite deposits. Most of the commercial gypsum deposits are rock gypsum, which, in the western part of the State, are all of Triassic age and occur in large lenses or beds that are included in massive limestone. Areas where these deposits occur are: east of Lovelock and at Table Mountain, Humboldt (now Pershing) County; south of Gerlach, Washoe County; near Ludwig, Lyon County; at Hawthorn, Mineral County; and at Mound House, Ormsby County, where both rock gypsum and gypsite occur.

In the southern part of the State, the gypsum is massive and granular and varies from white to red. Most of the gypsum occurs in Clark County, but there is one deposit near Galt in Lincoln County. The biggest of these deposits is near Arden, where the gypsum ranges from 25 to 80 feet in thickness. Gypsum also occurs near Moapa, which is north of Las Vegas and along the Virgin River.

The report includes a map of Nevada, scale 1 inch = about 80 miles, which shows the location of the gypsum deposits.

Jones, Verner, 1935, Origin of the gypsum deposits near Sandusky, Ohio: Econ. Geology, v. 30, p. 493–501.

The gypsum in Portage Township, Ottawa County, Ohio, occurs in numerous beds and lenses, which are interbedded with dolomitic limestones of the Monroe formation of Silurian age. Deep-well tests show that calcium sulfate underlies an extensive area in northern Ohio. At Cleveland 2 beds of anhydrite, which are associated with salt at depths of 2,154 and 2,300 feet below the surface, have been correlated with the gypsum beds of Portage Township, and probably can be correlated with the gypsum beds in New York and Ontario.

The gypsum that is being mined in Portage Township is in 2 beds; the top one is 5 feet thick and the bottom one is 4 feet thick. They are separated by as much as 2 feet of dolomite. The dolomite appears crumpled, possibly as a result of the alteration of the anhydrite to gypsum.

The gypsum-anhydrite relations in this section show that the contact is a gradational one with the gypsum replacing the anhydrite. From this evidence it is reasoned that the $CaSO_4$ was precipitated as anhydrite in basins of water charged with calcium sulfate, and that the gypsum was formed later by hydration of the anhydrite.

Kansas Geological Survey, 1951, Map showing the mineral resources of Kansas: scale 1:600,000.

The map, scale 1 inch=about 10 miles, shows the location of the gypsum deposits in Kansas.

Kauffman, A. J., Jr., 1952, Industrial Minerals of the Pacific northwest: U.S. Bur. Mines Inf. Circ. 7641, p. 28–30.

In Oregon, gypsum occurs in Baker County, about 5 miles northeast of Huntington; in Crook County, 30 miles east of Bend; in Grant County in the John Day area; in Jackson County, at the Alton or Baron mine; and in Josephine County, in the Galice district.

In Washington, deposits of gypsum have been reported in Yakima, Chelan, Ferry, Okanogan, Pierce, Skamania, Stevens, Lincoln, and Spokane Counties. Only in Okanogan County is gypsite mined.

In Idaho, gypsum has been reported from Custer, Butte, Clear Lake [sic.], Lemhi, and Washington Counties. Only in Washington County, near Weiser has any deposit been developed. Extensive high-grade deposits have been examined in Lemhi and Bear Lake Counties.

In Montana, gypsum has been reported from Meagher, Jefferson, Madison, Big Horn, Beaverhead, Cascade, Judith Basin, Ellis [sic], Fergus, Park, and Carbon Counties. Deposits have been developed in Carbon and Fergus Counties. In Cascade County, gypsum occurs on the north flank of the Little Belt Mountains, southeast of Great Falls; in Big Horn County, on the flanks of the Big Horn Mountains; in Beaverhead County, 10 miles west of Lima; in Deer Lodge County, near Limespur, 40 miles east of Butte; and in Meagher County, gypsum occurs 4 miles from Lingshire.

Kay, G. F., 1915, A new gypsum deposit in Iowa: U.S. Geol. Survey Bull. 580–E, p. 59–64.

In 1910, a gypsum deposit was discovered in the southern part of Iowa near Centerville, Appanoose County, by the Scandinavian Coal Co. This deposit occurs in rocks of Mississippian age, at a depth of 542 to 547 feet below the surface. Overlying the gypsum is a 5-foot bed of anhydrite that is overlain by limestone. The gypsum is resting on 2 to 3 feet of buff dolomitic limestone. A hole, which was drilled 1,700 feet northwest of the discovery hole, cut 19 feet of gypsum at a depth of 572 feet.

In 1913, a shaft was sunk to the gypsum, but large quantities of artesian water entered it so that, at the time of this report, the shaft had not been completed.

The gypsum recovered in the drill cores is white, saccharoidal, and friable. Some selenite crystals are associated with the rock gypsum. Analyses indicate that the gypsum ranges from 98 to 99 percent pure.

Kelley, K. K., Southard, J. C., and Anderson, C. T., 1941, Thermodynamic properties of gypsum and its dehydration products: U.S. Bur. Mines Tech. Paper 625, 73 p.

The system $CaSO_4$—H_2O is found to have six substances: one $CaSo_4 \cdot 2H_2O$; two $CaSO_4 \cdot \frac{1}{2}H_2O$; two soluble $CaSO_4$; and one insoluble $CaSO_4$. The two hemihydrates have been described as the stable form (alpha) and the metastable form (beta). Alpha-hemihydrate may be prepared from the dihydrate in the presence of liquid water that is above 97°C, or in a saturated-steam atmosphere. Beta-hemihydrate may be formed from the dihydrate by dissociation in a vacuum, or in a nearly dry atmosphere, at about 100°C.

The two forms of soluble $CaSO_4$ are related to the hemihydrates. They have been labeled alpha and beta. The alpha soluble anhydrite contains almost no water, and is made by heating alpha-hemihydrate in a vacuum at 100°C. Beta soluble anhydrite is made by dissociation of beta hemihydrate in a vacuum at 100°C, or by nearly complete calcination of gypsum at about 200°C. The beta-anhydrite always contains a few tenths percent of water.

The heats of rehydration of the five dehydrated products have been determined, along with specific heats and dissociation vapor-pressure measurements of the six substances. The results of these observations lead to a set of thermodynamic relationships, which are consistent with the data already developed in the literature and explain some of the discrepancies heretofore encountered.

Kelley, V. C., and Silver, Caswell, 1952, Geology of the Caballo Mountains [New Mexico]: New Mexico Univ. Pub. 4, p. 102–103, 210–211, 213–215.

The Caballo Mountains are a northward-trending range in southern New Mexico, along the east side of the Rio Grande Valley. Gypsum occurs throughout the Yeso formation, but is more abundant in the upper part; it also occurs to a lesser extent in the overlying San Andreas formation. Both formations are of Permian age. The gypsum in the Yeso, which ranges from a few feet to more than 30 feet in thickness, is mostly white, but contains some greenish and reddish shades. It is fine to coarse crystalline and is generally irregularly laminated with thin partings of dark clay or limestone. Gypsum occurs, only locally, as thick lenses in the San Andreas formation.

The report contains a geologic map of the Caballo Mountains, scale 1:63,360.

King, P. B., 1948, Geology of the southern Guadalupe Mountains, Texas: U.S. Geol. Survey Prof. Paper 215, p. 89–91.

The Castile formation wedges out against the Guadalupe and Delaware Mountains in Texas, and thickens eastward. The formation is dominantly anhydrite bearing in the subsurface and gypsum bearing on the surface. It crops out in a broad plain covered with gypsite masses between the Guadalupe and Delaware Mountains on the west and the Rustler Hills on the east. The gypsum is cavernous and contains abundant sinkholes which are, in places, up to a mile in diameter. The gypsum that is exposed on the surface is banded, crenulated and contorted, and badly weathered. The Salado formation, or upper part of the Castile, is mostly salt. The Castile anhydrite is marked by thin, light and dark laminae, made up of pure anhydrite alternating with strongly bituminous and calcareous anhydritic material. Some limestone beds occur within the Castile formation.

King, R. H., 1947, Sedimentation in Permian Castile Sea: Am. Assoc. Petroleum Geologists Bull., v. 31, no. 3, p. 470–477.

The Permian Castile formation of west Texas and southeast New Mexico consists predominantly of laminated anhydrite but contains some calcite, massive anhydrite, and halite. Two problems are considered: (a) the scarcity of salt in the formation, which is present in insignificant quantity in comparison with the amount of anhydrite present; and (b) the original composition of the calcium sulfate whether it was gypsum or anhydrite.

The Castile formation was deposited in the Delaware basin of west Texas. Communication of the basin with the open sea was maintained through a shallow channel at the southwest corner so that fresh sea water could enter to replace that which had been evaporated from the basin.

In the Castile formation the ratio of sodium chloride to calcium sulfate is less than 1 to 1, whereas in normal ocean water, the ratio is 30 to 1. The lack of salt in the Castile formation, is attributed to the cessation of the precipitation of salts when the specific gravity of the water that was being evaporated reached 1.21. This is the density at which sodium chloride is precipitated, and is achieved when 90 percent of the original water is evaporated. The residue which was saturated with sodium chloride was returned to the sea by overflowing the barrier or by percolating through it. Therefore, the reflux would have been 10 percent of the original water or inflow. The height and composition of the barrier are unknown.

The duration of the deposition of the Castile formation, assuming that each lamina represents a year's deposition, was about 300 thousand years. The varves average 1.63 mm thick. This amounts to evaporation of 9.5 feet of water a year, which is equivalent to the evaporation that takes place in west Texas now.

If the temperature at the time of deposition of the salts was above 42°C, anhydrite would have been precipitated. If the temperature was 30°C or less, gypsum would have been precipitated until concentration of the brine became about 4.8 times that of normal sea water and the specific gravity became 1.11; then anhydrite would have been deposited. It is probable that most, if not all, the calcium was precipitated as anhydrite.

Kinney, D. M., 1948, Gypsum and anhydrite, *in* Weisenborn, A. E. ed., Geological resources of the Trinity River tributary area in Oklahoma and Texas: Texas Univ., Bur. Econ. Geology Pub. 4824, p. 100–104.

The properties of gypsum and anhydrite and their uses are described. In the Trinity River tributary area, gypsum is of Permian age and occurs in beds that crop out from Woods County, Okla., on the Oklahoma-Kansas border, to the Colorado River in Coke County, Tex., which is a distance of about 400 miles. The outcrop of the gypsum beds continues northward into Kansas. South of the Colorado River, the beds are covered by younger rocks. The beds of gypsum thicken and thin in the outcrop area and in some places are missing.

Anhydrite which contains a little gypsum, occurs in the Trinity and Fredrick groups of Cretaceous age, and is found in several wells that penetrated these formations in northeast Texas. The Ferry Lake anhydrite is found in wells in east Texas. Anhydrite also occurs in salt dome caprocks. The operating companies in the area are listed, and it is noted that there are 125 billion tons of gypsum and anhydrite in Oklahoma. A sketch map shows the location of gypsum-bearing formations.

Knappen, R. S., and Moulton, G. F., 1931, Geology and mineral resources of parts of Carbon, Big Horn, Yellowstone, and Stillwater Counties, Montana: U.S. Geol. Survey Bull. 822–A, p. 9, 14–20, 67.

Gypsum occurs interbedded with red shales in the Chugwater formation of Triassic age, in beds that range from less than 1 inch to about 35 feet in thickness. The thickest bed is near the top of the formation. The upper part of this bed is characteristically a white granular gypsum that shows no impurities in hand specimen, but the basal part contains some red clay. Overlying the Chugwater is the Sundance formation of Jurassic age which also contains gypsum in beds that are 1 foot or less in thickness.

From 1897 to 1904 a plaster mill was operated in Montana in sec. 18, T. 7 S., R. 24 E., with gypsum that was derived from the upper part of the Chugwater formation. The distance from transportation and fuel made the enterprise unprofitable. The report indicates a large reserve is present. A geologic and structure map, scale 1:125,000, shows the outcrop of the Chugwater formation.

Knight, W. C., 1904a, The gypsum deposits of Laramie Plains, Wyoming: Franklin Inst. Jour., v. 157, no. 1, p. 74–75.

Gypsum occurs either as rock gypsum or gypsite in the Laramie Plains, Wyo. The rock gypsum beds are in the basal part of the sequence, and range in thickness from 6 to 50 feet. The beds dip west at an angle of less than 10°. At Red Buttes, south of Laramie, gypsum is quarried from a bed that is 6 to 10 feet thick.

The gypsite occurs in the undrained depressions below the red beds and thus it is scattered along the entire length of the Laramie Plains. Each of the gypsite deposits generally cover an area of several acres and are as much as 9 feet thick. For many years both gypsum and gypsite have been used at Laramie for making plaster.

——— 1904b, Wyoming *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 79–85.

Economic deposits of gypsum are confined to red beds, which have been considered Triassic in age. Some of the red beds in the southeastern part of the State are probably Permian in age. About 1,500 miles of outcrop of gypsum-bearing rocks are exposed in the State, in beds ranging from 5 to 50 feet in thickness. Besides rock gypsum, beds of gypsite, which are derived from the weathering of the rock gypsum deposits, are present.

In the Laramie Mountains, gypsum beds have been traced along the outcrop for a distance of more than 50 miles northward from the Colorado State line, and thence northwestward for an additional 25 miles. Beds on the west side of the mountains are as much as 50 feet thick, and nowhere along this outcrop are the beds too thin to work. The gypsum is in beds that are horizontal or are dipping slightly to the west. On the east side of the Laramie Mountains, the beds are steeply dipping and, although some gypsum has been found, none is of economic importance.

In the Medicine Bow Mountains, extensive beds of gypsum are found on the northern flank. Gypsum is also found around the Rawlins uplift, where it occurs in the Freezeout Hills; at the western base of the Shirley Mountains; in the Seminole, Ferris, Rattle Snake, Big Horn, Owl Creek, Absoroka, Prior, Wind River, and Gros Ventre Mountains; in the Salt Creek Range; and around the edge of the Black Hills.

A map, scale 1 inch=65 miles, shows the outcrop pattern of the red beds.

Kroenlein, G. A., 1939, Salt, potash, and anhydrite in Castile formation of southeast New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 23, no. 11, p. 1682–1693.

In early Castile (Permian) time, the Delaware basin was an abrupt deep, lying lower than the top of the Capitan reef. It was a partially closed basin which was 1,800 to 2,000 feet deep, and was connected with the sea to the south. The inflow of marine water was less than the rate of evaporation, and, consequently, evaporites were deposited. The lower Castile reaches a thickness of 2,000 feet, and is composed of laminated anhydrite, white anhydrite, and halite. The anhydrite laminae, which are considered to have been deposited in an annual cycle, indicate that it would have taken about 300,000 years to deposit the laminated part of the formation.

The lower part of the Castile formation accumulated during a period of predominantly anhydrite deposition whereas the upper Castile formed in a period that was predominantly one of halite deposition. It is difficult to separate the upper and lower parts of the formation, because of the irregular lenses of anhydrite that occur in the upper Castile.

The Rustler formation, which overlies the Castile, grades from the upper part of the Castile without a break in the Delaware basin. Most of the Rustler is anhydrite, but it also contains lesser amounts of gray and red clay, red sand, and dolomite. The Rustler beds lap over the underlying Castile at its margins. The period was closed by deposition of clastic material, which resulted from the invasion of terrestrial waters carrying fine clay and silt.

Kruger, H. A., Hamilton, W. J., and Enriguez, E. W., 1910, Geology of the Perry Park syncline [Colorado]: Colorado School Mines Bull. 5, no. 2, p. 90–94, 98–99.

A gypsum bed, 30 to 40 feet thick, crops out along the southern slope of a hogback of Permian and Lower Jurassic rocks in Perry Park, Douglas County, Colo., about 5 miles west of the Larkspur railroad station. The upper 5 to 10 feet of the gypsum bed is massive crystalline, and slightly stained by iron. The lower 20 to 30 feet appears to be impure. A chemical analysis of the top part of the bed indicates that it contains gypsum that is 96 percent pure.

Krumbein, W. C., 1951, Occurrence and lithologic associations of evaporites in the United States: Jour. Sed. Petrology, v. 21, no. 2, p. 63–81.

Evaporite deposits occur in rocks of every geologic system from Ordovician through Tertiary. There are four major stratigraphic aspects in which evaporites occur: (a) normal marine sediments above and below the evaporite, (b) marine beds below the evaporite and red beds above, (c) red beds below and normal marine above, and (d) within a red-bed sequence.

Examples of the first sequence are the Ordovician evaporites of the Williston basin; the Silurian evaporites of the Williston and Michigan basins; the Devonian evaporites in the Williston, Iowa, and Michigan basins; the Mississippian evaporites in the Michigan and Illinois basins; and the Cretaceous evaporites in Florida. Examples of the second sequence include the Mississippian evaporites in central Montana, the Amsden-Minnelusa evaporites in the Black Hills of Wyoming and South Dakota, and the Jurassic and Cretaceous evaporites in parts of the Gulf Coast region. Examples of the third sequence include the Silurian evaporites in New York, the Pennsylvanian evaporites in the Paradox basin in Utah and Colorado, the Permian evaporites of east-central Montana, and the Cretaceous evaporites in Florida. Examples of the fourth sequence include the Devonian and Mississippian evaporites of southwestern Montana; the Permian evaporites in Kansas, Oklahoma, and the Black Hills of South Dakota and Wyoming; and the Triassic evaporites of eastern Wyoming.

The report describes the evaporite occurrences and contains maps of the United States, which show the rocks of each geologic system, and the areal extent of the evaporites in each geologic system. A brief discussion of the origin of evaporites is also included.

It is concluded that since evaporites are so widespread geologically, there is no need for "general aridity" to be present during the formation of evaporites in any geologic period. Rather the implication is that "tectono-environmental" conditions for evaporites were of common occurrence, and the evaporites fit into the climate periods of any geologic time as a normally expected phenomena. Evaporites, and their specific lithologic associations, represent deposits that cut across elements of the tectonic framework, and, as such, they show different relations whether they occur on shelves, in intracratonic basins, or in miogeosynclines. Evaporites apparently are absent in typical eugeosynclines. The deposits that developed in basins upon the cratons are the most typical and are by far the most volumetrically important.

Kulstad, R. O., Fairchild, Paul, and McGregor, Duncan, 1956, Gypsum in Kansas: Kansas State Geol. Survey Bull. 113, 110 p.

In Kansas, all the gypsum deposits are found in rocks of Permian age, which crop out in a band that extends from Marshall County, near the northern border of the State, southward to Barber and Comanche Counties, and from there, into Oklahoma. Gypsum occurs in three areas: the southern or Medicine Lodge area, which includes Barber and Comanche Counties where gypsum occurs in the Blaine formation; in central Kansas where gypsum occurs in the Wellington formation; and in the Blue Rapids area, northern Kansas, where gypsum occurs in the Easly Creek shale.

In the southern area, gypsum is mined near Sun City, from the Medicine Lodge gypsum of the Blaine formation, which is found on the surface in much of Barber and Comanche Counties. The bed has a maximum thickness of 30 feet.

In the central part of the State, the Wellington formation, which is stratigraphically lower than the Blaine, contains salt, gypsum, and anhydrite. The formation is exposed in few places on the surface, mostly in Saline and Dickinson Counties. Gypsum has been mined from this area in the past, but there is no production at present.

In Blue Rapids, Marshall County, gypsum is being mined from the Easly Creek shale, which is stratigraphically lower than the Wellington formation. The gypsum here is about 8 feet thick. Other gypsum and anhydrite deposits are found in the Day Creek dolomite at the top of the Permian sequence, in the Stone Corral dolomite of the lower part of middle Permian age, and in the Oaks shale member of the Hamlin shale of lower Permian age.

The report contains maps that show the outcrops of the Blaine gypsum and the Wellington formation scale 1 inch=about 1½ miles, geologic sections of the Wellington formation, and large-scale maps of the mines at Sun City and at Blue Rapids.

Ladoo, R. B., and Myers, W. M., 1951, Nonmetallic minerals: New York, McGraw-Hill Book Co., Inc., 2d ed., p. 259–272.

A general description of the composition, physical properties, occurrence, mining, milling, calcination, and utilization of gypsum is given. The report also includes a table of gypsum analyses from the major deposits in the United States and tables that show the production of gypsum and gypsum products from 1944 to 1946.

Lakes, Arthur, 1899, Gypsum and clay: Mines and Minerals, v. 20, no. 5, p. 227–229.

West of Loveland, Larimer County, Colo., gypsum occurs in a gray granular massive bed, between thin beds of siliceous limestone and red marl of Jurassic age, which lie on the top of a low arch in the main axis of an anticlinal fold. The gypsum that is exposed in the quarry is 250 feet long and 28 feet thick, and thins to 7 feet at the edges. The gypsum is fractured, and some of the fractures are filled with red clay. The overburden is 18 inches thick.

The gypsum, which is 99.5 percent pure, is used for making a variety of plaster products, such as stucco, dental, molding, and cement plaster. The mining and processing of the gypsum are discussed. A sketch shows the ridges and uplifted strata and the location of the gypsum deposit.

Lakes, Arthur, 1904, Colorado, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 86–88.

In Colorado, economic deposits of gypsum crop out at intervals along the entire eastern front of the Rocky Mountains. In addition, there are several deposits scattered throughout the State that could be economic.

Gypsum has been mined at Loveland, Larimer County; Morrison, Jefferson County; Perry Park, Douglas County; near Colorado Springs, El Paso County; and Canon City, Fremont County.

Gypsum deposits of commercial grade and size are known at Gypsum, Eagle County, and in Montrose, Delta, and San Miguel Counties. The deposits on the eastern foothills of the Rocky Mountains are probably of Jurassic and Triassic age, and those in the west-central part of the State are of Carboniferous age.

Landes, K. K., 1937, Mineral resources of Kansas counties: Kansas Geol. Survey Mineral Resources Circ. 6, p. 8, 21, 27, 58.

Gypsum occurs in Barber, Comanche, Dickinson, and Marshall Counties, Kans. In the southwestern part of Barber County, gypsum is mined south of Sun City from beds of Permian age and is shipped about 20 miles east to Medicine Lodge for processing. Large tonnages of gypsum are available in a belt that extends from southwest Barber County, about 12 miles northwestward along the valley of Salt Fork Creek, into southeastern Comanche County.

Gypsum occurs in southern and western Dickinson County in 2 beds; the upper bed is about 5 feet thick, and the lower is about 14 feet thick. The gypsum deposits have been exploited at Hope and Solomon, Dickinson County, but in recent years, no production has been reported from these localities. South of Blue Rapids, Marshall County, gypsum was mined (1937) by the Certainteed Products Corp. The gypsum is near the upper part of the Big Blue series of Permian age.

Lang, W. B., 1937, The Permian formations of the Pecos Valley of New Mexico and Texas: Am. Assoc. Petroleum Geologist Bull., v. 21, no. 7, p. 833–898.

The report classifies the Permian rocks of west Texas and southeast New Mexico. These include gypsum-bearing rocks, which occur from the Delaware basin eastward into the main Permian basin. A tentative correlation is made with the Permian rocks of northern Texas and Oklahoma.

Larrabee, D. M., Clabaugh, S. E., Griffitts, W. R., and others, 1947, Map showing construction materials and nonmetallic mineral resources of Colorado: U.S. Geol. Survey Missouri Basin Studies Map 10, scale 1:500,000.

In Colorado, gypsum is found near the base of the Lykins formation of Permian(?) age, along the front of the Rocky Mountains, and as far south as Colorado Springs. The gypsum deposit at Coaldale, Fremont County, is probably of Permian age. Large deposits of white to pink, gray, and dark-gray gypsum and gypsiferous shale of Permian age occur along the Eagle, Grand, and White Rivers and their tributaries in Rio Blanco, Garfield, Eagle, and Pitkin Counties. Gypsum-bearing rocks occur along the canyon of the Gunnison River in Delta and Montrose Counties and in the salt anticlines in Montrose and San Miguel Counties. In the Rico Mountains, gypsum is found at the base of the Hermosa formation of Pennsylvanian age. Near Pueblo, two deposits of gypsite were formed from the weathering of older bedded deposits.

Alabaster occurs in beds of rock gypsum in Larimer County. A deposit of nodular gypsum, which is interstratified with minor amounts of shale, has been reported to occur 7 miles north of Ouray, Ouray County, in a bed that is 50 feet thick and extends 150 to 200 feet along the strike.

Larsen, E. S. [1923], Microscopic examination of raw or calcined gypsum, *in* Iowa Geol. Survey Ann. Repts. for 1917 and 1918, v. 28, p. 392–399.

In raw gypsum, the minerals that are found generally include gypsum, quartz, anhydrite, calcite, and clay. When calcined, the gypsum becomes hemihydrate or soluble or insoluble anhydrite. Some lime and calcium hydroxide may be formed from the calcite, and the clay may be dehydrated. The physical and optical characteristics of each mineral are described in the report.

Several methods of estimating the amount of anhydrite and other minerals either in a thin section or in a powdered sample are given. The simplest method of estimating the content of a sample is as follows:

1. Place a small amount of powder of the material in question on a glass slide.
2. Add a drop of oil that has a refractive index of about 1.550.
3. Cover the specimen with a cover glass and place it on a microscope stage.
4. Shade one side of the field.

All grains of gypsum will show a bright border on the shaded side and a dark border on the bright side; the anhydrite on the contrary will show a dark border toward the shaded side; the quartz grains will have bluish-white borders on the shaded side; and the clay will be cloudy with dark-gray borders. The calcite grains will have strong birefringence, perfect cleavages, and will disappear when the stage is revolved under crossed nicols. Most grains of anhydrite will show bright interference colors between crossed nicols. An estimation can be made of the number of grains of each mineral.

Lee, W. T., 1908, Geologic reconnaissance of a part of western Arizona, with notes on the igneous rocks of western Arizona, by Albert Johannsen: U.S. Geol. Survey Bull. 352, p. 36.

Between Temple Bar and Boulder Canyon on the Colorado River, which is a distance of about 12 miles, the Colorado River crosses the old debris-filled valley which, on the south side of the river, is known as Detrital-Sacramento Valley and, on the north side, as the Valley of the Virgin. The filling of the valley is apparently composed of two distinct formations. The older one consists of alternating layers of sand and clay and contains extensive beds of gypsum, and salt. The gypsum and gypsiferous clays are conspicuously exposed over a large area along the river.

A topographic and geologic map of a part of western Arizona, scale 1 inch = 18 miles, is included.

Lee, W. T., and Girty, G. H., 1909, The Manzano group of the Rio Grande valley, New Mexico: U.S. Geol. Survey Bull. 389, p. 14–30.

In the Manzano group of Pennsylvanian age, the Yeso formation consists of alternating strata of gypsum, shale, friable sandstone, and earthy limestone. The beds vary greatly in both lateral and vertical extent, and no stratum can be traced for any great distance.

Generalized sections of the Yeso formation, which were taken along the Rio Grande from Santa Fe southward to Dona Ana County, N. Mex., show that the gypsum ranges from about 100 feet in thickness in the Sandia Mountains in the north to about 150 feet in Mesa del Yeso south of Socorro. In Dona Ana County, at least 4 beds of gypsum are present, which range from about 10 feet to more than 150 feet in thickness and which are separated from each other by shales and sandstones.

The gypsum in the Yeso formation is generally white to blue, but some is pink. Included within the gypsum, are beds of shales, sandstones, and fossiliferous limestones.

Lees, J. H., 1919, Some features of the Fort Dodge [Iowa] gypsum: Iowa Acad. Sci. Proc. for 1918, v. 25, p. 587–597.

Underlying the gypsum at Fort Dodge, Iowa, is a basal conglomerate that contains fossils of Pennsylvanian or Permian age, which show that the gypsum is Pennsylvanian or later in age. The surface of the gypsum has been eroded and is remarkably irregular. Glacial drift covers the gypsum, which indicates that erosion of the gypsum took place before the Pleistocene.

In areas that have been cleared of overburden, some of the gypsum is seen to have been arched and to have formed a number of hollow domes. The walls of the domes are 6 inches to 1 foot thick. The age and cause of the doming are unknown.

Leininger, R. K., Conley, R. F., and Bundy, W. M., 1957, Rapid conversion of anhydrite to gypsum [abs.]: Indus. Eng. Chemistry, v. 49, no. 5, p. 818–821.

Detailed studies that were made of the influence on the rate of hydration of anhydrite to gypsum included (a) particle size of anhydrite, (b) seeding, (c) ratio of solid to liquid, (d) activation, (e) temperature, (f) agitation, (g) time, and (h) washing. The processes that have been developed for altering anhydrite to gypsum commercially so far are too expensive and time consuming. For this series of experiments, the anhydrite was obtained from the deposits in southwestern Indiana.

It is concluded that the following process can be used for rapid conversion of anhydrite to gypsum. Finely ground anhydrite, which contains a minor amount of gypsum, is mixed as a slurry in a water solution of an alkali sulfate. The slurry should contain from 10 to 50 percent or more solid anhydrite at the beginning of conversion. The solution may be 0.5 to 0.75 modulus sodium sulfate or 0.5 to 1.0 modulus potassium sulfate, saturated with respect to calcium sulfate. The temperature should be held at 30°C. After agitating for from 1 to 7 hours, the slurry is filtered, and the cake is washed with water or saturated calcium sulfate solution.

Lenhart, W. B., 1950a, Akron [New York] plant [National Gypsum Co.]: Rock Products, v. 53, no. 12, p. 107.

The Akron, N. Y., plant of the National Gypsum Co. formerly received its rock from underground operations near the plant, but now (1950) all the rock is trucked about 15 miles from Clarence Center. This plant uses 2 rotary kilns for calcining that have a combined capacity of 25 tons per hour. The gypsum is made into plaster, wallboard, and lath.

________ 1950b, Baltimore [Maryland] plant [National Gypsum Co.]: Rock Products, v. 53, no. 12, p. 102–103.

The Baltimore plant, the newest of the National Gypsum Co., receives waterborne rock from Nova Scotia (1950). To tide over the winter months, storage facilities are provided for 200,000 tons of rock. The plant has four 16-ton capacity kettles, which, when operating on a 2-hour cycle, will turn out about 750 tons of stucco in 24 hours. The products of this plant are wallboard, lath, and plaster.

Lenhart, W. B., 1950c, Clarence Center [New York] gypsum plant [National Gypsum Co.] : Rock Products, v. 53, no. 12, p. 98–102.

At Clarence Center, N. Y., gypsum is mined by "room and pillar" system from a 3½- to 4½-foot bed of gypsum which is interbedded between beds of limestone.

The rock is blasted and loaded into shuttle cars and taken to mine cars, which take the gypsum to the primary crusher. After it is crushed, the rock is taken by bucket to the surface where it is further crushed and ground and delivered to 5 coal-fired calcining kettles, which are 10 feet in diameter and 13 feet high. The stucco from the calciners is sent to storage, and from there it is packaged for plaster or for use in wallboard manufacture.

________ 1950d, Fort Dodge [Iowa] plant [National Gypsum Co.]: Rock Products, v. 53, no. 12, p. 107.

The National Gypsum Co. plant at Fort Dodge, Iowa, gets its gypsum from open-quarry operations. One of the problems in mining the gypsum is stripping the overburden, which is as much as 20 feet thick in some parts of the quarry. There are four calcining kettles in the present plant, and a fifth is being added.

________ 1950e, Medicine Lodge [Kansas] plant [National Gypsum Co.]: Rock Products, v. 53, no. 12, p. 106.

The National Gypsum Co. plant at Medicine Lodge, Kans., was formerly owned and operated by the Best Brothers Keene Cement Co. Keene's cement is still the main product (1950), but soon the plant will make wallboard, lath, and plaster. Keene's cement is used for making artificial bathroom tile, artificial marble, colored stucco, filler in fine papers, and also is used extensively in the rubber and drug industries.

The rock is mined and crushed 26 miles from the plant. At the plant, the rock is crushed again before processing, and then sent to 3 rotary kilns for calcining. The wallboard plant will be supplied by two 16-ton capacity kettles, which on a 2-hour calcining cycle will turn out 400 tons of stucco in 24 hours. The wallboard will be made on a 560 foot long belt and will be dried in a natural gas-fired dryer.

________ 1950f, National City [Michigan] plant [National Gypsum Co.]: Rock Products, v. 53, no. 12, p. 107.

The National Gypsum Co. plant at National City, Mich., is an open-pit operation. Stripping is extensive, and it is estimated that 2,150,000 cubic yards of overburden was removed in the period 1940–50. The plant has five calcining kettles. The products of the plant are wallboard, lath, and plaster.

________ 1950g, New York City (Bronx) [New York] plant [National Gypsum Co.]: Rock Products, v. 53, no. 12, p. 105.

The New York City (Bronx) plant of National Gypsum Co., which is one of the company's largest, has five large kettles. The plant receives rock from Nova Scotia, which it stores under cover.

________ 1950h, Portsmouth [New Hampshire] plant [National Gypsum Co.]: Rock Products, v. 53, no. 12, p. 107.

The Portsmouth, N. H., plant of the National Gypsum Co. is a two-kettle plant with rock-drying facilities and a wallboard and gypsum lath plant. The rock is shipped from Nova Scotia and is separated into gray and white rock. Specialty plasters that are made from the pure white rock are a featured product of the plant.

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Lenhart, W. B., 1950i, Savannah [Georgia] plant [National Gypsum Co.]: Rock Products, v. 53, no. 12, p. 104–105.

The plant at Savannah, Ga., is the most southerly of the Atlantic Coastal plants of the National Gypsum Co., and serves the building industry of the southeast. The rock comes from Nova Scotia; outdoor storage space for a 190,000-ton stockpile is provided for use when shipments are suspended during the winter. In the plant are four 16-ton capacity oil-fired kettles. The product of the plant is plaster, wallboard, and lath. The belt on which the wallboard and lath is made is 600 feet long, and on it can be made board that is as much as 4 feet wide, or 3 strips of gypsum lath. The longest board that is made is about 12 feet.

——— 1950j, Rotan [Texas] plant [National Gypsum Co.]: Rock Products, v. 53, no. 12, p. 106–107.

The Rotan, Tex., plant of the National Gypsum Co. has five kettles, and is the only plant of the company which uses gypsite as well as gypsum for making plaster products. The gypsum is used primarily for board products and some white plaster products, and the gypsite is used for the other plaster products.

Lincoln, G. L., 1930, Quarrying and milling gypsum: Eng. Mining Jour., v. 129, no. 4, p. 181–184.

The gypsum deposit at Alabaster, about 60 miles north of Bay City, Mich., supplies gypsum to plants at East Chicago, Ind., and at Detroit, Mich., for manufacturing various types of plasters, wallboard, tile, lath, and other gypsum products. The gypsum bed is very thick and has a 15- to 45-foot overburden of clay and shale. The raw material is transported by water to the plants. The mining and processing of the gypsum are described.

Lindgren, Waldemar, 1901, The gold belt of the Blue Mountains of Oregon: U.S. Geol. Survey 22d Ann. Rept., p. 639–640, 753.

Gypsum of Triassic(?) age occurs about 6 miles north of Huntington, Oreg., near the summit of a ridge that overlooks the Snake River Canyon. The gypsum, as exposed in the mine of the Oregon Plaster Co., is about 20 feet thick. It rests upon slate and limestone and underlies red and green tuffaceous slate. About 80 feet higher up, is another bed of gypsum which is 30 to 40 feet thick. The gypsum is, in part, pure white and crystalline, but contains thin streaks and films of greenish chloritic material. The Oregon Plaster Co. produced 1,800 tons of rock in 1896 and several hundred tons of plaster of paris in 1899 and 1900. A geologic and locality map, scale 1 inch=about 7 miles, is included.

Lintner, E. J., 1937, Methods and costs of mining and crushing gypsum at the mine of the Victor Plaster, Inc., Victor, N. Y.: U.S. Bur. Mines Inf. Circ. 6967, 18 p.

The mine and plant of the Victor Plaster, Inc., are about 2 miles northeast of Victor, Ontario County, N. Y. The gypsum is in the Salina formation of Silurian age, in regularly stratified elongate lenses, which are a few inches to as much as 6 feet thick. The gypsum bed at Victor is 6 feet thick and lies 110 feet beneath the surface. It is massive, hard, fine grained, and brownish-gray, and is overlain by a thin seam of gray dolomite. Development is accomplished by a 4-compartment vertical shaft and a room-and-pillar system of mining.

The report describes the mining methods used and discusses all phases of extracting and processing the rock. Cost and production figures are given.

A location map of New York State, which shows the outcrop of the Salina formation, is included.

Lippard, T. R., 1949, Gypsum *in* Industrial Rocks and Minerals: New York, Am. Inst. Mining Metall. Engineers, 2d ed., p. 436–444.

A brief description of the properties of gypsum is given, and mining and milling practices that are used in calcining and finishing gypsum products are reviewed. The report includes a section on the price structure of the finished gypsum products.

Lloyd, A. M., and Thompson, W. C., 1929, Correlation of Permian outcrops on eastern side of West Texas basin: Am. Assoc. Petroleum Geologists Bull., v. 13, no. 8, p. 945–956.

The report includes a geologic map, scale 1 inch=about 16 miles, which The gypsum-bearing Double Mountain group of upper Permian age crops out in a narrow band in north-central Texas, from the Red River southward to Taylor and Nolan Counties. This group consists, from the bottom upward, of the San Angelo, Blaine, Whitehorse, and Cloud Chief formations. The upper three contain the gypsum, which is interbedded with red shale and thin dolomite beds. These beds dip west and are covered by younger beds to the south and west.

The report includes a geologic map, scale 1 inch=about 16 miles, which shows the outcrop pattern of gypsum and dolomite beds.

Logan, C. A., Braun, L. T., and Vernon, J. W., 1951, Mines and mineral resources of Fresno County, California: California Jour. Mines and Geology, v. 47, no. 3, p. 504–506.

The report describes the location and geology of the gypsite deposits in Fresno County. A map, scale 1 inch=6 miles, shows the location of the gypsite deposits.

Longwell, C. R., 1928, Geology of the Muddy Mountains, Nevada, with a section through the Virgin Range to the Grand Wash Cliffs, Arizona: U.S. Geol. Survey Bull. 798, p. 1, 19, 38–52, 74–89.

The gypsum in the Muddy Mountains, in the eastern part of Clark County, Nev., occurs in four formations: the Supai formation of Pennsylvanian age, the Kaibab limestone of Permian age, the Moenkopi formation of Triassic age, and the Horse Spring formation of Tertiary(?) age. In addition, red gypsiferous shales occur in the Chinle formation of Triassic age. The gypsum in the Supai occurs near the top of the formation, and is massive, porous, and interbedded with red gypsiferous shale. In the Kaibab, the gypsum occurs as massive beds that are interbedded with red gypsiferous shales in the middle of the formation. The gypsum in the Moenkopi formation is in thin-bedded to massive lenses. A geologic section, which was measured in Horse Spring Valley, shows that, near the base of the formation, there are zones in which white massive gypsum occurs interbedded with clay and limestone. These zones are as much as 150 feet thick, with individual beds of gypsum which are as much as 25 feet thick. Gypsum in the Horse Spring formation is associated with clay, sandstone, and volcanic tuff.

The report includes stratigraphic sections of each of the formations, as well as geologic sections, and a geologic map, scale 1 inch=about 4 miles.

———— 1936, Geology of the Boulder reservoir floor, Arizona-Nevada: Geol. Soc. America Bull., v. 47, no. 9, p. 1393–1476.

The report describes the gypsum in the Muddy Creek formation of Pliocene(?) age. The gypsum occurs in several washes in both Arizona and

Nevada; these include the Virgin River-Detrital Wash basin, and Callville basin. The Detrital Wash basin area is now known as Bonelli Landing on Lake Mead. The gypsum is white on weathered outcrop, but becomes anhydritic where it is newly exposed in canyons. Some salt is present, but whether the salt is mixed with the gypsum is not known. Impurities in the gypsum include volcanic ash. The gypsum beds grade east and south into cream and buff silt and clay beds.

Louderback, G. D., 1903, Some gypsum deposits of northwestern Nevada [abs.]: Jour. Geology, v. 11, p. 99.

A gypsum deposit occurs about 7 miles south of Virginia City, Storey County, Nev. The main body has a surface exposure that is more than 100 yards wide and 150 yards long, and is enclosed in limestone walls. It is a milk-white holocrystalline granular aggregate which averages more than 90 percent pure. Some soft secondary earthy gypsum occurs at the surface of the deposit and along a gully that drains the area.

Another large deposit which is interstratified with limestone and quartzite occurs in the Humboldt Range, 5 miles east of Lovelock, Pershing County. The surface exposures of these rocks are 300 yards or more wide, and are composed mostly of pure gypsum; the thickest gypsum bed is about 150 feet thick. Both deposits are probably of Middle or Late Triassic age.

Love, J. D., 1939, Geology along the southern margin of the Absaroka Range, Wyoming: Geol. Soc. America Spec. Paper 20, 134 p.

The Absaroka Range covers an area of about 430 square miles in northwestern Wyoming and includes the southern margin of the Absaroka Range, the western end of the Owl Creek Mountains, and the northwestern part of the Wind River basin, which are all in Fremont County. Gypsum occurs in the Gypsum Spring member of Chugwater formation of Triassic age, and is interbedded with lesser amounts of red shale and white limestone.

Specific locations in which the gypsum occurs are given. A geologic map, scale 1 inch=about 1¼ miles, is included.

Love, J. D., Tourtelot, H. A., Johnson, C. O., and others, 1945, Stratigraphic sections and thickness maps of Jurassic rocks in central Wyoming: U.S. Geol. Survey Oil and Gas Inv. Prelim. [OC] Chart 14.

Stratigraphic sections and thickness maps of Jurassic rocks in central Wyoming, which include the gypsum-bearing Gypsum Spring formation, are given.

Love, J. D., Weitz, J. L., and Hose, R. K., 1955, Geologic map of Wyoming: U.S. Geol. Survey, scale 1:500,000.

Geologic formations of the State are shown.

Luoma, W. E., 1946, Mineral collecting in northern Michigan: Rocks and Minerals, v. 21, no. 10, p. 664–665.

Some collector's specimens of gypsum were found at the Quincy mine in Hancock, Houghton County, Mich.

Lupton, C. T., 1913, Gypsum along the west flank of the San Rafael Swell, Utah: U.S. Geol. Survey Bull. 530–N, p. 221–231.

The San Rafael Swell is a dome that is 60 to 80 miles long and 20 to 30 miles wide, and is located east of the Wasatch Plateau and west of Green River. The area is accessible from Price, Utah, by wagon road. The gypsum deposits are in the Upper Jurassic red beds, which crop out on the west flank of the swell, in 2 gypsum-bearing zones that are separated by about 950 feet

of red shale and sandstone. The gypsum in the upper zone, which generally crops out in cliffs, is reddish and averages about 10 feet thick. The gypsum in the lower zone averages about 30 feet thick and crops out in a monoclinal valley in a broad belt along the flank of the swell. In places, beds that overlie the gypsum are contorted and deformed, due probably to the removal of portions of the underlying gypsum in solution by ground water.

A detailed description of localities is given. Chemical assays of the gypsum from these localities average about 98 percent. The upper beds contain an estimated 2.4 billion tons of gypsum and the lower, about 7.3 billion tons.

Lupton, C. T., and Condit, D. D., 1916, Gypsum in the southern part of the Big Horn Mountains, Wyoming: U.S. Geol. Survey Bull. 640–H, p. 139–157.

In the southern part of the Big Horn Mountains, in parts of Washaki, Johnson, Big Horn, and Hot Springs Counties, Wyo., gypsum occurs as beds in the Chugwater and Embar formations. The gypsum on the west side of the mountains is thicker and better exposed than that on the east side. The deposits in the Chugwater are thicker than those in the Embar, but the purity of the gypsum in the 2 formations averages 95 percent or more. The report describes deposits at Stucco, Graybull, and Hyattville in Big Horn County; at Tensleep and Big Trails, Washakie County; and east of Thermopolis, Hot Springs County. In addition, the report gives geologic sections, which were measured in the gypsum around the Big Horn Mountains. A map of the southern part of the Big Horn Mountains, scale 1 inch = 15 miles, shows the outcrops of the gypsum-bearing formations.

McAnally, S. G., 1930, Regulation of setting time, changes caused by hotpit storage, effects of bin storage, devices for preventing kettle leaks, kettle peculiarities: Rock Products, v. 33, no. 21, p. 46–48.

The setting time of most calcined gypsum finished products is regulated at the mill. Generally the higher the grade of the gypsum, the slower the plaster sets, because nearly all the impurities that occur in gypsum accelerate the setting time. Fine-ground gypsum produces a slower setting plaster than does a coarsely ground gypsum. Calcined gypsum attains its maximum setting time when calcined between 320° and 360°F. Higher temperatures produce quicker sets. Letting calcined gypsum stand in a hot pit or a storage bin for any length of time quickens the setting time of plaster, though this reaction is less in a storage bin than in a hot pit, mainly because of the lower temperature in the storage bin. Another, and probably the chief cause of quick set of plaster is leaky kettle gates, which let raw gypsum into the hot pit. The report describes methods of preventing kettle leaks.

——— 1931a, The physical testing of gypsum products: Rock Products, v. 34, no. 15, p. 54–56.

The testing of gypsum products, including the testing of the consistency and the setting time, is described.

——— 1931b, The chemical analyses of gypsum: Rock Products, v. 34, no. 12, p. 66–67.

Laboratory determinations are made on raw and calcined gypsum for combined water, calcium carbonate, and sulfur trioxide. To determine the combined water in raw gypsum, finely grind a portion of the sample and dry it in a closed oven for 1 hour at 155°F or 2 hours at 135°F. Heat 1 gram of the dried sample in a crucible for 4 hours at 500°F, or 2 hours at 600°F, or 1 hour at 700°F. Cool and weigh the sample for loss of combined water.

The amount of anhydrite in a sample is determined by finding the amount of SO_3 present and determining the amount of combined water present. Tables are given for converting the combined water content to the gypsum content: this information is used to determine the percentage of anhydrite in a gypsum sample.

McAnally, S. G., 1931c, The manufacture of keene's cement: Rock Products, v. 34, no. 8, p. 47–49.

Keene's cement is made by calcining lump gypsum to a red heat (between 600° and 1,300°F) and grinding it; the calcined material is then treated with a 10-percent solution of alum and recalcined to a red heat again. The result is a hard-finish plaster. Heating is slow; 4 to 5 days are required for calcining a 100-ton batch.

Uncalcined anhydrite can be used to make a hard plaster according to the formula: uncalcined anhydrite, finely pulverized, 1,000 parts; potassium sulphate, finely pulverized, 5 parts; zinc sulphate, finely pulverized, 5 parts; and dehydrated alum, finely pulverized, 5 parts. Anhydrous sodium sulphate can be used in place of the dehydrated alum.

——— 1931d, Retarders and accelerators and their action on plaster and stuccos: Rock Products, v. 34, no. 4, p. 37–39.

Various ingredients that can be added to gypsum to change its properties are: retarders to slow setting time, accelerators to increase setting time, admixtures to increase surface hardness, and colors to tint the plaster. Retarders that have been used include gums, starch, borax, molasses, sugar, and glue. In general use today, is a commercial retarder that is made from the refuse from stockyards. The ordinary setting time of stucco is about 30 minutes. The addition of 7 pounds of retarder to 1 ton of stucco increases the ordinary setting time to 29 hours.

Accelerators increase the set of plaster considerably. The addition of 8 to 12 pounds of dry raw gypsum to 1 ton of cold plaster will decrease the set of the plaster from 20 to 5 minutes. Sodium chloride and sodium sulfate can also be used as accelerators.

Manganese sulfate, some soluble borates and barium hydrate, among other additives, increase the strength and hardness of plasters.

Colored plasters are prepared by mixing the pigments with the dry plaster.

——— 1931e, Mixing of gypsum and the making of special plasters: Rock Products, v. 34, no. 6, p. 56–58.

The process of plaster grinding and mixing stucco with the retarder, accelerator, or other additives are discussed. Special plasters require different methods of finishing. Most plasters, including hardwall, finishing, casting, molding, and dental plasters, use gypsum that has only been calcined once. Finishing plasters contain 1 to 2 pounds of retarder and some hydrated lime is mixed in for a smooth interior wall; the setting time varies from 1 to 3 hours. Dental plaster is fine ground, white, and sets in about 5 minutes. Some hardwall plasters have fibers that have been added along with 2 to 3 parts of sand to 1 part of plaster. Fine dry sand will cause the plaster to set quicker than coarse wet sand.

McCormack, J. T., 1926, Experiments on the dehydration of gypsum: Jour. Geology, v. 34, no. 5, p. 429–433.

The primary deposition of both gypsum and anhydrite in nature has been established. However, some beds pass from gypsum to anhydrite at depth, posing the question of whether the bed was originally laid down as gypsum and subsequently changed to anhydrite by the pressure, or whether the bed was originally anhydrite and subsequently transformed to gypsum by ground water.

Experiments with gypsum under pressure were tried, with pressures that ranged from 600 to 316,000 pounds per square inch. Additional experiments were tried with pressure and heat and with heat alone. The results show that heat causes the gypsum to lose water of crystallization, where as pressures have no apparent effect on the composition of gypsum. Therefore, pressures have no effect in the alteration of gypsum to anhydrite.

McDivitt, J. F., 1952, A report on gypsum deposits in Washington County, Idaho: Idaho Bur. Mines and Geology Pamph. 93, 15 p.

In Idaho, gypsum deposits occur along the Snake River, about 30 miles northwest of Weiser, Washington County. The deposits of gypsum appear as banded lenses, which are as much as 30 feet thick. The quality of the gypsum varies and is purest in the center of the lenses; green chloritic material occurs scattered throughout the gypsum. The gypsum is faulted and contorted; consequently, a complete section of the gypsum could not be measured. The gypsum lies on chlorite schist and is overlain by limestone. Reserves are estimated at about 300,000 tons. The gypsum was possibly formed by the action of sulfur waters of limestone.

An additional deposit of gypsum is found about 8 miles to the northeast near Mineral, Idaho.

Location maps, scale 1 inch = 4 miles and 1 inch = 2,000 feet, are included.

MacDonald, G. J. F., 1953, Anhydrite-gypsum equilibrium relations: Am. Jour. Science, v. 251, no. 12, p. 884–898.

The system $CaSO_4 \cdot H_2O$ has six solid phases, each having distinct thermodynamic properties. These are: $CaSO_4 \cdot 2H_2O$ (gypsum), two polymorphs of $CaSO_4 \cdot \frac{1}{2}H_2O$, two polymorphs of soluble $CaSO_4$, and one unsoluble $CaSO_4$ (anhydrite). Soluble $CaSO_4$ and $CaSO_4 \cdot \frac{1}{2}H_2O$ are rare in nature and are found mainly in the calcining process of gypsum. The mineral bassanite may have the formula $CaSO_4 \cdot \frac{1}{2}H_2O$.

At a temperature of 40°C, gypsum, anhydrite, and pure water can coexist at 1 atmosphere total pressure. Below 40°C gypsum is the stable phase, and above 40°C, anhydrite is the stable form in the presence of water. An increase in total pressure will favor the formation of gypsum. In a buried deposit, a pressure on the liquid phase lowers the dehydration temperature 1° for every 39.45 bars. At a pressure of 500 bars, the dehydration temperature is 27°C.

If the water is not pure but contains 5 moles of sodium chloride, gypsum is in equilibrium with anhydrite at 21°C. At temperatures below 21°C, gypsum is the stable form. The higher the amount of salt in solution, the lower the transition temperature is between gypsum and anhydrite. Also, in a 1.9 molar solution of sodium chloride, the slope of the curve of different pressures acting on the liquid and solid phases is 42.4 bars per degree.

Sea water contains about 1.26 grams of calcium sulfate in 1,000 grams. In an environment of saturation, where the sea water has a chlorinity of 65 per thousand, gypsum will precipitate out of sea water below 34°C, and anhydrite will precepitate above 34°C. Pressure has little effect on this temperature. As an example, the following history is given: At 25°C, salts are concentrated until the chlorinity reaches 65 per thousand; at this point gypsum is precipitated and continues to be precipitated until the chlorinity reaches 119 per thousand; whereupon anhydrite is precipitated. In addition, gypsum that is in contact with sea water of chlorinity above 113 per thousand will be unstable and break down to anhydrite. In saturated NaCl solutions, gypsum will precipitate only at temperatures below 14°C. The maximum depth at which gypsum will be found is controlled by the temperature gradient over a region, the composition of pure water, and the ratio of hydrostatic to lithostatic pressure. In salt dome caprocks, this depth is between 1,360 and 2,000 feet below the surface.

McGregor, D. J., 1952, Geology of the gypsum deposits near Sun City, Barber County, Kansas [abs.]: Geol. Soc. America Bull., v. 63, no. 12, pt. 2, p. 1277–1278.

About 4 square miles, in the vicinity of the Pioneer Mine, Sun City, Barber County, Kans., were mapped to determine the relationship between gypsum and anhydrite in the Medicine Lodge gypsum of lower Permian age. The gypsum bed dips regionally to the southwest at the rate of 11 feet per mile; a few irregularities occur in the dip. Anhydrite is not present on the outcrop but is exposed in the mine as a lenticular deposit, which is about 10 feet above the base of the gypsum, and which is about 30 feet thick. Where the anhydrite is absent, solution channels are generally present within the gypsum. These channels are zones of brecciation in which the gypsum is soft, porous, and sugary.

Petrographic studies show (a) gradation of anhydrite to gypsum, (b) gypsum fracture filling in the anhydrite, (c) absence of anhydrite in the gypsum bed, and (d) no evidence of distortion within the gypsum.

———— 1954, Gypsum and anhydrite deposits in southwestern Indiana: Indiana Dept. Conserv., Geol. Survey Prog. Rept. 8, 24 p.

In southwestern Indiana, gypsum occurs in an evaporite unit in the lower part of the St. Louis limestone of Mississippian age. The top of the unit is drawn on a lithologic break which occurs in the middle of the St. Louis limestone, and the base is on the Salem limestone. An isopach map, scale 1:500,000, which shows the thickness of the evaporite unit, and an isopleth map, scale 1:500,000, which shows percent of evaporites in the evaporite unit, are included. These maps show three major intrasilled basins where the maximum accumulations of evaporites are found: (a) in southwestern Orange County, northern Spencer County, Perry County, and southwestern Crawford County; (b) in central and western Martin County and eastern Daviess County; and (c) in northern Greene County, southwestern Owen County, and southern Clay County.

McKee, E. D., 1938, The environment and history of the Toroweap and Kaibab formations of northern Arizona and southern Utah: Carnegie Inst. Washington Pub. 492, p. 17–22, 35, 50–51, 121–126.

Gypsum is common in certain parts of the Kaibab and the underlying Toroweap formations, both of which are Permian in age. The Kaibab formation contains gypsum in northwest Arizona and southwest Utah. The Toroweap formation is divided into three members: the upper, middle, and lower. Gypsum is reported in the upper and lower members, and crops out in northwest Arizona (Mohave County), southwest Utah (Washington County), and southeastern Nevada (Clark County). The upper member represents a time of receding seas, and the lower, a time of advancing seas. The gypsum deposits have been examined in only two places: in the vicinity of Havasu Canyon, Ariz.; and north of Wolfe Hole, near the Arizona-Utah boundary. The gypsum shows great lateral variation both in thickness and composition. In comparatively short distances, the gypsum varies from dense, hard, white material to a coarse soft sacchroidal type, in beds that range from 1 foot to about 4 feet in thickness. Included in the beds are breccias that consist of angular fragments of limestone and gypsum.

The gypsum probably was formed as a result of evaporation of sea water, either in inland seas or in arms of the ocean. The report describes the deposition of gypsum along the fringe of the Gulf of Mexico and in Lake Karabugas, on the eastern side of the Caspian Sea.

Included in the report are measured geologic sections and a map scale 1 inch = about 50 miles, which shows the locations of these sections, as well as maps, scale about 1 inch = 100 miles, which show outcrops of the members of the Toroweap and Kaibab formations.

Mansfield, G. R., 1927, Geography, geology, and mineral resources of part of southeastern Idaho: U.S. Geol. Survey Prof. Paper 152, p. 348–349.

Gypsum that occurs in the Wells formation of Pennsylvanian age is found in the SW½SW¼ sec. 32, T. 12 S., R. 45 E., and in the adjoining part of sec. 5, T. 13 S., R. 45 E. The deposit is about 1,000 feet above the bottom of Montpelier Canyon and about 3½ miles east of Montpelier, Bear Lake County. The gypsum overlies a yellowish-red porous breccia and underlies a reddish-yellow sugary sandstone. The gypsum, which is quite pure in places, is sugary and massive to thin bedded; it ranges from 1 to 20 feet in thickness. A geologic map of the Montpelier quadrangle, scale 1:125,000, is included.

Mapel, W. J., and Bergendahl, M. H., 1956, Gypsum Spring formation, northwestern Black Hills, Wyoming and South Dakota: Am. Assoc. Petroleum Geologists, v. 40, no. 2, p. 84–93.

The Gypsum Spring formation of Middle Jurassic age crops out sporadically for about 150 miles along the western and northern flanks of the Black Hills in northeastern Wyoming, near Spearfish, and along Redwater Creek in west-central South Dakota. The formation ranges from 15 to 125 feet in thickness. The thickest section is about 10 miles northwest of Hulett, Wyo., but the formation thins rapidly toward the south. Where the formation is thickest, it can be divided into two members: the lower member, which contains about 75 feet of interbedded white gypsum, in beds that are as much as 10 feet thick, and reddish-brown claystone; and the upper member, which consists of light-gray limestone and gray or red claystone. In thinner sections, the upper member is not present.

Unconformably underlying the Gypsum Spring formation is the Spearfish formation, which consists of red mudstone and thick gypsum beds.

Several geologic sections of the Gypsum Spring formation are given.

Martin, H. M., Compiler, 1936, The centennial geological map of the northern peninsula of Michigan [and] The centennial geological map of the southern peninsula of Michigan: Michigan Dept. Conserv., Geol. Survey Div. Pub. 39, Geol. Ser. 33, scale 1:500,000.

The maps show the geologic formations of Michigan.

Masson, P. H., 1956, An occurrence of gypsum in southwest Texas: Jour. Sed. Petrology, v. 25, no. 1, p. 72–77.

Crystals and rosettes of selenite have been found in mudflats along the edges of the Laguna Madre, on the southeast coast of Texas. On the surface of the mudflat, crystals of gypsum, which are 0.5 mm long are mixed with algal fibers, clay, and fine calcite. At a depth of several feet, layers of nearly pure gypsum, thin beds of gypsiferous clay or individual selenite crystals are present. Rosettes of crystals, which were about 20 inches in diameter, have been dredged from a depth of 20 feet. The dominant crystal forms are $(\bar{1}11)$ and $(\bar{1}02)$. The gypsum originated by precipitation from highly saline sea water, which periodically moves in windblown sheets across the mudflats, evaporating and depositing the gypsum. The gypsiferous waters sink into the underlying sediments and enlarge the gypsum crystals at depth.

Meinzer, O. E., and Hare, R. F., 1915, Geology and water resources of Tularosa Basin, New Mexico: U.S. Geol. Survey Water-Supply Paper 343, p. 11, 44–45, 57–60, 65, 69–71, 160–161.

The Tularosa Basin includes parts of Otero, Lincoln, Dona Ana, and Socorro Counties, and covers an area of about 6,000 square miles. Within the basin, are dunes that are made up entirely of gypsum sands, the largest of which rises more than 50 feet above the surrounding plains. The dunes cover an area of 270 square miles. The gypsum sands are derived from an alkali flat to the west of the dunes. The floor of the flat is covered with gypsum crystals that were deposited by ground waters. Wind winnows out the impurities and concentrates the gypsum into dunes.

Gypsum has also been brought into the interior of the Tularosa Basin by surface and ground waters which carry, in solution, the gypsum that is derived from the Manzano group of Pennsylvanian age in the mountains to the west. The gypsum in the basin, as seen in wells or outcrops, shows the following stratigraphic sequence from the surface: (a) Gypsite, (b) massive rock gypsum from 1 to several feet thick, (c) soft homogeneous gypsum ranging in thickness from about 5 to 10 feet, and (d) red homogeneous gypseous adobe. All this material was undoubtedly deposited in a periodic lake.

A deep well, which was drilled in the basin at Ancho, has cut a gypsum bed, 30 feet thick, at a depth of more than 550 feet. Most of the ground water in the basin contains large amounts of gypsum salts. A geologic map of the Tularosa Basin, scale 1:125,000, and a locality map, scale 1 inch=6 miles, are included.

Merrill, F. J. H., 1901, Geologic map of New York: New York State Mus., scale 1:316,800, 12 sheets.

The map shows the geologic formations of New York.

Meschter, Elwood, 1958, Flintkote builds modern plant in fight for piece of gypsum market: Rock Products, v. 61, no. 4, p. 66–71, 122.

The report describes the operation of the gypsum plant of the Flintkote Co. in Sweetwater, Nolan County, Tex. The plant in which gypsum products are manufactured receives gypsum from 4 beds of Permian age, which aggregate about 50 feet in thickness. Processes and equipment that are used in the manufacture of the gypsum products are described in detail.

Michigan Department of Conservation, Geological Survey Division, 1877–1909, Annual reports of the commissioners of mineral statistics.

These annual publications list statistics on gypsum production, uses, and prices. Brief statements on the producing areas are also included.

________ 1910–57, Michigan's mineral industries.

These annual publications list statistics of gypsum production. They include statements on the annual developments of the gypsum industry. Some of the publications give detailed descriptions of the occurrences of gypsum. A map, scale 1 inch=50 miles, shows rock and mineral developments and mineral industries in Michigan.

Midwest Research Institute, 1946, Map showing mineral resources of Nebraska, Iowa, Kansas, Missouri, Oklahoma, and Arkansas: Kansas City, Mo., Gas Service Co., scale 1:250,000.

The map shows the location of gypsum deposits and mills, and other mineral resources, in the six-State area.

Mining Cong. Journal, 1953, Open Texas gypsum mine: v. 39, no. 4, p. 134.

The Casner Chemical Co. opened a new gypsum mine in Hudspeth County, 75 miles east of El Paso, Tex. The deposit, which is estimated to contain 5 million tons, is being mined by open-pit methods. The gypsum is trucked 4 miles to a railroad spur.

Mining World, 1958, v. 20, no. 2, p. 81.

A gypsum deposit near Camp Verde, Yavapai County, Ariz., was brought into production by the Verde Gypsum Co., which trucks about 27 tons of gypsum a day to the Phoenix area for sale as agriculture gypsum. The deposit contains no overburden and requires no blasting.

Miser, H. D., 1920, Arkansas, *in* Stone, R. W., and others, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 57.

The only gypsum deposits that are known to occur in Arkansas are located in Pike and Howard Counties, in the southwestern part of the State. The gypsum is confined to the De Queen limestone member in the upper part of the Trinity formation of Lower Cretaceous age. The thickest exposure of gypsum is in a single bed at Plaster Bluff, Pike County, which ranges in thickness from 10 to 14 feet. The deposit consists of pure saccharoidal gypsum that contains thin seams of satin spar. As much as 3 feet of clay is interbedded with the lower part of the gypsum.

Gypsum has been reported to crop out west of Plaster Bluff, as far as Messers Creek in Howard County. The gypsum here is not pure and is only 3 feet thick.

At Augusta, Woodruff County, gypsum has been reported at 100 feet in depth. This gypsum is probably Eocene in age, and underlies sand and clay.

No production had been reported from Arkansas as of 1920.

________ 1954, Geologic map of Oklahoma: U.S. Geol. Survey, scale 1:500,000.

The map shows the geologic formations of the State.

Miser, H. D., and Purdue, A. H., 1929, Geology of the De Queen and Caddo Gap quadrangles, Arkansas: U.S. Geol. Survey Bull. 808, p. 174–175.

Gypsum is found in the De Queen limestone member of the Trinity formation of Cretaceous age. At Plaster Bluff, Pike County, 10 to 14 feet of gypsum is exposed in a bluff that is 65 feet above the Little Missouri River, and 65 feet from the top of the bluff. Some clay is found at the base of the gypsum. The National Gypsum Co. mined this deposit in 1922 and 1923 for a retarder to be used for portland cement.

To the west of Plaster Bluff, a few other outcrops occur, but these do not exceed 3 feet in thickness. A geologic map, scale 1 inch = 2 miles, is included in the report.

Mitchell, R. H., and Laird, W. M., 1943, Notes on gypsum crystals in Morton County, North Dakota: Rocks and Minerals, v. 18, no. 1, p. 10.

In southeastern Morton County, gypsum occurs in the form of crystalline balls or rosettes and well-formed crystals in the sands and sandy shales of the

Hell Creek formation of Upper Cretaceous age and in the Cannonball and Ludlow formations of Tertiary age. The gypsum crystals are closely associated with fragmental plant remains and marcasite concretions.

Moore, B. N., 1935, Some strontium deposits of southeastern California and western Arizona: Am. Inst. Mining Metall. Engineers Tech. Pub. 599, p. 12–17.

Gypsum is associated with celestite deposits in the Avawatz Mountains, San Bernardino County, and in the Fish Creek Mountains, Imperial County, Calif. In the Avawatz Mountains, stratigraphic sections show that there are at least 3 beds of gypsum, which range from about 2 to 6 feet in thickness, and which are separated from each other by gypsiferous celestite rock. In the Fish Creek Mountains, about 100 feet of gypsum underlies 10 feet of celestite rock.

——— 1937, Nonmetallic mineral resources of eastern Oregon: U.S. Geol. Survey Bull. 875, p. 7–8.

The only gypsum deposit that is known in Oregon is near Gypsum Station in the Snake River Canyon. The gypsum bed was 30 to 40 feet thick, but all the gypsum has been mined out and only the unaltered anhydrite is left. Prospecting may reveal other occurrences of the anhydrite bed that were near enough to the surface to have been hydrated to gypsum by weathering.

Moore, B. N., Callahan, Eugene, and Rubey, W. W., 1936, Gypsum, *in* Hewett, D. F., and others, Mineral resources of the region around Boulder [Hoover] Dam: U.S. Geol. Survey Bull. 871 p. 166–168.

In California, gypsum occurs (a) in the Fish Creek Mountains of the Salton Sink, Imperial County, where the gypsum deposit, which is about 1 mile wide, 3 miles long, and from 50 to 150 feet thick, rests on Tertiary granitic rocks; (b) at Midland, Riverside County, where the gypsum occurs in highly folded metamorphosed rocks that are thought to be Precambrian; and (c) near Gypsite, Kern County, and Amboy, San Bernardino County, where gypsite is mined from dry lake beds.

In southeastern Nevada, gypsum occurs in Clark County near Arden, south of the Narrows of Muddy Creek, and at the south end of the Muddy Mountains. Near Arden, the gypsum occurs in beds that are 5 to 15 feet thick within the Supai formation and the overlying Kaibab limestone. The gypsum passes into anhydrite 50 to 100 feet from the outcrop. South of the Narrows of Muddy Creek, the gypsum occurs interbedded with red sandy shale in the upper part of the Chinle formation of Triassic age. Here, the gypsum is relatively pure and ranges from 10 to 90 feet in thickness. The deposit averages 20 feet thick and reaches a maximum thickness near the north and south ends of the outcrop belt. Reserves are estimated to be 1.5 million tons. At the south end of the Muddy Mountains, the gypsum occurs in thick beds within the Horse Spring formation of Tertiary age. An analysis of this material indicates that it contains between 86.8 and 96.6 percent gypsum.

Moore, R. C., Frye, J. C., and others, 1942, Mineral resources map of Kansas: Kansas Geol. Survey Bull. 41, pt. 4, p. 182–184, scale 1:633,600.

The map, scale 1 inch = 10 miles, shows the location of the gypsum deposits and mills in Kansas.

Moore, R. C., and Landes, K. K., 1937, Geologic map of Kansas: Kansas Geol. Survey, scale 1:500,000.

The map shows the geologic formations of the State.

Morgan, A. M., 1938, Geology and shallow-water resources of the Roswell artesian basin, New Mexico: New Mexico State Engineer 12th and 13th Bienn. Repts., p. 160, 171–174.

The Roswell artesian basin is in southeastern New Mexico and is traversed from north to south by the Pecos River. The Permian rocks of the area belong to the Chalk Bluff formation, which consists of red beds, salt, gypsum, and anhydrite, and to the underlying Chupadera formation. The upper unit of the Chupadera formation is composed predominantly of limestone and dolomite; the thin middle unit is composed of sandstone; and the lower unit, the Yeso member, is composed of red beds, anhydrite, and gypsum.

The Chalk Bluff formation is more than 1,000 feet thick. The gypsum beds in this formation are 1 foot to as much as 60 feet thick, and are scattered throughout the formation. A drill log quoted in the report shows that 10 beds of gypsum are present, and that gypsum rather than anhydrite is found throughout the 1,000 feet of the formation. The top gypsum bed is 90 feet below the surface.

The Yeso member consists largely of gypsum and red beds with interbedded limestone and yellow sandy shale. This unit, which crops out in the vicinity of Tularosa and Alamogordo, N. Mex., is so variable in composition that no single description holds true over a large area.

Moses, A. J., 1893, One of the gypsum crystals from the cave at South Wash, Wayne Co., Utah: Science, v. 21, no. 534, p. 230–231.

A selenite crystal from a deposit in Emery County in southern Utah is described; the crystal was 27 inches long and weighed 24½ pounds.

Moyer, F. T., 1939, Gypsum and anhydrite: U.S. Bur. Mines Inf. Circ. 7049, 45 p.

Various methods of producing and processing gypsum and anhydrite are described. The deposits are listed by State, and figures on mine production, imports, and apparent supply of crude gypsum in the United States are given. A generalized flowsheet of a combined kettle and rotary-kiln gypsum processing plant is included. The report contains a bibliography of processing methods.

Muir, J. L., 1934, Anhydrite-gypsum problem of Blaine formation, Oklahoma [with discussion]: Am. Assoc. Petroleum Geologists Bull., v. 18, no. 10, p. 1297–1312.

Several theories have been advanced for the origin of gypsum and anhydrite. These are—

1. G. Bischof in 1864, followed by Carl Ochsenius in 1877, postulated the bar theory for the origin of the Strassfurt saline deposits. J. H. Van't Hoff and F. Weigert in 1901, indicated that either gypsum or anhydrite could be deposited by evaporation in a lagoon or land-locked basin. They also indicated that anhydrite is precipitated at temperatures above 25°C and gypsum below.
2. Gypsum can be formed by the action of sulfurous acids on limestones.
3. E. B. Branson in 1915 suggested a modified bar theory to include an inner basin with connecting lagoons such that the inner one would receive only waters concentrated with calcium sulfate.
4. A. W. Grabau in 1923 suggested that many salt deposits were of continental origin, the salts having been leached from surface formations by ground water.
5. A. F. Rogers in 1910 concluded that most gypsum was formed by the hydration of anhydrite.

6. Gypsum is altered to anhydrite only by heat, pressure having only a very minor part.

Various writers have indicated that when anhydrite alters to gypsum, there is a volume change. The estimates of the volume change range from 33 to as much as 60 percent.

The studies of this report were made of the Blaine formation near Southard, Okla. The Blaine formation contains 3 beds of gypsum, which are, from the bottom upward: the Medicine Lodge, which is about 6 feet thick; the Shimer, which is about 18 feet thick; and the Lovedale, which is about 8½ feet thick. Both megascopic and microscopic studies were made of the gypsum from these beds.

The Medicine Lodge gypsum member is, in general, fine, compact, crystalline, and somewhat laminated on surface exposures. A microscopic study shows that the lower part is composed of irregularly shaped crystals, which are less than 0.05 to 5 mm in diameter. In the middle part of the bed, anhydrite is present within the gypsum. In the top part of the bed, gypsum occurs as very fine crystals with minute fibrous crystals of anhydrite.

The Shimer gypsum member consists of 3 types of gypsum: (a) large coarse crystals of satin spar and selenite, 1.0 to 2.5 mm in diameter; (b) very fine grained white gypsum that occurs as nodules in a coarser gypsum matrix; and (c) massive white gypsum. The middle part of the member is made up predominantly of anhydrite.

The Lovedale gypsum member is made up of fine-grained massive crystalline gypsum, which is olive gray to white. Included in all the gypsum are minute crystals of dolomite and ferrous hydroxide.

It is concluded from these studies that (a) the gypsum results from the hydration of anhydrite, (b) the hydration occurs without volume change, (c) the anhydrite is the primary precipitate mineral, and (d) the original precipitation implies a hot and arid climate.

Discussion: H. C. Griley reports that there is evidence of expansion of the gypsum on hydration. He cites that pressure ridges or miniature anticlines, which are as much as 5 to 8 feet in height and 15 to 20 feet in width, are developed in the Blaine formation in Major County, Okla.

Munyan, A. C., 1937, A new occurrence of gypsum in Kentucky: Am. Mineralogist, v. 22, no. 10, p. 1069–1071.

Gypsum occurs in Kentucky as small deposits in limestone caves and as isolated selenite crystals in the Niagaran shales on the eastern flank of the Cincinnati arch. In addition, selenite crystals have been found in an air entry of a coal mine near Nortons Gap in Hopkins County. The gypsum is associated with clay between coal seams Nos. 11 and 12. The gypsum was formed by acid waters from a coal seam acting on limestone.

Murdoch, Joseph, and Webb, R. W., 1948, Minerals of California: California Div. Mines Bull. 136, p. 165–166.

The report discusses briefly the localities in which gypsum occurs in California, either as masses of rock gypsum or as isolated crystals of gypsum that are associated with sand or clays. Also included is a bibliography of these occurrences.

Nelson, E. W., 1951, The rock nobody knows: Nature Mag., v. 44, no. 10, p. 538–540.

A popular description of gypsum, including its occurrences and uses, is given.

New Mexico Miner, 1952, Suwanee gypsum mine has started production: v. 14, no. 8, p. 11.

Agricultural gypsum is being produced from a mine at Suwanee, Valencia County, which is 30 miles west of Albuquerque, N. Mex.

Newcombe, R. B., 1928, Non-metallic minerals, review of industries and production, *in* Mineral resources of Michigan: Michigan Dept. Conserv., Geol. Survey Div. Pub. 37, Geol. Ser. 31, p. 103–108.

In Michigan, the occurrence of commercial gypsum is confined to the lower part of the Michigan formation of Mississippian age and to a formation indefinitely correlated with the Salina formation of Silurian age.

The mining of gypsum in Michigan is centered in two areas: the Grand Rapids-Grandville district in Kent County and the Alabaster district in Iosco County. In Kent County, at least 3 and probably 4 beds of gypsum are present: the upper 2 beds are about 6 and 12 feet thick, respectively, and the third bed is 22 feet thick with a shale parting in the middle. The gypsum is massive and granular, and ranges from gray and cream through various shades of pink and red.

At Alabaster, the upper gypsum bed is 18 to 23 feet thick. Test holes, which were drilled north of Alabaster, show that a number of deeper gypsum beds are present which range from 5 to 25 feet in thickness. Another bed of white and granular gypsum that is of minable thickness occurs south of Alabaster, near Turner, Arenac County.

In the Upper Peninsula, gypsum of Silurian age occurs near St. Ignace and on St. Martins Island. The aggregate thickness of these beds is 60 feet; some of the individual beds range from 9 to 21 feet in thickness.

Large quantities of anhydrite have been found in the southern part of the State at depths that are too great for commercial exploitation.

The uses of gypsum are discussed, and the production figures of gypsum mined in Michigan from 1868 to 1926 are given.

Newland, D. H., 1921a, Geology of gypsum and anhydrite: Econ. Geology, v. 16, p. 393–404.

In the $CaSO_4$ series, anhydrite is the major rock-forming member, and gypsum is a weathering product of anhydrite. Exploration shows that, although gypsum occurs near the surface, anhydrite occurs at depth. In New York State the outcrop of the beds on the surface is represented by a topographic depression, and gypsum is found at between 20 and 40 feet below the surface. Anhydrite is found at depths of 100 to 125 feet below the surface.

——— 1921b, Relation of gypsum supplies to mining: Am. Inst. Mining Metall. Engineers Trans., v. 66, p. 89–98.

Anhydrite and gypsum are associated below the surface. The maximum depth at which gypsum changes to anhydrite is about 500 feet and generally not more than 250 to 300 feet. Anhydrite succeeds gypsum in depth where pressure contributes to the stability of the mineral. At a pressure estimated for a depth that is equal to 115 pounds for each 100 feet of cover, the process of hydration is delayed. For any further increase in depth, anhydrite becomes the stable form, as the change from the anhydrous to the hydrous form necessitates a volume increase of about 50 percent.

Solution of the deposit by ground waters is an important consideration in mining gypsum, because solutions create soft weathered outcrops and produce sinks, mudseams, and caves within the deposit.

Newland, D. H., 1929, The gypsum resources and gypsum industry of New York: New York State Mus. Bull. 283, 188 p.

Gypsum was discovered in New York in 1792 and was first used for land plaster. It was not until 1892 that gypsum was first calcined. Production of gypsum in New York from 1810 to 1926 is estimated to be about 19 million tons.

All the gypsum is found in the Salina formation of Silurian age that crops out from Albany County westward to the Niagara River and into Ontario. The formation is exposed also in a belt that crops out along the Hudson River southward into New Jersey. The beds dips to the south at the rate of 20 to 50 feet to the mile. Gypsum is present only from Herkimer County west to the Niagara River, and it is not in a continuous seam. Only in a few places are the beds of sufficient purity and size to justify mining. The gypsum beds become anhydritic under cover of about 100 feet.

The most easterly occurrence of gypsum in New York is in Herkimer County where small bodies of gypsum were found. Gypsum has also been found in all the counties westward to Erie County, although most of the gypsum, which has been produced in the State has come from Erie, Genessee, and Monroe Counties.

In Erie and Genessee Counties, reserves are estimated at 60 million tons and in Monroe County, at about 50 million tons. Little exploration has been done to the east. The beds thicken from about 3½ feet in Erie County, eastward to Cayuga County, where the beds range from 30 to 40 feet in thickness. Several chemical analyses are given which indicate that the gypsum in the western part of the State is purerer than that in the eastern part.

The technology of calcining gypsum is described. Maps, which show the location of gypsum deposits, are included.

Newland, D. H., and Leighton, Henry, 1920, New York, *in* Stone, R. W., and others, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 187–217.

Workable deposits of gypsum occur only in the Salina formation of Silurian age, which crops out in a band from Buffalo, eastward to Albany County. The Salina formation in the western part of the State consists mainly of shale, which contains beds and lenses of gypsum that are capped by a thin limestone bed.

The gypsum in the western part of the outcrop belt is as much as 5 feet thick. In the eastern part of the belt, the deposits are thicker and less pure. The report describes the deposits by counties. Included in the report are maps that show the location of gypsum deposits in Onondaga, Monroe, Genessee, and Erie Counties.

Nickell, W. P., Gypsum at Grand Rapids and Alabaster, Michigan: Michigan Mineralog. Soc. Pub. 2, p. 8–9.

The gypsum deposits at Grand Rapids, Kent County, and Alabaster, Iosco County, are nearly all of the massive granular bedded variety. In some areas the deposits occur as lenses in shales, shaly limestone, and sandstone. Crystals and plates of transparent to milky selenite occur in pockets, solution channels, and cracks within the gypsum.

The types of gypsum that are found include (a) granular gypsum, salmon to reddish brown and white, with streaks of gray to pale pink, which is found at Grand Rapids; (b) alabaster, compact enough to be used for carving, is found at Alabaster; (c) flattened nodules of compact massive or granular gypsum with semicrystalline surfaces, which can be found in shales and sandstones, in the vicinity of gypsum deposits. These nodules range generally from the size of a bean to a foot in diameter, and are generally deep orange to reddish brown; and (d) five-sided columnar deposits of reddish-brown gypsum with crystalline structure, which are found at Grand Rapids.

Nordberg, Bror, 1950a, Manufacture of gypsum plaster and wallboard: Rock Products, v. 53, no. 1, p. 137–141, 166, 174.

At Blue Diamond, Nev., which is 23 miles southwest of Las Vegas, plaster and wallboard are made by the Blue Diamond Corp. in a plant that was erected in 1941. Before this, the gypsum was sent to Los Angeles for processing.

The gypsum is mined underground from 2 roughly horizontal strata, each 16 feet thick, and quarried from 2 other beds that are slightly thinner. The beds vary in purity; therefore selective mining is done.

The rock is soft and easily blasted, and the broken rock from the underground mine is placed by joy loaders onto shuttle cars, which load the rock into trucks. The trucks are loaded by shovel from the quarries. Plant production requires 800 tons of gypsum rock to be delivered in 8 hours; 2 trucks, without interruption, can deliver 960 tons in 8 hours. The rock is crushed and taken by a 3,700-foot tramway down 900 feet to the plant where the gypsum is ground in a raymond mill before calcining. The plant has four 20-ton capacity kettles that operate on a 2½-hour cycle. The wallboard machine belt is 560 feet long and operates at 90 feet per minute; the capacity of the machine is, therefore, 55,000 square yards of perforated lath in 24 hours.

Perforated lath is the major product of the plant. Other products are gypsum wallboard; a variety of plasters, which includes hardwall, plaster of paris, dental plaster, and gaging plaster; agricultural gypsum; and portland cement retarder.

________ 1950b, The National Gypsum Company story: Rock Products, v. 53, no. 12, p. 83–91.

In 1950, the National Gypsum Co. produced almost 2 billion square feet of board products and more than half a million tons of plaster, from more than 3 million tons of gypsum and lime.

In 1925, the first gypsum plant of the National Gypsum Co. was established at Clarence Center, N.Y., just outside Buffalo. In 1935, the company took over the Universal Gypsum & Lime Co. with gypsum plants at Akron, N.Y., Rotan, Tex., Fort Dodge, Iowa, and Baltimore, Md. National Gypsum Co. next acquired plants in Portsmouth, N. H., and New York City, together with Nova Scotia gypsum quarries. In 1937, the company acquired Best Brothers Keene's Cement Co. in Medicine Lodge, Kans.

By 1950, the National Gypsum Co. had added gypsum plants at Savannah, Ga., and at National City, Mich. The report describes the policies of the company and the products other than gypsum that it manufactured.

Ochsenius, Carl, 1888, On the formation of rock-salt beds and mother liquor salts: [U.S.] Natl. Acad. Sci. Proc., pt. 2, p. 181–187.

Ocean waters, from which salt deposits were formed, contain 3½ percent of salts, by weight, in solution. Of this, about 2½ percent is sodium chloride, and 1 percent is calcium sulfate and other salts. Salts are not precipitated in open sea, but in bays, which are partly cut off by a bar that allows only enough water to cross to compensate for that lost by evaporation. The upper sheets of water, when warmed by the sun, sink as they get heavier from the concentration of salts; and in course of time, a vertical circulation takes place. As the saltiness increases, the free-swimming organisms leave and the planktonic ones die. The first salts that are precipitated are iron and calcium carbonate, then calcium sulfate and sodium chloride, and finally, the magne-

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sium and potassium salts. The report mentions that this process is taking place in the Gulf of Karaboghaz, on the east side of the Caspian Sea.

Offutt, J. S., and Lambe, C. M., 1947, Plasters and gypsum cements for the ceramic industry: Am. Ceramic Soc. Bull., v. 26, no. 2, p. 29–36.

The report describes the properties of gypsum plaster, especially of alpha-gypsum (alpha-hemihydrate), as they apply to the ceramic industry. Calcining ordinary gypsum at atmospheric pressure results in particles which are porous aggregates of hemihydrate crystals. Alpha-gypsum is made by placing lumps of gypsum, which are as much as 2 inches in diameter, in an autoclave and applying steam pressure. The charge is calcined at about 250°F. The product is a uniformly dehydrated mineral in unbroken, comparatively large, dense, and stubby-shaped crystals. The normal consistency between alpha-gypsum and regular gypsum is compared, and the characteristics that are required in plasters and alpha-gypsums for important ceramic applications, such as in whiteware molds, and in glass manufacture, are discussed. The advantages of using alpha-gypsum over gypsum plasters are described.

Ogniben, Leo, 1955, Inverse graded bedding in primary gypsum of chemical deposition: Jour. Sed. Petrology, v. 25, no. 4, p. 273–281.

The upper Miocene Sulfur series of Sicily consists, from the top downward, of a marly limestone and marl formation, a gypsum marl and clay formation, and a limestone formation.

The gypsum occurs in beds from 1 to tens of meters thick. These beds consist mostly of anhydrite that is altered to gypsum and a thin basal zone of primary gypsum of chemical deposition. The primary gypsum is a white-grayish rock that is made up of rhythmic laminations. The secondary gypsum is characterized by swelling structures that may be seen under the microscope.

The rhythmic primary gypsum is bedded in laminae that are 2 or 3 mm thick. These laminae are made up of a mosaic of gypsum crystals with the finer crystals at the base and the coarser at the top. The inverse size grading is due to a seasonal concentration increase that is caused by evaporation, possibly together with an average seasonal temperature increase. The return to the initial small sizes at the base of each laminae is attributed to a rainy, perhaps cold season, which interrupted the evaporation.

Olson, G. G., and Long, J. T., Jr. [no date], Arizona's natural resources: Phoenix, Ariz., Arizona Devel. Board, p. 18–19.

The most extensive gypsum deposits in Arizona are east of Feldman, Pinal County, where two companies are quarrying gypsum: (a) Arizona Gypsum Co., which ships gypsum to Rillito, Ariz., for use as a cement retarder, and (b) Union Gypsum Co., which ships gypsum to Phoenix for use in the manufacture of wallboard. Gypsum also occurs in the Verde Valley, south of Camp Verde, Yavapai County. A small tonnage of gypsum has been shipped from here to Phoenix for agricultural use. Other areas that contain gypsum include (a) east of Douglas, Cochise County, (b) near Winslow, Navajo County, (c) southwest of Bouse, Yuma County, (d) north of Wenden and south of Salome, Maricopa County, (e) Navajo County on the Navajo Indian Reservation, and (f) south of Mammoth in San Pedro Valley, Pinal County, where large reserves have been discovered by well drilling.

Oklahoma City Geological Society, 1956, Panhandle of Oklahoma, northeastern New Mexico, south-central Colorado: Guidebook 35th Anniversary Field Conf., p. 109.

The locations of gypsum and anhydrite deposits in El Paso County on Colorado State Highway 115 northeast of Canyon City, Colo. are given. These deposits are in the Curtis-Summerville of Jurassic age and in the Lykins formation of Permian age.

Oregon State Bureau of Mines, 1912, The economic geological resources of Oregon: p. 64.

In Oregon, gypsum occurs in two localities: (a) on the eastern border of the State, 6 miles north of Huntington and along a ridge above the Snake River, where white and crystalline gypsum that contains films of greenish chloritic material occurs in lenses, which are 10 to 40 feet thick and interstratified with limestone, shale, and volcanic tuffs; (b) an undeveloped impure deposit which occurs in Crook County, near Bend. This material has been used to a limited extent for fertilizer.

Osterwald, F. W., and Osterwald, D. B., 1952, Wyoming mineral resources: Wyoming Geol. Survey Bull. 45, p. 77–86.

In Wyoming, thick rock gypsum beds occur mainly in the Embar formation of Permian age, Chugwater and Spearfish formations of Triassic age, and Gypsum Spring formation of Jurassic age. The deposits are briefly described by counties, which include Albany, Big Horn, Carbon, Converse, Crook, Fremont, Hot Springs, Johnson, Natrona Park Platte Sheridan, Washakie, and Weston. A sketch map that shows the outcrops of gypsum-bearing strata is also included.

Pabst, Adolf, 1938, Minerals of California: California Div. Mines Bull. 113, p. 180–184.

The location and geology of gypsum occurrences in California are described briefly by counties.

Parker, E. W., 1898, Mineral resources of the United States, nonmetallic products, except coal and coke: U.S. Geol. Survey 20th Ann. Rept., pt. 6 (Continued), p. 666.

In Florida, gypsum occurs about 6 miles west of Panasoffkee, in a low-lying area of hummock land that is known as Bear Island. The gypsum is almost uniformly mixed with impure limestone and some hard flinty boulders. Very little overburden is present. Chemical analysis indicates that the deposit contains gypsum of less than 95 percent purity.

Parsons, A.L., 1927, The dehydration of gypsum: Toronto Univ. Studies, Geol. Ser. 24, p. 24–27.

When gypsum is heated in air, it loses all its water in a single stage and yields a second form of anhydrous calcium sulfate, which corresponds to the mineral bassanite, $CaSO_4 \cdot \frac{1}{2}H_2O$. The grains of gypsum lose water in their outer parts first, and, as the reaction progresses, additional layers give off water.

Plaster of paris is not a definite chemical compound but is an intimate mixture of bassanite and gypsum in proportions that vary 3:1 and 2:1 (bassanite-gypsum).

Parsons, W. H., 1947, Geology of the Michigan gypsum deposits: Michigan Mineralog. Soc. Pub. 2, p. 4–7.

In Michigan, gypsum is found in beds of Silurian and Mississippian age. The Silurian gypsum crops out in the St. Ignace area, Mackinac County, in several beds; one is at least 13 feet thick and interbedded with shales and dolomites. These beds underlie most of the southern peninsula at depths as much as 6,000 feet below the surface.

The gypsum in the Grand Rapids-Grandville area, and those at Alabaster and National City, Iosco County, are in the Michigan formation of Mississippian age, which consists of dolomite, limestone, shales, and irregular lenses of sandstone. This formation is continuous from Grand Rapids to Alabaster and ranges generally in thickness from 200 feet at the edges of the basin to 460 feet in the center of the basin. Thick beds of gypsum are not present throughout the formation, but vary considerably in number and thickness.

Patton, L. T., 1930, The geology of Stonewall County, Texas: Texas Univ. Bull. 3027, 77 p.

Gypsum occurs within the Peacock and the underlying Blaine formation of Permian age. In the Blaine formation, the gypsum beds alternate with red shale throughout a thickness of about 200 feet; the maximum bed is about 30 feet thick and the average is about 10 feet. These beds are highly lenticular, and a thick bed will thin laterally in a short distance. The thickest and most continuous bed is near the top of the formation.

In the Peacock formation, there are 2 gypsum beds. The lower bed, which is about 10 feet thick, is called the Swenson gypsum and forms a conspicuous escarpment. The upper gypsum is in 2 beds, each ranging from 2 to 5 feet in thickness.

Peck, R. L., 1956, Anderson-Dunham, Inc.—dominant Louisiana concrete producer: Pit and Quarry, v. 48, no. 10, p. 252–254.

Gypsum is quarried at Winnfield, Winn County, La. The gypsum occurs in the caprock of a salt dome and underlies about 40 feet of limestone and 10 feet of overburden. The gypsum is about 35 feet thick and is exposed over an area of about 15 acres. It is massive, gray, and occurs as a continuous layer of irregular thickness between the limestone and anhydrite. Some anhydrite is included with the gypsum. The anhydrite that underlies the gypsum averages about 110 feet thick. Under the anhydrite is rock salt, which has been mined since 1931 by the Cary Salt Co. The limestone that caps the gypsum is Cretaceous and forms a ridge against which Tertiary sediments were deposited. If it is assumed that the gypsum averages 20 feet thick, an estimated 3.7 million tons of rock is available. Annual production of gypsum amounts to about 150,000 tons.

Peppel, S. V., 1904, Ohio, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 38–44.

In Ohio, gypsum deposits occur in the Rondout formation of Silurian age, in Portage and Erie Counties. The beds of gypsum vary in thickness from 9 inches to about 9 feet. In Portage County, 200 acres is underlain by commercial deposits of gray gypsum that contains some carbonaceous material.

In Erie County, gypsum of Silurian age has been found in drill holes near Castalia, at depths of about 75 feet. The report contains a map of the gypsum area, scale 1 inch = 4½ inches.

Perry, E. S., 1949, Gypsum, lime, and limestone in Montana: Montana Bur. Mines and Geology Mem. 29, p. 1–23.

Gypsum occurs in many workable deposits in Montana. These are (a) on the south flanks of the South Moccasin Mountains and in and north of the Big Snowy Mountains, near Lewistown, Fergus County; (b) on the north flank of the Little Belt Mountains, southeast of Great Falls; (c) on the west and east flank of the Big Horn Mountains, near Bridger, Carbon County, and Wyola, Big Horn County; (d) in the mountains 10 miles west of Lima, Beaverhead County; (e) near Limespur, Jefferson County, 50 miles east of Butte; and (f) in the Gravelly and Madison Ranges, Madison County.

The deposits, which are on the south flanks of the South Moccasin Mountains and in and north of the Big Snowy Mountains, occur in the lower part of the Ellis formation of Jurassic age. The deposits at Heath, Fergus County, which have been operated since 1916, are in 2 nearly horizontal beds; the upper bed ranges from 13 to nearly 20 feet in thickness, and the lower, 8 to 12 feet. The deposit is worked by underground methods. Only about 11 feet are mined; the remaining gypsum is left in the roof. The gypsum is fabricated into wallboard and other plaster products.

At Hanover, Fergus County, gypsum has been mined since 1916, mostly for portland cement retarder. The deposit lies on the south flank of the South Moccasin Mountains, which consist of a circular laccolithic dome, around which the Cretaceous and lower strata have been folded and exposed. The gypsum is exposed only around the flank of a smaller dome to the south of the main laccolith, and dips 25° away from the center of the dome. At least 6 beds of gypsum are present. These beds, which range from 4 to 8 feet in thickness, are separated by shale and limestone beds from 1 to 8 feet in thickness. Anhydrite occurs with the gypsum.

East of Lewistown, 10 feet of gypsum is exposed 2½ miles south of Piper.

South of Great Falls, gypsum occurs at Kibbey, Judith Basin County; at Riceville, Cascade County; and near Lingshire, Meagher County. All these deposits are around the flanks of the Little Belt Mountains. At Kibbey and Lingshire, the gypsum occurs in the Kibbey formation of Mississippian age; at Riceville, the gypsum is in the Otter formation of Mississippian age. The 2 gypsum formations are 200 to 300 feet apart. Gypsum has been worked at both Riceville and Kibbey, and a prospect pit has been dug at Lingshire.

An additional exposure of gypsum in the Otter formation occurs south of Geyser, Judith Basin County.

Gypsum has been produced near Bridger, Carbon County, in the Big Horn Basin. The development was done by an adit that was driven into the hillside. The gypsum here is in the upper part of the Chugwater formation of Triassic age. The bed is reported to have been 10 to 12 feet thick. Gypsum occurs persistently from a point east of Bridger to Wyoming.

Petsch, B. C., 1953, Geologic map of the State of South Dakota: South Dakota Geol. Survey, scale 1:580,000.

The map shows the geologic formations of the State.

Pettijohn, F. J., 1957, Sedimentary rocks: New York, Harper & Bros., 2d ed., p. 478–485.

A general review of the occurrence of gypsum, anhydrite, and other evaporites, including a discussion of the origin of evaporites, is given.

Phalen, W. C., 1914, Celestite deposits in California and Arizona: U.S. Geol. Survey Bull. 540–T, p. 521–533.

Two areas where gypsum occurs with celestite are described: in the Avawatz Mountains, San Bernardino County, Calif.; and 15 miles south of Gila Bend, Maricopa County, Ariz.

In the Avawatz Mountains, lake beds that contain salt, gypsum, and celestite are overlain by gravels. The beds are separated into five units: the basal, celestite, gypsum, salt, and upper series. No thickness of gypsum series is given. The gypsum is light colored and there is no sharp division between the gypsum series and the overlying salt. At the base of the gypsum series, the gypsum is mixed with dolomite, sand, and other impurities.

In the Arizona deposit, the gypsum is closely associated with the celestite beds, in lake beds of Quaternary age. They are associated with conglomerate and are steeply dipping 15° to 75° to the west.

Phillips, F. C., 1947, Oceanic salt deposits: London, Chem. Soc. Quart. Rev., v. 1, p. 91–111.

Waters of the present-day ocean tend to display a remarkable degree of consistency in the relative proportions of the more important ions present. There are two terms used to describe the composition of sea water, chlorinity and salinity. Chlorinity is determined by the precipitation of the halogens with a silver salt. Salinity, which is a quantity that is slightly less than the dissolved solids, can be calculated from the chlorinity or determined from a measurement of the density. Sea waters contain about 34 parts per thousand of dissolved salts. The report lists the more important salts that occur in marine evaporites. Of these, the calcium salts include anhydrite, gypsum, glauberite, syngenite, and polyhalite. The deposition of all the salts is discussed in detail.

Pierce, W. G., and Andrews, D. A., 1941, Geology and oil and coal resources of the region south of Cody, Park County, Wyoming: U.S. Geol. Survey Bull. 921–B, p. 99, 110–111.

The area covered by this report is south of Cody, which is in the north-central part of Park County, Wyo., and on the western margin of the Big Horn basin. The oldest formation is the Chugwater, which crops out in the northern part of the area and is composed of nearly 1,000 feet of red shales and sandstones that are interbedded with gypsum. Overlying the Chugwater is the Sundance formation, which consists of about 500 feet of marine shales, sandstones, and red shales. A 12-foot bed of gypsum occurs in the middle of the Sundance formation. A geologic map, scale 1:63,360, and geologic sections are included.

Pit and Quarry, 1947, New $500,000 Phoenix plant relieves gypsum products shortage in Arizona: v. 40, no. 1, p. 79–80.

The operation of the gypsum plant of the Union Plaster Co. in Phoenix, Ariz., is described briefly. The raw material comes from deposits near Winkelman, Pinal County, which contain more than 15 million tons of gypsum.

——— 1955, National Gypsum's new Shoals, Indiana plant: v. 48, no. 6, p. 91–95.

The National Gypsum Co.'s plant at Shoals, Ind., was opened in September 1955. The area was first drilled in 1953, and a large block of gypsum, enough for 100 years' operation, was found. The gypsum lies about 500 feet below the surface, in a bed that is 12 to 15 feet thick, and is reached by a sloping shaft about 2,000 feet long. The mine is worked by the room-and-pillar system. Above the gypsum is a layer of shaly limestone, which is up to 12 inches thick, and in the mine, is bolted to a solid limestone above by roof bolts to prevent caving.

The rock is crushed underground and brought to the surface by a belt conveyor whose capacity is 300 tons per hour. From the conveyor belt the rock is screened, and the oversize is crushed. The plant feed of minus three-fourths inch is reground in a raymond roller mill, and the minus 100-mesh product of the mill goes to a calciner. The calcined product goes either to the board machine or is mixed and packaged for plaster.

Pit and Quarry, 1957, Arizona Gypsum Corporation opens raw products plant: v. 49, no. 9, p. 120.

The gypsum quarry at Feldman near Winkelman, Pinal County, Ariz., is owned by the Arizona Gypsum Corp. of Phoenix. The main product is a portland cement retarder for the Arizona Portland Cement Co. at Rillito. A shallow quarry face that is 10 to 12 feet in height is being worked, and, because the overburden is almost entirely pure gypsite and vegetation, no stripping is needed before blasting. Material crushed to minus 6 inches plus one-quarter inch is used as retarder. The minus one-quarter inch is discarded because this contains the impurities. Some of the minus 6-inch fraction is reground to 85 percent passing 100-mesh for agricultural and commercial use.

Pohlman, Julius, 1888, Cement rock and gypsum deposits in Buffalo [New York]: Am. Inst. Mining Metall. Engineers Trans., v. 17, p. 250–253.

Pure white gypsum was penetrated in a drill hole at a depth of 43 feet in Buffalo, N.Y. The core shows that 3 beds of gypsum are present; the top bed is 4 feet thick, the middle bed, 12 feet, and the bottom bed, 4 feet. These beds are separated by 1 to 2 feet of shale. Ground water in large quantities precluded any attempt to mine the deposit. It is assumed that the water came from the higher land to the south rather than from Lake Erie.

Poindexter, O. F., Martin, H. M., and Bergquist, S. G., 1951, Rocks and minerals of Michigan (revised): Michigan Geol. Survey Pub. 42, 3d ed., p. 61, 66, 90, 102.

The areas where gypsum occurs in Michigan are described. Besides the areas in which gypsum is mined, samples of gypsum can be found in the following areas: Satin spar samples at Pointe Aux Chenes, Mackinac County; gypsum as a gangue mineral in the Copper Falls mine, Keweenaw County.

Porter, J. M., 1926, The technology of the manufacture of gypsum products: U.S. Bur. Standards Tech. Circ. 281, 81 p.

The report discusses briefly the process of manufacturing gypsum, from mining to the final product. The uses of calcined gypsum are discussed. The gypsum plants in Texas, Oklahoma, Kansas, Iowa, Michigan, Ohio, and New York are described.

Posnjak, Eugen, 1938, The system, $CaSO_4$–H_2O: Am. Jour. Sci., 35A, p. 247–272.

Van't Hoff and others have shown that four solid phases of calcium sulfate existed: anhydrite, gypsum, hemihydrate, and "soluble anhydrite." The report concludes that Van't Hoff was in effect correct in defining "soluble anhydrite." Gypsum can only disassociate to form hemihydrate, which occurs at 97.5 $\pm$ 1°C. The transition point between the deposition of anhydrite and gypsum occurs at 42° $\pm$ 1°C. Between 42° and 97.5°C, gypsum is metastable. Salt solutions may lower considerably the transition temperature of gypsum to anhydrite.

The transition temperature of hemihydrate to "soluble anhydrite" is very high, and, because of the instability of the two phases, it cannot be determined. A monotropic relationship exists between anhydrite and "soluble anhydrite."

——— 1940, Deposition of calcium sulfate from sea water: Am. Jour. Sci., v. 238, no. 8, p. 559–568.

The coexistence of gypsum and anhydrite takes place only at a four-phase equilibrium point which occurs at 42°C. The four phases include two solids,

a liquid and a vapor stage. The equilibrium point is governed by the intersection of the solubility curves of saturated aqueous solutions of gypsum and anhydrite. The solubility of gypsum and anhydrite first increases rapidly in the presence of an increased amount of sea salts; then it goes through a maximum solubility at about twice the usual salinity of sea water, and from there, it gradually decreases. The decrease is much faster for anhydrite than for gypsum, and the two curves cross at about 4.8 times the usual salinity of sea water. Originally sea water is unsaturated, and only after its salt content has increased by evaporation to 3.35 times the usual salinity, can depositions of salts take place. Between this concentration and 4.8 times the salinity of sea water, nearly one-half of the total amount of $CaSO_4$ will be deposited at 30°C. It is assumed that evaporation of a marine basin will take place at a lower temperature, and most of the $CaSO_4$ will be precepitated as gypsum. Sedimentary deposits of pure anhydrite must have been at least partly derived from gypsum, or they must have been deposited originally at temperatures above 42°C, which is the transition point of the two minerals.

Potter, F. C., 1939, Origin of the gypsum sands of New Mexico [abs.]: Geol. Soc. America Bull., v. 50, no. 12, pt. 2, p. 1928.

The four theories on the origin of the White Sands of the Tularosa Basin, N. Mex., are—

1. Gypsum from the Chupadera formation in the mountains was carried to the basin and deposited as valley fill.
2. Most of the gypsum sands were derived from the alkali flats as they were being excavated by wind action.
3. The gypsum that is derived from the flats is original valley fill, which is supplemented by gypsum washed into the flats by rain, deposited on the surface by capillary action, and to a minor degree, deposited from the disintegration of the large selenite crystals that occur west of the flats.
4. Additional gypsum is provided by capillary action within the dune belt.

Prater, L. S., 1947, Beneficiation tests on gypsum rock from Washington County, Idaho: Idaho Bur. Mines and Geology Pamph. 77, 6 p.

The gypsum that was tested for this report came from north of Weiser, Washington County, Idaho. The rock was white to light gray, with well-defined bands of nodules and irregularly shaped particles of gray siliceous limestone scattered through the gypsum. The sample was crushed to minus one-fourth inch and assayed. The result showed that the content of gypsum was 83.7 percent; anhydrite, 4.8 percent; calcite, 2.1 percent; and insoluble residue and other ingredients, 9.4 percent. The sample was screened and a sizing assay test was made, which showed that the 28-mesh is the best splitting size between a high-grade undersize and a low-grade oversize product.

Ransome, F. L., 1901, The ore deposits of the Rico Mountains, Colorado: U.S. Geol. Survey 22d Ann. Rept., pt. 2, p. 253, 273–280, 337–339.

The "Enterprise blanket" of the Rico Mountains district is found in the mines of Newman Hill, south of Rico, Colo. The "blanket" is an unconsolidated breccia in the middle part of a series of sandstones, shales, and limestones. It rests upon the "blanket limestone," and is overlain by fissile black shale. In places, considerable bodies of gypsum occur above the "blanket limestone" and occupy the space generally filled by the "blanket." The gypsum appears to be fairly extensive and is probably more than 10 feet thick. In places, it rests on the limestone, and in other places, the two rocks are separated by gray silty material. The underside of the gypsum, where seen in mine workings, shows signs of solution. The unconsolidated "blanket" breccia fits against the gypsum much like morainic material might crowd against the melting front of a glacier. The gypsum is wasting away by solution, and, as fast as it is dissolved, the "blanket" breccia takes its place.

The gypsum is silvery gray, fine grained, and nearly pure. It is part of an original bed that was laid down with the Hermosa shales, sandstones, and limestones. The gypsum bed probably was lenticular in form and may not have been extended far beyond the present bounds of Newman Hill.

The ore occurs chiefly as a replacement of the lower part of the "blanket," but it sometimes extends up into the breccia. No ore is found where the gypsum occupies the usual place of the "blanket." A geologic map of the central part of the Rico Mountains, scale 1 inch=55 miles, is included.

Reeside, J. B., Jr., and Bassler, Harvey, 1922, Stratigraphic sections in southwestern Utah and northwestern Arizona: U.S. Geol. Survey Prof. Paper 129–D, p. 53–77.

Several geologic sections are given of the gypsum-bearing members of the Moenkopi formation of Triassic age (Shnabkaib shale member and Rock Canyon conglomerate member) and of the Harrisburg gypsiferous member of the Kaibab limestone of Permian age.

In the Moenkopi formation, the gypsum is not plentiful in Washington County, Utah, or in Mohave County, Ariz. In the Kaibab formation, gypsum is present only in the northwestern part of Arizona and southwestern part of Utah. No exact thickness of gypsum is given. The thickest beds are reported as being 145 feet.

Reeves, Frank, 1922, Geology of the Cement oil field, Caddo County, Oklahoma: U.S. Geol. Survey Bull. 726–B, p. 41, 45–50.

The area covered by the report is in the central and southeastern parts of Caddo County, Okla. The gypsum that crops out in the area belongs to the Cyril gypsum member of the Greer formation of Permian age. The Cyril gypsum consists wholly of gypsum in some parts of the area, and in other parts, it is composed of 2 beds of gypsum that are separated by 15 to 20 feet of gypsiferous sandy shale. The greatest thickness of the gypsum is in Tonkawa Township where 85 feet is present. The upper gypsum bed has been eroded from most of the area. The lower gypsum bed ranges from 1 to 40 feet in thickness and underlies about half of the Cement area. Gypsum is prominently exposed in South Cement, Doyle, and Tonkawa Townships, and it is in scattered outlenses in North Cement Township. The lower and upper beds of gypsum resemble each other, except that the lower gypsum is laminated in places and has the appearance of thin-bedded limestone.

The report includes a geologic section of the rocks that are exposed in the Cement oil field; a generalized geologic section of the Permian red beds of Oklahoma; a geologic structure map of the Caddo oil field, scale 1 inch = half a mile; and a geologic map of Oklahoma, scale 1 inch = 70 miles.

Richards, P. W., 1955, Geology of the Bighorn Canyon-Hardin area, Montana and Wyoming: U.S. Geol. Survey Bull. 1026, p. 3, 36–40, 87.

The area described in this report is in Big Horn County and in parts of Carbon County, Mont., and Big Horn County, Wyo. Gypsum occurs in several formations which include the Embar formation of Permian age, the Chugwater formation of Permian and Triassic age, and the Piper formation of

Middle Jurassic age. The gypsum in the Embar occurs as thin beds and stringers, from the middle to the top of the formation, in a series of maroon siltstone and gypsiferous sandstone and dolomite.

The Chugwater formation consists of red sandstone and siltstone with minor amounts of gypsum, which occurs in the form of stringers and veinlets throughout and as thin beds at the base. In this formation, the thickest beds of gypsum are in Big Horn County, Mont., along Soap Creek, where there are 3 beds of gypsum, which range from 8 to 38 feet in thickness and contain numerous red shale partings.

The Piper formation consists of 150 feet of red sandstone and siltstone, limestone, and gypsum. The basal unit of the formation consists of about 47 feet of white and granular gypsum, which occurs in 2- to 4-foot beds that are separated by red shale and dolomtic shale, which are as much as 4 inches thick. The Piper formation crops out in Big Horn County, Mont., and the thickest beds of gypsum are along Grapevine Creek.

Richardson, G. B., 1905, Salt, gypsum, and petroleum in Trans-Pecos Texas: U.S. Geol. Survey Bull. 260, p. 573–585.

The report describes results of a rapid reconnaissance in the area north of Van Horn, Tex., to the Texas-New Mexico boundary. A broad belt of gypsum extends from New Mexico southward into Texas for 50 miles between the Delaware and Guadalupe Mountains on the west and the Rustler Hills on the east. The belt is 30 miles wide at the Texas-New Mexico border, but averages about 15 miles wide. The gypsum covers an area of about 600 square miles. The gypsum is massive, granular, generally white, and comparatively pure, although, in places, dark-gray and red gypsum is present. Locally, selenite is present in great abundance. Thin beds of limestone are included within the gypsum. On the surface the gypsum is earthy and includes some native sulfur. Caverns formed by solution of the gypsum are abundant within the formation.

A sketch map of the area, scale 1 inch=18 miles, is included.

________ 1914, Description of the Van Horn quadrangle [Texas]: U.S. Geol. Survey Geol. Atlas, Folio 194, p. 1, 3, 5–7, 9.

The Van Horn quadrangle in Texas is in the eastern part of El Paso (now Hudspeth) and Culberson Counties. Within the quadrangle, there are several mountains that rise abruptly out of an extensive bolson. The sequence of rocks exposed in the Delaware Mountains, in the northern part of the quadrangle, ranges from Precambrian to Quaternary and includes the Castile formation of upper Permian age, which contains gypsum. The gypsum weathers on the surface to gypsite, but at depth the gypsum is white and granular. The formation here is about 275 feet thick. In places, crystals of gypsum, which were derived from the evaporation of gypsum-bearing waters on the bolson, have been blown into dunes that are 20 to 30 feet high.

The report includes topographic and geologic maps, scale 1 inch=2 miles, and geologic sections of the area.

________ 1915, Description of the Castle Rock quadrangle [Colorado]: U.S. Geol. Survey Geol. Atlas, Folio 198, p. 1, 5–6, 12.

The Castle Rock quadrangle includes parts of Douglas, El Paso, and Elbert Counties, in an area between Denver and Colorado Springs. Gypsum occurs in beds that are as much as 50 feet thick at the top of the Lykins formation of Permian age. A geologic map, scale 1:125,000, shows the outcrop of the Lykins formation.

Riddell, W. C., 1950, Physical properties of calcined gypsum: Rock Products, v. 53, no. 5, p. 68–71, 102.

This article is a review of Kelley, K. K., Southard, J. C., and Anderson, C. T., 1941, Thermodynamic properties of gypsum and its dehydration products: U.S. Bur. Mines Technical Paper 625.

All varieties of $CaSO_4 \cdot H_2O$ have the same energy content and probably the same crystal form, which is monoclinic prismatic with 4 or 8 molecules in the unit cell. The crystal lattice is considered to be made up of layers of calcium atoms and sulfate groups, which are separated by sheets of water molecules. A difference exists in structure between the dehydrate and the hydrites of lower form. Hemihydrate occurs in two forms: alpha $CaSO_4 \cdot \frac{1}{2}H_2O$ and beta $CaSO_4 \cdot \frac{1}{2}H_2O$. The hemihydrate is described as a deformed monoclinic structure with 12 molecules of $CaSO_4 \cdot \frac{1}{2}H_2O$ in a unit cell. The lattice structure possesses great stability because the molecular arrangement gives a strong bond between the calcium atoms in one layer and the sulfate group in the adjacent layers. The forces that hold the water molecules are less than the forces between the other groups, and thus at least part of the water can be removed without disrupting the crystalline structure.

Alpha $CaSO_4 \cdot \frac{1}{2}H_2O$ can be prepared by dehydration of gypsum in water above a temperature of 97°C, by dissociation in a salt solution below this temperature, and by dissociation in an atmosphere of steam.

Beta $CaSO_4 \cdot \frac{1}{2}H_2O$ can be prepared by dissociation of gypsum in a vacuum at 100°C.

Both alpha and beta forms of $CaSO_4 \cdot \frac{1}{2}H_2O$ have the same crystal forms. The beta form has a higher energy content and a higher solubility. Experiments showed that, in a batch of calcined gypsum for use in hardwall plaster, the plaster had a content of 75 percent alpha $CaSO_4 \cdot \frac{1}{2}H_2O$ and 25 percent beta $CaSO_4 \cdot \frac{1}{2}H_2O$. A batch of calcined gypsum that was made by the addition of 0.1 percent of salt, such as $CaCl_2$, in the kettle for manufacture of casting plasters, was practically all in the form of alpha $CaSO_4 \cdot \frac{1}{2}H_2O$.

There are two forms of soluble anhydrite that correspond to the alpha and beta forms of hemihydrate. Alpha soluble anhydrite can be prepared by dehydration of alpha-hemihydrate in a vacuum at 100°C or at 110°C, in air saturated with water vapor at room temperature. Beta soluble anhydrite can be prepared by dehydration of beta-hemihydrate at 100°C or by heating gypsum in an atmosphere of low water vapor content at 140 to not over 200°C. Both forms have some residual water, but it is less than 1 percent. Both forms are excellent drying reagents absorbing water to form hemihydrate.

There is only one form of insoluble or natural anhydrite, $CaSO_4$. This can be prepared by heating gypsum at 900°C for 1 hour. Insoluble anhydrite has the lowest solubility rate of all the calcium sulfates. It is a simple orthorhombic lattice; the unit cell contains 4 molecules.

Solubility determinations (solubility of grams of $CaSO_4$ per 100 grams H_2O), over a range from 0° to 100°C, on $CaSO_4 \cdot 2H_2O$, the 2 hemihydrates, and soluble and insoluble anhydrites, show that the solubility curves of all forms intersect between the temperatures of 97° and 100°C. Hydrogen-ion determinations on various samples of gypsum and calcined gypsum show that the pH of natural gypsum ranges from 4.80 to 7.80 and of plasters, from 6.30 to 11.60.

Roberts, R. W., Branner, G. C., and Owens, M. R., 1942, Arkansas natural resources—their conservation and use: Little Rock, Ark., Democrat Printing & Lithographing Co., p. 121–122.

Gypsum is found in the De Queen limestone member, of the Trinity formation of Cretaceous age, which crops out in a narrow belt from the Little

Missouri River at Plaster Bluff, Pike County, westward through Sevier County into Oklahoma. At Plaster Bluff, the thickest exposure is 10 to 12 feet. Since 1932, gypsum has been produced from Highland, 4 miles west of Plaster Bluff.

Robertson, A. F., 1951, Mines and mineral deposits (except fuels) Cascade County, Mont.: U.S. Bur. Mines Inf. Circ. 7589, p. 73.

Gypsum has been mined and processed in Cascade County from 1908 to 1915, from a deposit near Riceville. A railroad, which since has been abandoned, ran close to the deposit. The gypsum is interbedded with gray-green shale and sandstone near the top of the Otter formation of Mississippian age. In all, about 100,000 tons of gypsum was shipped from this deposit, most of it going to Great Falls. The mine is now inaccessible.

Another gypsum deposit occurs at Goodman about 3 miles north of Riceville. No gypsum has been produced from this deposit.

Robertson, Percival, 1935, An occurrence of gypsum rosettes in a cave in Jefferson County, Missouri [abs.]: Missouri Acad. Sci. Proc., v. 1, p. 123.

Rosettes of gypsum have been found at the top of the Plattin limestone in a cave in Jefferson County, Mo.

Robinson, T. W., and Lang, W. B., 1938, Geology and ground-water conditions of the Pecos River Valley in the vicinity of Laguna Grande de la Sal, New Mexico, with special reference to the salt content of the river water: New Mexico State Engineer 12th and 13th Bienn. Repts., p. 77–100.

The area covered in this report is in the Pecos River Valley, southeast of Carlsbad, Eddy County, N. Mex. The Permian formations present in the area, which contain gypsum and anhydrite, include the Rustler, Salado halite, and Castile anhydrite formations. The Rustler formation is about 500 feet thick and is divided into 2 sections: the upper part is about 200 feet thick and contains beds of gypsum that are as much as 100 feet thick and that are separated by red beds and dolomitic gypsiferous beds; the lower part contains alternating sandstone and red beds. At the base is a gypsum bed that is more than 100 feet thick.

The Salado halite formation is made up principally of salt, but also contains supplementary beds of anhydrite. Most of the anhydrite is in the lower part.

The Castile anhydrite formation attains a thickness of 2,500 feet, and is composed mainly of anhydrite, but also contains lenses and beds of salt, limestone, and sandstone.

The Quaternary deposits in the Pecos Valley contain some gypsum, as does the Playa Laguna Grande de la Sal. The playa is filled to a depth of 55 feet with fine crystalline gypsum.

The report contains a geologic map, scale 1 inch = 1 mile, of the Pecos River Valley from Laguna Grande de la Sal to Pierce Canyon. A generalized columnar section of the Rustler formation in the Pecos Valley is also included.

Rock Products, 1947, Southwest's newest plaster mill: v. 50, no. 6, 106–107.

The Union Plaster Co. of Phoenix, Ariz. has been mining gypsum since 1946 from a deposit that is estimated to contain 40 million tons. The gypsum is blasted and then loaded on trucks for transportation to the railroad for shipment to Phoenix. At the plant, the material is crushed before being put through one of two Raymond mills. The pulverized material is placed in a steel silo, where it can either be drawn for agricultural uses or be sent to one of two calcining kettles. From the hot pits, the stucco is mixed with fiber and retarder and sacked for plaster.

Rock Products, 1950a, Gypsum operations: v. 53, No. 12, p. 95–96.

The report briefly describes the physical and chemical properties of gypsum and the methods of fabricating gypsum products. The locations of the ten gypsum plants of the National Gypsum Co. are described, as well as the sources of raw material for each plant.

——— 1950b, Quarrying and milling, practices [National Gypsum Co.]: v. 53, no. 12, p. 112.

The National Gypsum Co. mines gypsum by both open-quarry and underground methods. In quarrying, the major problem is stripping, because the surface of most gypsum deposits is eroded and pockety, and the pockets are filled with dirt and clay, which are difficult to remove. In Nova Scotia, stripping involves removing trees and brush as well as overburden.

At Clarence Center, N.Y., the gypsum beds are about 60 feet below the surface and remarkably uniform in thickness. When exploratory diamond drilling is done at Clarence Center, the holes are spaced as far as 800 feet apart.

——— 1950c, Transportation of products and raw materials [National Gypsum Co.]: v. 53, no. 12, p. 115–118.

Transportation of gypsum by the National Gypsum Co. is a broad subject. Haulage of raw gypsum from Nova Scotia to the four coastal plants is done by three company-owned ships, each having a 10,000-ton capacity, from about April 1 to November 15, and amounts to more than a million tons a year.

Finished gypsum products are shipped by rail and truck. Pallet loading speeds all shipments by making handling easier.

——— 1958, Automatic control in board-lath plant—use latest techniques: v. 50, no. 11, p. 84–85.

The operation of the gypsum plant of the Fibreboard Paper Products Corp. near Florence, Colo. is described. The gypsum, which is used for the manufacture of the gypsum products, is quarried at Coaldale, 50 miles west of the plant, and shipped to the plant by rail.

Rogers, A. F., 1910, Anhydrite and associate minerals from the salt mines of central Kansas: Am. Jour. Sci., v. 29, 4th ser., p. 258–261.

Massive gray or reddish granular anhydrite was collected from the dump piles of the salt mines at Kanopoho, Ellsworth County, and at Lyons, Rice County, Kans. The anhydrite occurs both with and below the salt deposits in lower Permian rocks, and is in thin layers that are rarely more than 4 inches thick. Under the microscope, it is an aggregate of imperfect subangular squares. Some gypsum is present as a subordinate mineral and is, apparently, always secondary.

——— 1912, The occurrence and origin of gypsum and anhydrite at the Ludwig mine, Lyon County, Nevada: Econ. Geology, v. 7, p. 185–189.

The occurrence of gypsum at the Ludwig Copper mine, Lyon County, Nev., is described. White gypsum crops out for a distance of 4,000 feet in a bed that is 450 feet wide. The bed dips 60°E. and strikes north. The gypsum is pure and uniform in composition, averaging about 96 percent pure, and is underlain by quartzite and overlain by limestone. The copper occurs above the limestone. At a depth of 400 feet, the gypsum bed was cut by a drift from the copper mine, which went through 10 feet of gypsum before penetrating anhydrite. This is the deepest gypsum that has yet been found (1912). The author concludes that the gypsum was formed by the alteration of anhydrite, which was formed from evaporation of water in an inland sea.

Rock Products, 1915, Notes on occurrence of anhydrite in the United States: New York, Columbia Univ. School Mines Quart., v. 36, no. 2, p. 123–142.

It is pointed out that anhydrite is much more abundant than has been thought in the past. Anhydrite is easily mistaken for gypsum or limestone, but it can be distinguished by specific gravity, solubility, microscopic examination, and chemical test. Anhydrite generally occurs in sedimentary beds, and gypsum is formed near the surface by hydration of the anhydrite.

Roller, P. S., and Halwer, Murray, 1937, Relative value of gypsum and anhydrite as additions to portland cement: U.S. Bur. Mines Tech. Paper 578, 15 p.

The effectiveness of anhydrite, as compared with gypsum, for use as a retarder in portland cement was investigated. The conclusions, which were derived from this study, indicate that anhydrite used alone is less effective than gypsum, because about four times as much pure anhydrite as gypsum of equal fineness is needed to produce the same effect. Quantitative conclusions were drawn as to the effect of anhydrite on the setting and strength of the portland cement and as to the permissible limits of its use in admixture with gypsum.

Rollins, R. Z., 1951, Minerals useful to California agriculture: California Div. Mines Bull. 155, p. 105–116.

The use of gypsum as an agricultural mineral has increased from a few thousand tons in 1940 to about 400,000 tons in 1952. The value of using gypsum is in the combined sulfur contained in the mineral. The earthy gypsum or gypsite in the San Joaquin Valley contains about 70 percent gypsum and about 18 percent SiO_2. Anhydrite, gypsum, or gypsite are all usable in agriculture. The combined sulfur in 100 pounds of gypsum is equivalent to that in 76 pounds of anhydrite and 143 pounds of gypsite containing 70 percent gypsum.

Gypsum is applied to improve soil texture, increase permeability of the soil, alleviate clod and crust formation, render soil easier to work, and reclaim alkali soils. The process by which alkali soil is reclaimed is by the reaction of gypsum with the sodium carbonate to form calcium carbonate and sodium sulfate. Gypsum is also used on sulfur deficient soils but is not used to reduce the acidity of soils. In California, application ranges from 1 to 20 tons per acre. Agricultural gypsum costs about $1.75 per ton at the mine and $6 a tone delivered (1952).

A bibliography on the uses of gypsum in agriculture is included.

Ross, C. P., Andrews, D. A., and Witkind, I. J., 1955, Geologic map of Montana: U.S. Geol. Survey, scale 1:500,000, 2 sheets.

The map shows the geologic formations of the State.

Roth, Robert, 1942, Upper Pennsylvanian anhydrite, west Texas: Am. Assoc. Petroleum Geologists Bull., v. 26, no. 8, p. 1412–1413.

A geologic section of a well drilled in Dickens County, Tex., indicates that anhydrite is in an 85-foot bed in the Cisco formation of Pennsylvanian age. Anhydrite was not known previously here from rocks older than the Permian.

________ 1945, Permian Pease River group of Texas: Geol. Soc. America Bull., v. 56, no. 10, p. 893–907.

As exposed in Texas, the Pease River group of Permian age is described as including the San Angelo, Flowerpot, Blaine, and Dog Creek formations. The type section is in King and Knox Counties in north-central Texas. Gypsum and anhydrite occur throughout the section, though much of the anhydrite and gypsum, as well as salt, has been removed from the outcrop by solution. In

measured sections, the gypsum beds range generally from 1 inch to 12 feet in thickness and average less than 2 feet thick. The thickest beds are near the top of the Pease River group.

Rothrock, E. P., 1944, A geology of South Dakota, part 3, Mineral resources: South Dakota Geol. Survey Bull. 15, p. 180–181.

All commercial gypsum in South Dakota occurs in the Triassic red beds which come to the surface where they surround the core of the Black Hills. The gypsum occurs in lenses and beds, which range from thin veinlets to beds that are 20 feet thick. The largest is probably a 20-foot bed, which can be traced from Spearfish, to Rapid City, S. Dak. A great many 4- and 5-foot beds occur throughout the area of outcrop. Calcining plants have been in operation at Hot Springs, Rapid City, and Tilford, S. Dak. The latter is the only one still operating (1944).

Gypsum is fairly abundant in most Cretaceous formations where it occurs as crystals on the outcrops of all shale formations. Analyses of 46 chalk rock samples show that gypsum comprises from a small fraction of a percent to about 7 percent of the rock and averages about 0.78 percent. The gypsum in these rocks is too low to be used for portland cement, for it requires about 2 percent gypsum for a retarder.

Rowe, J. P., 1908, Some economic geology of Montana: Montana Univ. Bull. 50, Geol. Ser. 3, p. 31–39.

The economic gypsum deposits in Montana may be divided into three general fields: the north, middle, and south fields.

The north field is located in Cascade and Fergus Counties. One series of deposits is located near the towns of Armington and Kibbey, Cascade County, and another series of deposits, in the Big Snowy Mountains of Fergus County, near Portuguese.

The Jurassic beds, which contain the gypsum, can be traced along the flanks of the Big Belt Mountains to Riceville, Cascade County, then eastward to Kibbey, and thence around the flank of the Little Belt Mountains to the vicinity of Castle Mountain. In 1905, the only plaster mill in operation in the north field was located along Belt Creek, which is 6 miles south of Armington. The annual capacity of the mill is about 1,800 tons. The gypsum beds here are between 25 and 30 feet thick, and nearly horizontal. The gypsum is pure, a sample assaying about 99 percent, though in places some clay is interstratified with it.

The second deposit in the north field is located about 35 miles south of Lewistown, at Portuguese, Fergus County. The material has not been worked, but, because it lies close to a railroad, it will probably be exploited in the near future.

The middle field is about 2 miles east of Lime Spur, Jefferson County, and on the Northern Pacific Railway. Not much is known of this field, though the gypsum appears to be of good grade. Some gypsite was also found.

The south field is located in Carbon County. A small mill is located at Bridger. An outcrop to the southeast is 10 to 12 feet thick and dips to the northeast. Gypsum also crops out 1½ miles from Bowler, in beds that extend for about 2 miles and range from 15 to 200 feet thick.

Additional outcrops are about 16 miles southeast of Bridger, and about 4½ miles from Crocket. The total length of the outcrop is 3 miles, and the thickness ranges from 15 to 50 feet. The beds dip a few degrees west.

Runkle, Doris, 1952, Gypsum: Indus. Devel. Dept., Ohio Chamber Commerce Pub. 13, 4 p.

In Ohio, gypsum occurs near Port Clinton, Ottawa County, and at Castalia, Erie County; both counties are in the Sandusky Bay area. At present, only two companies are operating, both in Ottawa County, on the north side of Sandusky Bay, where the gypsum is within 50 feet of the surface. At Sandusky a drill hole penetrated gypsum at a depth of 272 feet. At Cleveland, anhydrite has been found below rock salt at depths of over 2,000 feet.

Drill records show that gypsum and anhydrite are widely distributed in the Monroe formation of Silurian age throughout central Ohio. A map shows the location of gypsum deposits in Ohio.

Sampson, R. J., and Tucker, W. B., 1942, Mineral resources of Imperial County [California]: California Jour. Mines and Geology, v. 38, no. 2, p. 134–136.

Gypsum occurs in several places in Imperial County. The largest deposit is in the Fish Creek Mountains where the deposit covers an area of 1,000 acres. The gypsum from this deposit is shipped to Plaster City to be made into plaster, or to be used as agricultural gypsum or as a retarder for portland cement.

Other deposits occur (a) on the south slope of the Carrizo Mountains, 7 miles north of Carrizo Springs, and (b) on Coyote Mountain, 3 miles north of Coyote Wells. The latter deposit averages 8 feet thick and covers an area of 10 acres.

Santmyers, R. M., 1929a, Gypsum, its uses and preparation: U.S. Bur. Mines Inf. Circ. 6163, 28 p.

The history, physical properties, solubility, compressive strength, mining methods, preparation, uses, and varieties of gypsum are given in a brief summary.

——— 1929b, Marketing of gypsum products: U.S. Bur. Mines Inf. Circ. 6157, 26 p.

Statistical data regarding sales of crude gypsum, gypsum building materials, and other gypsum products are presented.

——— 1929c, Development of the gypsum industry by States: U.S. Bur. Mines Inf. Circ. 6173, 44 p.

The statistics of production and sales of gypsum in the United States are summarized, from the inception of the gypsum industry to 1927. The occurrences of gypsum in the individual States are discussed briefly. The report includes a list of manufacturers of gypsum products in the United States for the year 1928.

Saxby, D. B., and Lamar, J. E., 1957, Gypsum and anhydrite in Illinois: Illinois State Geol. Survey Circ. 226, 26 p.

In Illinois, gypsum and anhydrite occur in the St. Louis formation of Mississippian age. The deposits are restricted to subsurface in the southern part of the State. The minimum depth that would have to be drilled to reach the anhydrite and gypsum is 470 feet. The thickest section of pure gypsum is 2 feet, cut at a depth of 896 feet below the surface. The report contains maps of southern Illinois, which show the location and the thickness of the evaporite units. Drill logs of 23 wells are included.

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, p. 1, 5, 15–16, 31.

The Permian salt basin that lies in southeastern New Mexico and western Texas was drilled for potash. Anhydrite is present in all the cores taken.

The anhydrite is banded by layers of magnesite or by clay which contains magnesite. The bands are not so perfect or abundant as those described by Udden (1924). The specimens of drill core, which consist predominantly of anhydrite, are compact, massive, and fine grained. Many of the anhydrite crystals show no regular shape, whereas others show a tendency toward a rectangular outline. The crystal shapes, however, are not true rectangles because the rectangle expression is inhibited by neighboring anhydrite crystals. Grain size of massive anhydrite ranges from 0.01 mm in diameter, for the smallest, to 0.12 mm in diameter, for the largest. Isolated grains, which are scattered throughout the anhydrite rock, have diameters up to 0.5 mm. The larger crystals represent a second or later generation. At places in the core, the anhydrite crystals are intergrown with halite and polyhalite crystals. The association seems to show that the halite has been intruded into the anhydrite and magnesite.

Gypsum is rare in the core examined. In one well, at a depth of about 755 feet, there is a 1-foot layer of brown, fine-grained, dull, and earthy-looking gypsum which lies between anhydrite.

A map, scale 1 inch = 65 miles, shows the location of drill holes in the New Mexico and Texas potash field.

Schloten, Robert, Keemon, K. A., and Kupsch, W. O., 1955, Geology of the Lima region, southwestern Montana and adjacent Idaho: Geol. Soc. America Bull., v. 66, no. 4, p. 400.

Gypsum occurs in the Tendoy Range about 10 miles west of Lima, Beaverhead County, Mont., in the shaly and limy beds of the Big Snow(?) group of Mississippian age. Several deposits are present, but the only one that has been worked is on the East Fork of Little Sheep Creek. The gypsum is as much as 15 feet thick, and occurs in a folded and faulted bed.

A geologic map and cross sections, scale 1 inch = 2 miles, show the outcrop and structural relationships of the gypsum-bearing rocks.

Scruton, P. C., 1953, Deposition of evaporites: Am. Assoc. Petroleum Geologists Bull., v. 37, no. 11, p. 2498–2511.

Studies of circulation patterns in estuaries and other restricted arms of the sea show that, in areas of humid climate where the quantity of fresh water that is introduced into the basin is greater than evaporation, surface water flows toward the sea and the sea water flows landward in a reverse current beneath the surface water. In arid climates, where evaporation is greater than the inflow from rivers plus precipitation, the current flows from the sea into the restricted arm on the surface and a reverse current flows beneath the surface current from the restricted arm toward the sea. The bottom current in this case has a higher salinity than the surface current because of evaporation in the basin. It is shown, therefore, that the surface current always flows in the direction of increasing salinity and that the bottom current flows in the direction of decreasing salinity.

When conditions of excess evaporation over precipitation and runoff exist, a slope of the water surface develops, causing a basinward flow of sea water due to hydrostatic pressure. If conditions remain uniform, an approximate equilibrium exists between input of fresh and salt water and output of bottom water. With this stability, salinity characteristics do not change and the horizontal gradient does not shift markedly within the basin.

Restriction of the deep water to the basin is necessary for high-salt content to be developed. These are of two types: a bar, sill, or other physical barrier; and a dynamic barrier, which is caused by a hydrostatic head and friction between the oppositely opposed currents and also between the bottom current and the basin or channel floor. Thus, water of low salinity will keep water of high salinity in an estuary.

The inferred process for evaporite deposition is as follows: An excessive rate of evaporation removes water from a restricted basin, which causes a slope of the sea surface to develop and a continuous flow of additional ocean water to enter the basin. A current of dense water flows seaward along the bottom. Mixing occurs between the two currents, which tends to increase the salinity of the incoming currents. The destruction of the organisms that are swept in results, and the shells are returned to the sea by the bottom current. Salts are precipitated in the order determined by J. Usiglio. An ideal vertical section through the evaporites will show that beds of iron oxide are overlain by calcium carbonate, calcium sulfate, and sodium chloride. However, deviation from this order is more probable since variations in rainfall, temperature, or sea level can alter the normal deposition sequence. Horizontal segregations of evaporite deposits can be produced by strong horizontal salinity gradients. The salinities increase from the entrance of the basin to the head of the evaporating pan so that $CaCO_3$ could be deposited at the seaward end of the basin, and NaCl at the headward end, with $CaSO_4$ being deposited in between.

The report includes overall examples of the geologic sequence of evaporite deposition.

Scott, G. L., and Ham, W. E., 1957, Geology and gypsum resources of the Carter area, Oklahoma: Oklahoma Geol. Survey Circ. 42, 64 p.

The Carter area covers 166 square miles along the North Fork of the Red River in southwestern Oklahoma, which is mostly in Beckham County, and in parts of Greer, Kiowa, and Washita Counties. The bedrock exposed within the area consists of the Guadalupe and Leonard series of middle Permian age. Gypsum occurs in the Flowerpot shale and the Blaine gypsum of the El Reno group of the Guadalupe series. The gypsum in the Flowerpot shale consists of 2 persistent thin beds, which occur in the upper part of the formation: the lower bed, the Chaney member, is generally 42 to 50 feet below the top of the formation and is typically gray to white massive gypsum that is 1 to 3 feet thick; the upper bed, the Kiser gypsum member, is about 25 feet below the top of the Flowerpot and is a well-bedded, greenish to reddish, very shaly gypsum that is 2 to 5 feet thick. These beds are separated by red, brown, and maroon shales.

The Blaine formation consists of 4 massive white gypsum beds that are separated from each other by beds of red and green shale. The formation ranges in thickness from 130 to 140 feet; of this, 90 feet, or about 70 percent, is massive gypsum. The gypsum beds thin toward the east and grade into shales east of the center area. From the base upward, the gypsum beds are: the Haystack, Cedar Top, Collingsworth, and Van Vacter gypsum members. The Haystack is correlated with the Medicine Lodge gypsum member, the Cedartop is correlated with the so-called Alabaster, the Collingsworth is correlated with the Nescatunga gypsum member, and the Van Vacter is correlated with the Shimer gypsum member. In the Carter area, the Haystack ranges in thickness from 17 to 24 feet and consists of a band of gray to dark-gray shaly gypsum, which is 1 foot thick at the base; white to gray, compact, massive, and very fine gypsum to fine-crystalline gypsum, which is somewhat laminated in the lower 8 feet; and a bed of dolomite, which is 1 to 5 inches thick and is present about 7 feet above the base.

The Cedartop is separated from the Haystack by about 12 feet of shale and from the overlying Collingsworth by about 14 feet of shale. The Cedartop has a constant thickness in the Carter area of about 18 to 20 feet, and is a massive white to slightly pink gypsum, which weathers to gray. Included in the gypsum bed is a thin limestone bed that is 0.5 to 2 inches thick. A gray compact coarsely crystalline anhydrite bed, which is about 2 feet thick, occurs in the middle of the member along a steep escarpment in the western part of the area.

The Collingsworth is fine grained, massive, white to slightly pink, and 18 to 22 feet thick. On the surface, it is badly weathered and, in places, is eroded, so it does not always appear in the section. Some anhydrite is present.

The Van Vacter, which is here described for the first time, is at the top of the Blaine formation. It directly overlies the Mangum dolomite member, which is a thin persistent dolomite bed, and is about 18 feet above the Collingsworth. In the type area, the Van Vacter is about 36 feet thick and consists of a lower and upper division of massive white and pink granular gypsum. The lower gypsum bed ranges from 12 to 15 feet in thickness, and the upper is 18 feet thick. The beds are separated by 3 to 4½ feet of red shale. Above the Van Vacter is the Dog Creek shale formation.

An estimated 375 million tons of gypsum reserves, averaging about 96.5 percent, is present in the Carter area. This figure was gained by calculating the material that occurred 30 feet or less below the surface, which could be easily worked by opencut. The average thickness of the 4 gypsum beds is about 13 feet. Material overlain by more than 30 feet of cover probably is anhydritic. Reserves of anhydrite to a depth of 130 feet are estimated to be about 1.14 billion tons.

A geologic map, scale 1 inch = half a mile, and a correlation diagram of the measured sections are included.

Sellards, E. H., and Baker, C. L., 1934, The geology of Texas: Texas Univ. Bull. 3401, v. 2, p. 623–631.

The properties of $CaSO_4$ are discussed. Anhydrite is the form in which $CaSO_4$ was originally deposited and the gypsum is secondary. In Texas, gypsum occurs in several different parts of the State. On the Gulf Coastal Plain, 6 miles southeast of Falfurrias, Brooks County, is a 50-acre mound of selenite crystals which are about 1,000 feet thick. Gypsum also occurs in north-central Texas in the Blaine formation of Permian age. In Culberson County, gypsum occurs in Permian beds, which crop out in the central and eastern part of the county. In the Malone Mountains in Hudspeth County, gypsum occurs in Permian beds. In Gillespie, Kinney, and Menard Counties, gypsum occurs in the Edwards limestone of Cretaceous age.

Beds of anhydrite have been found by drilling in northeastern Texas in the Trinity formation of Cretaceous age. Anhydrite and gypsum are found in the caprocks of probably 56 salt domes in the coastal section of Texas and 17 additional ones in the east Texas syncline.

Gypsum is being deposited at present in very shallow lagoonal waters along the southwest Texas coast. A considerable deposit of coarsely crystalline selenite, which contains sand grains, has been found in dredging at the southwest end of Laguna Madre.

The uses of gypsum are described and the producers of gypsum in Texas are listed.

Sellards, E. H., and Evans, G. L., 1943, Index to Texas mineral resources, *in* Texas mineral resources: Texas Univ., Bur. Econ. Geology Pub. 4301, p. 370, pl. 1 [1946]. *See also* Sellards and others, 1944.

Gypsum is widely distributed in Texas. The main occurrences are (a) in the Blaine and Double Mountain formations of Permian age, which crop out east of the High Plains; (b) in the Castile formation of Permian age, which crops out between the Delaware Mountains and the Pecos River in Culberson and Reeves Counties; (c) in rocks of probable Permian age in the Malone Mountains of Hudspeth County; (d) in the Edwards limestone of Cretaceous age in Gillespie and Menard Counties; (e) in the caprock of the Hockley dome in Harris County; and (f) in Gyp Hill in Brooks County.

Sellards, E. H., Evans, G. L., and Hendricks, Leo, 1944, Mineral locality map of Texas, scale 1:1,000,000, *in* Texas mineral resources 1943: Texas Univ., Bur. Econ. Geology Pub. 4301, plt. 1 [1946].

The map shows the occurrence of gypsum and other minerals, rocks, and oil and gas in Texas.

Shaler, M. K., 1907, Gypsum in northwestern New Mexico: U.S. Geol. Survey Bull. 315–H, p. 260–265.

Gypsum crops out along the western base of the Sierra Nacimiento, which extends approximately 35 miles from Gallina Mountain, southward to Jemes Peak, N. Mex. The gypsum deposits lie near the top of the red bed series of either Triassic or Jurassic age, and are underlain by a bed of bright yellow, poorly consolidated sandstone.

A geologic section of the gypsum, which was measured near the north end of the outcrop, shows that the gypsum is more than 40 feet thick. The thickness of the gypsum ranges from 54 to more than 100 feet at the south end of the outcrop. The gypsum is white and massive and, from a single analysis, nearly 100 percent pure. The reserves are apparently inexhaustible, but due to the difficulties involved in transportation, the gypsum is not economic to mine.

A sketch map, scale 1 inch = about 10 miles, is included.

Sharrer, G. H., 1952, Gypsum from public lands: Public Lands, Bur. Land Management, v. 2, no. 4, p. 5.

The report gives a brief history of the gypsite deposits in the Lost Hills oil field on the west side of the San Joaquin Valley in Kern County, Calif. The gypsite is mined by open-pit methods and used as an agricultural mineral. Reserves are estimated to be not less than 500,000 tons. Because the gypsum is on public land, royalties of 20 percent of the sale price, which is $1.65, are returned to the Government.

Shield, Elgean, 1937, Report on the O. L. Neyland gypsum mine in Gillespie County, Texas: Texas Univ. Mineral Resources Survey Circ. 19, 2 p.

The Neyland quarries are located 15 miles northwest of Fredricksburg, Gillespie County, Tex. The mine is located on top of long limestone ridge that fingers out from the West Edwards Plateau. The geologic section that is exposed here includes 18 feet of massive limestone, which overlies 13 feet of clear blue gypsum; underlying the gypsum is soft buff limestone. Several sinkholes occur, which are formed by the removal of gypsum in solution. Prospecting for additional deposits should be done in the vicinity of the sinkholes.

Shipments in 1936 averaged 10 carloads a month. Material was trucked to the Frisco and Northwestern Railroad at Fredricksburg.

Shreveport Geological Society, 1953, Upper and lower Cretaceous of southwestern Arkansas, Cambrian-Pennsylvanian of the Ouachita Mountains and Magnet Cove: Guidebook 19th Ann. Field Trip, p. 18.

The anhydrite and gypsum quarry at Highland (Plaster Bluff), Ark., is operated by the Arkansas Gypsum Co., and is in the De Queen member of the

Trinity formation, of Cretaceous age. Gypsum, limestones, and shales are equivalent to the Ferry Lake formation, which is found in the subsurface to the south and east.

Sloss, L. L., 1953, The significance of evaporites: Jour. Sed. Petrology, v. 23, no. 3, p. 143–161.

Interpretation of lithologic and paleontologic associations, of which evaporites form a part, permits classification and mapping of environments that are involved in evaporite occurrence. These environments include:

1. Brackish and terrestrial environments for rocks that are found along the margins of evaporites.
2. Normal marine environments that occur marginal to evaporites.
3. Euxenic environments, which are environments that are characterized by accumulations of black shales and limestones rich in organic matter.
4. Penesaline environments, which are intermediate between normal marine and saline environments.
5. Saline environments, which are characterized by major accumulations of halite and anhydrite.
6. Supersaline environments, which are characterized by abnormal concentrations of potash salts.

The last environment is found only in the Salado evaporite of Permian age, of west Texas, and the Elk Point group of the Middle Devonian, of southern Saskatchewan, Canada.

The two environments in which calcium sulfate is deposited are the penesaline and saline. A penesaline environment is characterized by primary dolomite interbedded with anhydrite. These sediments imply that the conditions maintained were characterized by concentrations of marine salts, which were sufficient to be toxic to normal marine life and yet insufficient to permit precipitation of chlorides. Saline environments are characterized by major accumulations of halite and anhydrite. Both of these environments imply that there was a restriction of marine waters under arid conditions, with a continued inflow of normally saline waters.

The report includes paleogeographic maps of the Permian in west Texas and New Mexico, the Silurian of the Michigan basin, the Devonian in Montana-Alberta, and the Mississippian of the Williston Basin.

Analysis of these areas indicates that there is a major evaporite cycle of normal marine environment, fossiliferous limestone and shales, which are overlain by rocks of penesale environment—anhydritic dolomite and anhydrite. These, in turn, are overlain by rocks of the saline environment—halite and anhydrite—above which are rocks of the penesaline environment—anhydritic dolomite and anhydrite—which are succeeded, in turn, by rocks of normal marine environment. Several minor variations in the evaporite cycle are included. The upward succession from normal marine to saline is the advancing restricted hemicycle, which is superseded by the relaxing restricted hemicycle, in which salines grade upward into rocks of the penesaline and normal marine environment.

The basinal subsidence of the province concerned tends to vary directly as the degree of environmental restriction; thus, the evaporite cycle is both an environmental and tectonic phenomenon.

The limestone phase gives little indication of tectonic differentiation. The penesaline phase is normally characterized by marked isopach rates of change, which reflect the differentiation into shelves and basins with hinge lines and platforms; these tendencies are increasingly manifest in the saline stage.

The advancing hemicycle is seen as a progression toward higher and higher stages of instability and differentiation, whereas the relaxing hemicycle shows the reverse course back to stability. The advancing half represents thicker and longer deposition. The return to stability, at the close of a cycle, involves an area that is generally subjected to erosion, and this part of the cycle may be missing.

An interrelationship exists between reef structure and evaporites. Most of the reefs that are associated with evaporites are linear complexes of the barrier type and are apparently developed along the tectonic hinges that separate basins and shelves.

Evaporites are commonly associated with black shales and limestones, either areally or vertically.

A submerged sill is almost universally postulated as being the inhibiting force, which let normal saline waters flow in to replace evaporation and inhibit the outflow of the concentrated saline water.

Evaporites can be classified as follows:

1. Intrabasin evaporites
   - A. Tectonically silled intrabasin evaporites; example: Mississippian of the Williston Basin, Mont.
   - B. Reef enclosed intrabasin evaporites; example: Silurian of the Michigan Basin.
2. Basin margin evaporites
   - A. Back reef evaporites—lagoonal types; example: Leonardian and Guadalupian evaporites of west Texas.
   - B. Topographically silled basin margin evaporites; example: isolated evaporites equivalent to the Gypsum Spring formation in the Jurassic in Montana.

Smith, R. A., 1912, Gypsum and gypsum products: Michigan Geol. Survey Pub. 8, ser. 6, p. 305–314.

In Michigan, gypsum of commercial importance occurs in 3 areas:

1. In the Grand Rapids-Grandview area, Kent and Ottawa Counties, where gypsum occurs in the Michigan formation of Mississippian age in 3 beds; the upper is 6 feet thick, the middle is 12 feet thick, and the lower is 22 feet thick.
2. At Alabaster, Iosco County, where the gypsum occurs in the Michigan formation in a single bed that is 18 to 23 feet thick.
3. At St. Ignace, Mackinac County, where 3 beds of gypsum that are 5, 13, and 21 feet thick, respectively, have been reported in the Monroe formation of Silurian age.

Additional beds are reported to occur 50 to 100 feet below the surface near Turner and Twining, in Arenac County, just south of Iosco County.

A sketch map shows the location of the gypsum-producing areas and the gypsum deposits.

Smith, R. A., and Stone, R. W., 1920, Michigan, *in* Stone, R. W., Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 122–129.

In Michigan, gypsum occurs to a limited extent in the Michigan formation, which is the lowest formation of the Grand Rapids group of Mississippian age. Other deposits are known in the Bass Island dolomite of Silurian age and in the Salina formation of Silurian age. The Grand Rapids group underlies the Michigan Coal basin and is exposed in a nearly continuous belt around it. Economic development of gypsum has been done in the Michigan formation, at Grand Rapids, Kent County, and Grandville, Ottawa County, where there are several beds of minable thickness; and at Alabaster, Iosco County, where the gypsum beds are 18 to 23 feet thick. The minable gypsum is in an area of 25 to 30 square miles. At Turner, Arenac County, a persistent bed of gypsum occurs 50 to 100 feet above the Alabaster gypsum bed.

At St. Ignac, Mackinac County, heavy beds of gypsum of Silurian age occur along the edge of Lakes Michigan and Huron. Water would probably be a problem in mining these beds.

Smith, R. W., 1956, Mineral industry map of Ohio showing non-metallic mineral deposits, scale 1:500,000; key to annual coal and non-metallic mineral report, with directories of reporting firms for 1955, by D. W. Alloway: Columbus, Ohio Dept. Indus. Relations, p. 145. Map not affixed to volume.

The location of two gypsum deposits in Ohio are shown. Both are in Ottawa County: one east of Port Clinton and the other at Gypsum.

Snider, L. C., 1913a, Oklahoma gypsum deposits and industry: Eng. Mining Jour., v. 95, no. 19, p. 931–933.

The gypsum deposits of Oklahoma occur in the western part of the State. The areas of gypsum occurrence may be divided into three districts: (a) the first line of gypsum hills, (b) the second line of gypsum hills, and (c) the southwestern area. The rocks that contain the gypsum are of Permian age.

The first line of hills enters the State from Kansas on the south side of the Salt Fork of the Arkansas River and swings back into Kansas along the northeast side of the Cimarron River. The formation crops out again on the southwest side of the Cimarron River, from the Oklahoma-Kansas line southward almost to El Reno, in Canadian County. The gypsum crops out in parts of Woods, Harper, Woodward, Major, Blaine, Kingfisher, and Canadian Counties. Gypsum generally occurs in three beds, which are separated by soft red shale and is selenitic in places. In the northern part of the district, the effects of the solution of gypsum is shown by the sinkholes and caves, which are present in great numbers. In the southern part of the district, the effects of solution are not as evident. Anhydrite, which is present within the gypsum as beds or lenses, becomes increasingly more pronounced toward the south. The anhydrite is a few inches to about 4 feet thick. Southeast of Watonga, the gypsum thins rapidly and becomes lenticular; the gypsum disappears north of El Reno.

The second line of gypsum hills occupies a large area in Dewey, Custer, Washita, and Caddo Counties. The gypsum is lenticular and not continuous over large areas. The number of beds of gypsum range from 1 thick bed and several thin beds in the northern part of the area to 4 or 5 thick beds in the southern part. Beds more than 100 feet thick have been reported in drill holes. The gypsum ranges from fine-grained and massive to coarsely crystalline selenite and from pure white to red or green.

The southwestern area occupies all of Harmon County, southeastern Beckham County, and western Greer and Jackson Counties. The gypsum beds resemble those of the second line of gypsum hills, though they are more regular in their stratification. The best exposures are along the Salt Fork of the Elm River.

The report describes the calcination process and discusses the costs involved in mining and milling gypsum. A list of the 12 plaster mills in Oklahoma is included.

_______ 1913b, The gypsum and salt of Oklahoma: Oklahoma Geol. Survey Bull. 11, p. 1–201.

The chemical and physical properties of gypsum are described, and also the occurrence of gypsum in nature. The various theories of the origin of gypsum are discussed, and it is concluded that the gypsum deposits in Oklahoma were formed by the evaporation of sea water in relatively shallow basins, which had at least an intermittent connection with the ocean. The report gives a brief description of the areal distribution of gypsum within the United States and abroad.

Included is a discussion of the mining, crushing, and calcining of gypsum, and the manufacturing of finished plaster products. At the time the report was written, 12 plaster mills in Oklahoma were operating: 2 at Watonga, and 1 each at Bickford, Okeene, Southard, Wilson (Homestead) and Ferguson, all in Blaine County; and 1 each at Okarche, Kingfisher County; Alva, Woods County; Rush Springs, Grady County; Eldorado, Jackson County; and McAlester, Pittsburg County.

Although there is an inexhaustible supply of gypsum in Oklahoma, it is a great distance from a source of coal. In addition, the Oklahoma mills are far from large trade centers. These factors make it unfavorable for further development of the gypsum industry in the State.

Raw gypsum is used as a fertilizer, as a retarder for portland cement, as a basis for paints, and several other minor uses, such as a filler for paper.

Calcined gypsum is used for plaster of paris and other wall plasters, wallboard, lath, partition block, and various specialty plasters.

The report describes the gypsum outcrops in four areas (a) Kay County; (b) the main line of gypsum hills, that is, the outcrop of the Blaine formation; (c) the second line of gypsum hills, or the eastern area of the outcrop of the Greer formation; and (d) the southwestern area, also the Greer formation.

A geologic map of western Oklahoma, scale 1 inch = about 12 miles, shows the outcrops of the Blaine and Greer formations and county maps show the outcrop of the gypsum-bearing formations.

Snider, L. C., 1920, Oklahoma, *in* Stone, R. W., and others, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 224–235.

The gypsum deposits in Oklahoma are in the western part of the State in the red beds of Permian age. In addition, there are several large deposits of gypsite that are scattered throughout the State.

The Oklahoma gypsum can be divided into three areas:

1. The main line of gypsum hills, which is produced by the outcrop of the Blaine gypsum, and consists of three beds of gypsum that are separated by layers of red shale. The main line of hills crops out in the north-central part of the State from the Kansas line southward in Woods, Harper, Woodward, Major, Blaine, and Canadian Counties.
2. The second line of gypsum hills, which crops out mostly in Dewey, Custer, Washita, Caddo, Grady, and Stephens Counties. The gypsum here forms a series of low rounded knolls and ridges. Though some of the lenses of gypsum are of considerable extent and thickness, no well-defined bed can be traced laterally very far.
3. In the southwestern area, where the gypsum crops out in Beckham, Greer, Harrison, and Jackson Counties. The gypsum here is in five beds that are separated by beds of red and green shale. The gypsum beds range generally from 3 to 25 feet in thickness, and each bed can be traced laterally over a considerable distance.

A map of Oklahoma shows the location of the gypsum deposits.

Soulé, G. H., 1952, Information concerning gypsum and a new all-purpose building material: U.S. Cong. H. Comm. on Interior and Insular Affairs, 76 p.

The uses, specifications, testing properties, and processing of gypsum are reviewed, and a brief description of the gypsum deposits in the United States and foreign importing countries is given.

A bibliography of gypsum is included.

South Dakota State Planning Board [1936], Portland cement, gypsum, and lime industries in South Dakota; a preliminary report of the Mineral Resource Committee: Brookings, S. Dak., p. 37–57.

The report includes descriptions of the occurrence of gypsum in the Black Hills and the operation of the gypsum plant at Piedmont, Meade County. A brief history of the gypsum industry in South Dakota is given.

Spurr, J. E., 1898, Geology of the Aspen mining district, Colorado, with atlas: U.S. Geol. Survey Mon. 31, p. 239–241.

Gypsum, which was formed by the alteration of the Weber limestone of Carboniferous age, occurs on the northeast side of West Aspen Mountain, Colo. The rock is brecciated both by faulting and by glaciation. Selenite has formed in crevices and as masses in the breccia, and many of the limestone boulders have been altered to gypsum. The gypsum is made up of coarse interlocking crystals that are intermixed with coarse granular calcite. The Castle Creek fault is marked for several miles by a zone that is composed largely of gypsum. Analysis of the gypsum that was taken from the fault indicates that it is about 87 percent pure. The gypsum was apparently formed in postglacial time, for it has altered and cemented a breccia that was formed during glaciation.

Stainbrook, M. A., 1944, The Devonian system in Iowa, *in* Symposium on Devonian stratigraphy: Illinois Geol. Survey Bull. 68, p. 182–183.

The Wapsipinicon formation is regarded as the basal division of the Devonian beds in Iowa, though the age is still in doubt. The formation consists of five members, of which the Spring Grove member, which is the second member from the top of the formation, is a nonfossiliferous, thinly laminated dolomite. At Linwood, Scott County, a thin layer of gypsum crops out at the top of the member. In the southeastern and central parts of Iowa, beds of gypsum and anhydrite are found in this member in the subsurface.

Steiger, George, 1910, Note on errors in the chemical analysis of gypsum, *in* Hess, F. L., A reconnaissance of the gypsum deposits of California: U.S. Geol. Survey Bull. 413, p. 33–36.

Some difficulty was experienced in determining the water content of gypsum samples in chemical analyses. Experiments with selenite showed that grinding tended to dehydrate the sample causing false determinations. Errors as much as 8 percent were found in finely ground material, which had been ground rapidly in a grinding machine, over material which was coarsely ground in a mortar. Only a small amount of the water that is lost in grinding is returned to the sample by exposing it to air for periods that range from 2 to 16 days.

Stenzel, H. B., 1943, Gypsum resources and mining on the Hockley dome, Harris County, Texas, *in* Texas Mineral Resources: Texas Univ., Bur. Econ. Geology Pub. 4301, p. 207–226 [1946].

The Hockley dome is located in the northwestern part of Harris County, Tex., in the Gulf Coastal Plain. The surface rocks consist of the upper part of the Lissie formation and the underlying Beaumont formation; both are of

Pleistocene age. The Hockley dome is a shallow piercement-type salt dome, the salt core of which rises to within 1,000 feet of the surface. The top of the salt is fairly flat and the sides are steep. The diameter of the core is about 2 miles. Above the salt lies the caprock, which is an irregular mass that is as much as 955 feet thick at the center. The gypsum in the caprock is pure with some included shale bodies and ranges in thickness from 5 to about 128 feet. The reserves of gypsum are indicated as being very large, though no figures are given. The report discusses the mining methods, uses, and the hazards present in mining. These include the presence of hydrogen sulfide gas and considerable ground water in the beds that overlie the gypsum. The Gulf Portland Cement Co. was operating the property in 1947.

In the appendix of the report are several analyses of gypsum, which indicate that the gypsum averages more than 95 percent pure. Included also are logs of drill holes in the caprock. The report contains maps of mine workings, scale 1 inch = about 160 feet, and a map of the salt dome, scale 1 inch = about three-fourths of a mile.

Stephenson, E. L., 1954, Geologic map of the State of Nevada: Reno, Nev., Brundidge's, 136 N. Sierra Street, scale 1: 500,000.

Outcrops of geologic formations within Nevada are shown.

Stewart, B. O., 1932, The occurrence of gypsum at Iyoukeen Cove, Chichagof Island, Alaska: U.S. Geol. Survey Bull. 824–E, p. 173–177.

The gypsum occurrence on Chichagof Island in Alaska has been known since before 1905. The deposit was located on Gypsum Creek, which enters Chatham Strait near the head of Iyoukeen Cove, on the east side of Chichagof Island. Mining was carried on for 20 years until the deposit was exhausted.

The lowest workings, from which gypsum was mined, were 300 feet below the surface, and 800 by 600 feet in extent. The gypsum that was produced throughout the mine was exceptionally pure, ranging from white to light-bluish gray. The gray gypsum was translucent and some approached alabaster in texture and appearance. The total output of the mine was about 500,000 tons, which was shipped to Puget Sound to be milled. Difficulties with flooding hampered the production from the mine.

Prospecting for new gypsum deposits is difficult because the bed rock is covered with gravel. There is evidence that additional deposits occur 1½ miles east of the old workings along the shore of Iyoukeen Cove, on property owned by the Gypsum-Camel group. The deposit has been explored by 3 tunnels, which range from 130 to about 250 feet in length. These workings have cut a body of gypsum that lies unconformably on tilted and folded beds of cherty limestone. More work is needed to determine the extent of the deposit.

Stokes, W. L., 1948, Geology of the Utah-Colorado salt dome region with emphasis on Gypsum Valley, Colorado: Utah Geol. Soc. Guidebook 3, 50 p.

An extensive region in southeastern Utah and southwestern Colorado is underlain by the Paradox member of the Hermosa formation of Pennsylvanian age. The Paradox consists mainly of salt, gypsum, and anhydrite, and also contains some black shale and limestone. The salt has flowed plastically and created the salt anticlines of the region. Gypsum is present as a caprock on the floors of the Gypsum, Paradox, and Sinbad Valleys in Colorado and the Salt, Castle Creek, Onion Creek, and Spanish Valleys in Utah. The report describes the origin of the salt anticlines. A geologic map of the Utah-Colorado salt dome region, scale 1 inch = about 8 miles, and a geologic map of the Gypsum Valley region in Colorado, scale 1 inch=about three-quarters of a mile, are included.

Stone, R. W., 1917, Gypsum products; their preparation and uses: U.S. Bur. Mines Tech. Paper 155, 67 p.

The steps that are used in processing gypsum are described, from the mining and quarrying of the rock through to the finished plaster. The various methods of grinding and calcining gypsum are discussed. Raw gypsum is used predominantly as a retarder for portland cement and land plaster, but some is used for making crayons, sulfuric acid, and fillers in paper and paint products. Calcined gypsum is used in all forms of plaster and board products. The occurrence of gypsum throughout the United States and Alaska is described briefly.

——— 1920, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 15–30, 33–45, 49–56, 99–100, 131–138, 236–238, 295–308.

The report includes a general discussion of the geology of gypsum and the gypsum industry and a description of the deposits by States.

Arizona

The only plaster that was being produced in Arizona in 1916 was from a deposit of gypsite that was east of Douglas, in Cochise County. Other deposits in Cochise County are near Benson and Land. In Mohave County, gypsum occurs along the Virgin River. In Navajo County, deposits of gypsum occur near Winslow in the Moenkopi formation of Triassic age. In Pima County, gypsum has been reported from the Serritas, Santa Rita, and Empire Mountains. The only deposit that is described is that in the Empire Mountains, where 2 beds of gypsum occur, each of which are about 50 feet thick and separated by limestone. The gypsum is believed to be Carboniferous in age. About 8 miles northeast of Tucson on the west side of the Santa Catalina Range, gypsum of probable Quaternary age occurs in 3 thin beds that are separated by clay layers. In Pinal County, gypsum occurs along the San Pedro River at Redington and at Feldman.

Idaho

Gypsum has been found in two localities in Idaho: Bear Lake County, 3 miles east of Montpelier, and Washington County, 10 miles northeast of Huntington, Oreg. The deposit at Bear Lake is small. It lies on, and fills cracks in, a limestone of Pennsylvanian age. The gypsum is fine grained, white, and massive. The bed is not well exposed but is probably more than 4 feet thick. The deposit in Washington County occurs in lenticular masses banded with grayish and greenish material; the lenses range from 6 to 20 feet in thickness. The gypsum is a pure white that is spotted with lumps of impure gypsum and country rock. The deposit is possibly of Miocene age.

Montana

Gypsum occurs in commercial quantities in Cascade, Fergus, Carbon, and Big Horn Counties, Mont. In Cascade County, the gypsum occurs at Millegan and Riceville, where it is about 14 feet thick, and is in beds of Carboniferous age. At Kibbey, several gypsum beds are present that are as much as 5 feet thick. In Fergus County, gypsum occurs in the Big Snowy Mountains, where the beds are more than 20 feet thick; at Heath, where the gypsum is about 14 feet thick; and at Hanover, where there are 2 beds of gypsum each as much as 7 feet thick. This gypsum is believed to be in the Ellis formation of Jurassic age. In Carbon County, gypsum beds that are as much as 20 feet thick, are known. In Big Horn County, beds of gypsum occur at the north end of the Big Horn Mountains in beds that are as much as 60 feet thick. In Madison County, beds of gypsum that are 10 feet thick have been reported along the Madison River and along the summit of the Gravelly Range. In Jefferson County, small amounts of gypsum have been reported, but not much is known of them.

Oregon

In Oregon, gypsum occurs in two areas: One at Gypsum, Baker County, and the other, 30 miles east of Bend, Crook County. Other, and minor, occurrences are found in Grant, Jackson, Josephine, and Wheeler Counties. The deposit at Crook County is principally gypsite. The deposit in Baker County is the only one that has been developed. The gypsum here is associated with thick limestone and shale beds and volcanic rocks in lenses which range from 10 to 40 feet in thickness. Much of the gypsum is white and crystalline and of good quality, but some contains thin strata of chloritic material and breccia fragments of limestone, which render the material almost valueless.

Wyoming

Gypsum in Wyoming occurs in the Chugwater, Embar, and Spearfish formations. The Chugwater is represented by the Spearfish in the Black Hills of South Dakota. Gypsite occurs in several parts of Albany County.

Gypsum has been worked at Red Buttes, Albany County; Greybull and Stucco, Big Horn County; Dayton, Sheridan County; and Alcova, Natrona County. In addition, gypsite has been quarried south of Laramie, Albany County.

Gypsum also occurs in the Black Hills, along the flanks of the Big Horn Mountains, around the edges of the Big Horn Basin, in the Owl Creek Mountains, on the east flank of the Wind River Mountains, and in several areas in southeastern Wyoming. These areas are described in detail. Included in the report is a map of Wyoming, scale 1 inch = 40 miles, which shows areas that are known to contain gypsum.

Stone, R. W., and Kay, G. F., 1920, Iowa, *in* Stone, R. W., and others, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 101–110.

Gypsum is found in two places in Iowa—at Fort Dodge, Webster County, and at Centerville, Appanoose County. Although the deposits at Fort Dodge lie unconformably on strata of Pennsylvanian and Mississippian age, no certain age correlation can be made, but they are probably Permian. The gypsum occurs in a single bed that lies practically horizontal and ranges in thickness from 10 to 30 feet. The area is sedimentary strata carrying the gypsum is 3 to 6 miles wide and 13 miles long. The surface of the gypsum is irregular and covered by glacial drift. It is estimated that about 40 square miles is underlain by gypsum which averages 10 feet thick. Reserves are estimated at more than 700 million tons of gypsum.

The deposits at Centerville contain gypsum and anhydrite that are as much as 22 feet thick and lie 500 feet below the surface. The gypsum is associated with limestone and sandstone of Mississippian age.

Stone, R. W., Wrather, W. E., Baker, C. L., and Hill, B. F., 1920, Texas, *in* Stone, R. W., and others, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 250–260.

Principal gypsum-bearing areas in Texas are (a) in the north-central part of the State, from Acme, Hardeman County, southward 150 miles to the Colorado River; (b) Hudspeth and Culberson Counties, and (c) in southeast Texas.

In north-central Texas, the largest area of gypsum lies east of the foot of the Staked Plains in a belt that is 20 to 50 miles wide and extends south from

Oklahoma, in rocks of the Clearfork group of Permian age. The beds of gypsum range from a thin layer to about 20 feet in thickness. At Acme, gypsum is exposed in two nearly horizontal layers that are closely associated with dolomite.

In Culberson County, the Castile gypsum formation of probable Permian age crops out in a belt that is 15 miles wide and extends southward from the New Mexico border for 50 miles. As much as 50 to 60 feet of gypsum is exposed in the arroyos. The gypsum is generally pure, though locally some impurities are present. On the surface, the gypsum is disintegrated and earthy, and in places contains abundant selenite.

In Hudspeth County, extensive exposures of gypsum occur in the Malone Mountains. These deposits have the advantage of being situated near the Southern Pacific railroad.

In southeast Texas deeply buried deposits of gypsum lie over salt domes. In Brooks County, 6 miles east of Falfurrias, there is a mound that is called Loma Blanca. It consists of a deposit of massive selenite, and is surrounded by gypsiferous sand. The gypsum in the mound has been found by drilling to depths of as much as 1,000 feet. Numerous caverns occur within the selenite mass.

Stose, G. W., 1920, Virginia, *in* Stone, R. W., and others, Gypsum deposits of the United States: U.S. Geol. Survey Bull. 697, p. 283–294.

Large deposits of gypsum and salt occur in Smyth and Washington Counties, Va., in a district that is 20 miles long as it extends northwest from the village of Plasterco. Much of the area is in or near the valley of the North Fork of the Holston River. The rocks, in which the gypsum occurs, belong to the Maccrady formation of Mississippian age, which consists of earthy limestone, gray calcareous sandstone, shaly limestone, gypsum, and salt. It is easily eroded and poorly exposed. The rocks on the southeastern part of the district are of Cambrian age and are thrust over the Carboniferous rocks on the northwest side of the district, along a flat fault plain.

The gypsum probably was derived from calcareous-argillaceous sediments that originally contained disseminated gypsum, which was formed by partial evaporation of sea water. The gypsum has since been concentrated by ground water that circulated chiefly along the fault contact, dissolving the calcium carbonate and segregating the gypsum into beds along the fault by chemical action.

An alternative explanation is that the area, which contains the gypsum, was once a lagoon from which sea waters evaporated. The area exposed is the west edge of the lagoon; the east edge of the lagoon is under the overthrust Cambrian rocks.

Talmage, S. B., and Wootton, T. P., 1937, The non-metallic mineral resources of New Mexico and their economic features (exclusive of fuels): New Mexico School Mines Bull. 12, p. 95–107.

Much of New Mexico is underlain by rocks of Permian and Jurassic age that contain gypsum and anhydrite in bedded deposits. These deposits range in thickness from a few inches to about 100 feet. In addition, immense quantities of Quaternary gypsum sands are present.

Gypsum is found in the Yeso member and the overlying San Andres limestone member of the Chupadera formation of Permian age, which consists of shale, limestone, and gypsum beds that are as much as 100 feet thick. The northernmost outcrop of gypsum in the Chupadera is in north-central New Mexico, near Lamy, Santa Fe County. The deposits increase in number and thickness southward. In Lincoln County, there are at least 6 beds of gypsum, which range in thickness from 20 to 80 feet. The Wingate sandstone, in the Rocky Mountain, Nacimiento Mountain, and Sandea Mountain uplifts, is overlain everywhere by beds of gypsum as much as 80 feet thick. The gypsum sands of Quaternary age cover an area of about 270 square miles in Otero and Dona Ana Counties. The dunes are estimated to contain 4½ billion tons of gypsum.

The report includes an index map which shows the areal distribution of gypsum deposits in New Mexico; a generalized columnar section which shows the stratigraphic distribution of gypsum in New Mexico; and geologic sections of gypsum in Chupadera mesa, Socorro County, in the Pihillips Hills, Lincoln County, and near El Rito Pueblo, Valencia County, A location map, scale 1 inch=16 miles, shows the distribution of commercial possible commercial, and noncommercial grades of gypsum.

Taylor, R. E., 1938, Origin of the cap rock of Louisiana salt domes: Louisiana Dept. Conserv. Geol. Survey Bull. 11, 191 p.

In Louisiana, 68 salt domes are present and are divided between two areas: one area in the northern part of the State and the other in the southern part. The salt domes of northern Louisiana are associated with rocks of Cretaceous and Eocene age and those in the southern part with rocks of Eocene to Recent age. The age of the deposits, which contained the original salt that formed the domes, is variously estimated from Permian to Lower Cretaceous.

The salt within the domes has been folded, and the sediments into which the salt has been intruded are distorted and displaced. Anhydrite forms 99 percent of the insoluble residues of the salt from the domes, and is in grains that vary from 1/16 to 1 mm in diameter. Inclusions are frequent within the anhydrite grains. In many domes there is a flat sharp contact between the caprock and the salt, which is called the "salt table" and truncates the isoclinal folding in the salt. The salt table consists of a mixture of salt and anhydrite sand. The caprock forms a mantle of rock that lies directly over the salt dome, and is characterized by anhydrite, gypsum, and calcite. The anhydrite forms an irregular zone above the salt and is overlain by gypsum and calcite. Anhydrite grains in the caprock are as much as 2.0 mm in length. They do not replace any of the other minerals, but are replaced by the other minerals. Gypsum is less common in caprock than is commonly thought, as gypsum is often confused with anhydrite.

There are four theories of the origin of the caprock:

1. It was formed as a block of sedimentary material which was thrust upward by the salt.
2. It was formed by the alteration of limestone by waters containing sulfuric acid.
3. It was precipitated in place by either (a) mixing water that contained calcium carbonate in solution, with water from the salt dome that contained soluble sulfates, or (b) water from the salt dome upon becoming saturated with calcium sulfate rose to the top of the salt dome and precipitated its load.
4. It was formed by residual accumulation of the less soluble constituents of the salt plug, mainly anhydrite.

The report contains a bibliography of literature on salt domes and caprocks. Included also is a map of Louisiana, scale 1 inch = about 17 miles, which shows the location of the salt domes.

Teas, L. P., 1931, Hockley salt shaft, Harris County, Texas: Am. Assoc. Petroleum Geologists Bull., v. 15, no. 4, p. 465–469.

A shaft, which was sunk to the salt in the Hockley dome in Harris County, Tex., passed through the caprock that contains considerable quantities of gypsum. The upper part of the caprock is a limestone that is veined with calcite. The limestone overlies a sandstone, which is 15 to 30 inches thick and is in sharp contact with the underlying gypsum. The gypsum is 18 feet thick and grades downward to anhydrite through a vertical distance of 3 feet. The anhydrite, which is cut with horizontal joints, probably is sedimentary in origin, because a thin gray calcareous sandstone occurs within it. The contact between the main salt bed and the anhydrite is practically horizontal and very sharp.

Tester, A. C., 1937, Geologic map of Iowa: Iowa Geol. Survey, scale 1:500,000.

A geologic map of the State shows the location of the gypsum-bearing rocks in Iowa.

Trauffer, W. E., 1944, Gypsum mine and plant near completion at Hockley, Texas: Pit and Quarry, v. 36, no. 10, p. 93–94.

The Hockley Gypsum Co., which is 4 miles from Hockley, Tex., is said to have the largest commercial gypsum deposit in country. The main shaft was originally started in 1927 and is expected to be completed to a depth of 280 feet in 1944. The deposit is a monocline that overlies a huge deposit of salt, which is mined at the 1,500-foot level. The top of the gypsum averages 110 feet below ground level and varies from 90 to 128 feet in thickness. Overlying the gypsum is a bed of limestone, and between the gypsum and the salt is a bed of anhydrite.

The deposit is being developed (1944) by a 2-compartment shaft 8 by 14 feet in cross section and 280 feet deep. Drifts will then be driven 100 feet, both to the east and west, before development of rooms begins. The rooms will be 40 feet square and 60 feet high. The gypsum will be used for cement, and mill to make wallboard is planned.

________ 1951, Certain-Teed products: Pit and Quarry, v. 43, no. 8, p. 67–70, 77.

The operation of the gypsum deposit and plant at Fort Dodge, Iowa, which is owned (1951) by the Certain-Teed Products Corp., is described. The rock is quarried from a bed that is 23 to 26 feet thick and is overlain by about 46 feet of overburden. The material is taken to the plant in trucks, where it is crushed and calcined in four 15-ton capacity kettles. Plaster, gypsum block, wallboard, and lath are made at the plant.

Trowbridge, A. C., 1932, Tertiary and Quaternary geology of the lower Rio Grande region, Texas: U.S. Geol. Bull. 837, p. 235–236, 249–251, 254.

About 5 miles south of Falfurrias, Brooks County, is a hill that is surrounded by a salt laguna. Gypsum crops out on the south side of the hill, halfway between the east and west sides. Drilling shows that gypsum occurs near the surface under the whole hill and extends 600 to 700 feet below the surface. The laguna around the dome is salty and, when it dries in summer, 5 or 6 inches of salt are deposited.

The rocks surrounding the hill consist of surficial calcareous clay and caliche, together with some roughly bedded dolomitic limestones of probable Quaternary age.

In 1927, the gypsum was being quarried by the Tidewater Gypsum Co.

The report includes several logs of wells that were drilled into the gypsum.

Tucker, W. B., and Sampson, R. J., 1945, Mineral resources of Riverside County [California]: California Jour. Mines and Geology, v. 41, no. 3, p. 167–172.

Large deposits of gypsum are found in the Little Maria, Palen, and Riverside Mountains of California. The deposits in the Little Maria Mountains, near Midland, are very pure and, in places, are several hundred feet thick. The gypsum is finely crystalline and varies in color from transparent white to slightly reddish.

In the Palen Mountains, the gypsum is interbedded with limestone. The deposit comprises 1,600 acres at the north end of the mountains, in a belt that is 2 miles long and about 1 mile wide.

In the Riverside Mountains, the Parkford gypsum deposit, which is on the east side of the mountains, forms a low hill that is about 250 feet high and 400 feet wide. The beds are 50 feet thick and extend 700 feet along the strike. An estimated 2 million tons of gypsum is present.

One mile northwest of the Parkford deposit, and 7½ miles south of Vidal, at a station on the Atchison, Topeka and Santa Fe Railway, the beds have an average thickness of 70 feet and can be traced for at least 1,000 feet along the strike. Samples are reported to average 98 percent gypsum. An estimated 10 million tons of gypsum is present here.

Additional gypsum in the form of low-grade gypsite, ranging from 15 to 38 percent gypsum, is present between Eagle and Hagador. The material is used for soil conditioner.

A chart, which shows the production of gypsum in Riverside County from 1893 to 1944, and a map, which shows the location of gypsum deposits, scale 1 inch = 6 miles, are included.

Turner, A. M., 1930, Gypsite and its products: Rock Products, v. 33, no. 22, p. 49–51.

Gypsite has been or is being worked in Oklahoma, New Mexico, Texas, Arizona, California, Nevada, and Wyoming. It was formed by evaporation of waters that contained gypsum and other impurities. A typical analysis of a gypsite deposit is: $CaSO_4 \cdot 2H_2O$, 75 percent; $CaCO_3$, 8 percent; SiO_2, 15 percent; miscellaneous, 2 percent.

Gypsite in the upper part of a given deposit is generally purer than that at depth in the same deposit. In addition, stucco made from gypsite taken from the top of a deposit has a different setting time than that made from the material taken from the base of the same deposit.

Gypsite plaster is generally darker than plaster made from gypsum. It is slower setting than gypsum plaster, and has less strength. Gypsite plaster will keep in storage indefinitely without deteriorating.

Udden, J. A., 1914, The deep boring at Spur [Texas]: Texas Univ. Bull. 363, Sci. Ser. 28, p. 24–54, 63–68.

Examination of cuttings and cores of a well that was drilled at Spur, Dickens County, Tex., shows that considerable calcium sulfate is present. The well cut three well-marked divisions: the upper division of 1,250 feet consists of red sands and beds of gypsum, anhydrite, and salt of Permian age; the succeeding division of 2,800 feet consists of dolomite with strata of anhydrite, sandstone, and shale; the lowest division of 389 feet consists of limestones and shales. In the upper unit, gypsum occurs in beds that are less than 1 foot to more than 10 feet thick. Some of the gypsum is granular and white, and some is coarsely crystalline. Gypsum is found to a depth of about 254 feet below the surface, below which the calcium sulfate is anhydrite. The thickest bed of anhydrite that was cut by the drill is 73 feet thick and lies 330 feet below the surface.

________ 1924, Laminated anhydrite in Texas: Geol. Soc. America Bull., v. 35, no. 2, p. 347–354.

The Castile formation, where it was cut by a well in Culberson County, Tex., 22 miles west-northwest of Toyah, consists predominantly of anhydrite but contains some gypsum and shale. It has been well established that the gypsum turns to anhydrite at a depth below the surface of 400 to 700 feet. The total thickness of the anhydrite, as originally laid down, is estimated at 1,640 feet.

The anhydrite is laminated by layers that average less than 2 mm in thickness. The demarcation of the layers is made by very thin films of brownish bituminous material and calcite; the laminae are considered to have been deposited in an annual cycle. An average thickness of the laminae was calculated and an estimation was made of the number of laminae present, which indicated that the anhydrite bed was deposited over a period of about 360,000 years.

U.S. Bureau of Mines, 1924–1931: Mineral resources of the United States.

These annual publications list statistics on gypsum production, consumption, uses, prices, imports, and exports. Domestic production is generally reviewed by States. Brief statements on the annual developments in the gypsum industry are included.

———— 1932–58: Minerals Yearbook.

These annual publications list statistics on gypsum production, consumption, uses, price, imports, and exports. Domestic production is generally reviewed by States. Brief statements on the annual developments in the gypsum industry are included.

U.S. Geological Survey, 1882–1923: Mineral resources of the United States.

These annual publications list statistics on gypsum production, consumption, uses, prices, imports, and exports. Domestic production is generally reviewed by States. Included are brief statements on the annual developments in the gypsum industry. Some of the volumes contain more detailed information on occurrences and resources.

U.S. Inter-Agency Committee on the Arkansas-White-Red River Basins, Minerals and Geology Work Group, 1955, Minerals and geology, pt. 2, sec. 16, *of its* Arkansas-White-Red River Basins Rept.: U.S. 81st Cong., 2d sess., sec. 205, Public Law 516, p. 132–137.

Most of the gypsum reserves in the Arkansas-White-Red River drainage basins occur in Oklahoma, Kansas, and Texas in the Blaine gypsum of Permian age. Some gypsum also occurs along the Front Range in Colorado and in southwestern Arkansas. Anhydrite occurs in the caprocks of salt domes in Texas and Louisiana. The report gives production figures, in dollars, for gypsum in Arkansas, Kansas, Texas, and Oklahoma and for anhydrite in Louisiana. A map scale 1:2,500,000, shows the location of the gypsum deposits.

Utley, H. F., 1947, "World's richest gypsum quarry" supplies new board plant: Pit and Quarry, v. 40, no. 3, p. 114–117, 124.

The Standard Gypsum Co.'s plant at Long Beach, Calif., has a daily capacity of 300,000 square feet of lath and board products and 150 tons of plaster. Raw material for this plant is shipped by water from the company's quarry on San Marcos Island, in the Gulf of California. The deposit averages about 99.6 percent pure gypsum, and the grade never drops below 99.0 percent. Another inherent advantage of this rock is that it contains no free moisture.

The rock is unloaded from a company-owned, self-unloading ship and ground in three raymond mills. Calcining is done in three 11-ton kettles, for about 2¼ hours are at a temperature of 350°F. The main products of the plant are wallboard and lath. The process of making these products is described.

Utley, H. F., 1948, Speed pays off in Utah: Pit and Quarry, v. 41, no. 4, p. 80–84.

The plant of the Western Gypsum Co. in Sigurd, Utah, began operation in April 1948. The deposit is located in the foothills of the Wasatch Mountains near Sigurd, Servier County, Utah, and is comprised of several thousand acres of very high grade material, averaging 98 percent gypsum. The deposit is mined by open-pit methods, after the overburden, which ranges from 6 inches to 10 feet in thickness, is stripped. About 5,000 tons, which is enough for about 1 week's operation, is blasted at a time. At the plant, the material is crushed, put through two raymond mills, and either sold raw as agricultural gypsum or calcined in three 15-ton kettles. From the kettles, the stucco is either mixed for specialty plaster and keene's cement or used to make wallboard or lath.

——— 1952a, Columbia Gypsum Products uses kettle of unusual design: Pit and Quarry, v. 44, no. 8, p. 93, 107.

Columbia Gypsum Products, Inc., of Spokane, Wash., owns or controls nearly 4,000 acres of gypsum in British Columbia, which it mines and ships by rail to Spokane. The gypsum is crushed at the quarry, and crushed again and dried in Spokane. The product is used as agricultural gypsum or calcined in a stainless kettle, which has an inverted cone bottom. This kettle, which provides a lower bottom temperature than the ordinary flat-bottomed kettles, measures 10 feet in diameter and is 12 feet high. Calcination is carried on in 2-hour cycles; 13 tons of raw gypsum yield about 11 tons of finished stucco. The calcined products that are produced are plaster and gypsum tile. A board machine and dryer are planned.

——— 1952b, Kaiser expands gypsum board plant at Redwood City, [California] acquired in 1949: Pit and Quarry, v. 45, no. 1, p. 82–83, 90.

In 1949, Kaiser Gypsum Co. took over the plant of the Pacific Portland Cement Co. at Redwood City, Calif. The plant capacity was increased to make 225,000 square feet of wallboard a day. Raw material for this plant and the plant at Long Beach, Calif., is quarried and crushed to a 4-inch maximum size at San Marcos Island, in the Gulf of California, and transported by a 10,000-ton capacity ship to the plants. At Redwood City, the material is crushed again to a 1-inch maximum size and put through three raymond mills for grinding to 85 to 95 percent through 100-mesh. The mills are heated to temperatures of 1,300° to 1,400°F, for flash calcination at the same time. The stucco is used to make plasterboard, punched lath, and exterior sheathing.

The Long Beach, Calif., plant has four kettles and manufactures a complete line of wallboard, plaster products, and other gypsum specialties.

——— 1956, Kaiser Gypsum's Seattle plant—northernmost link in chain: Pit and Quarry, v. 48, no. 7, p. 104–106, 108, 110.

Extensions were recently completed on the Kaiser Gypsum Co.'s Long Beach, Calif., plant, which increased the capacity 60 percent and permitted an annual production of nearly 210 million square feet of ⅜-inch board. At Antioch, Calif., another plant is being built, which will have an annual capacity of 180 million square feet of wallboard and 20,000 tons of plaster. In addition, a new board plant is being erected also at Antioch, which will have an annual capacity of about 94 million square feet of wallboard.

At Seattle, production began in 1954. The plant has a capacity of 100 million square feet of gypsum board a year and about 35,000 tons of plaster. The crude gypsum is unloaded from a ship, and is stored under a huge umbrellalike roof of steel, which is 175 feet in diameter, before it is crushed and ground to 85 percent passing 100-mesh and calcined in two 10- by 15-foot kettles. The potential annual production of all Kaiser plants will be 100 million square feet of wallboard and 100,000 tons of plaster.

The raw gypsum that is used in the plants comes from San Marcos Island, which lies southeast of Santa Rosalia in Baja, Calif., and about 1,200 water miles from the Long Beach plant. Nearly a quarter of a billion tons of high-grade crude gypsum remains in the quarry. Mining is by open-quarry methods, and the material is crushed to minus 4 inch before loading.

The report contains pictures of the quarry operations and plant facilities.

Utley, H. F., 1957, Union Gypsum's board and lath plant—Arizona's first: Pit and Quarry, v. 49, no. 7, p. 106.

Union Gypsum Co. makes gypsum board and stucco at their plant in Phoenix, Ariz. The raw material is shipped from Feldman, Pinal County, which is 10 miles by truck to Winkelman, and then by rail 90 miles to Phoenix. The raw material has an average purity of 92 percent. The report gives a detailed description of the plant operation.

Valentine, G. M., 1949, Inventory of Washington minerals, part 1, Non-metallic minerals: Washington Dept. Conserv. Devel., Div. Mines and Geology Bull. 37, p. 46–47.

Gypsum occurs in Pierce, Yakima, Chelan, Okanogan, and Perry Counties. In Pierce County, gypsum occurs with andesite porphyry near Orting where gypsum makes up 10 percent of the rock. In Yakima County, gypsum occurs as cavity fillings in volcanic breccia. In Chelan County, gypsum occurs as isolated crystals in clay and in altered andesite. In Okanogan County, the gypsum occurs as gypsite in several playas and as coatings on limestone at the contact of quartz veins. In Ferry County, gypsum accompanies quartz and gouge in gold-silver-copper-lead veins.

A map, scale 1 inch = about 23 miles, shows the location of the gypsum.

Ver Planck, W. E., Jr., 1951, Gypsum resources of California, *in* Jenkins, O. P., ed., Minerals useful to California agriculture: California Div. Mines Bull. 155, p. 117–121.

Gypsite occurs along the east side of the San Joaquin Valley from Merced County south to Kern County; east of Bakersfield, Kern County; near Palmdale, San Luis Obispo County; northeast of Los Angeles; near Corona, Riverside County; and at Bristol Lake, San Bernardino County. Gypsite deposits are found in three typical localities: (a) on the weathered outcrops of beds containing disseminated gypsum, (b) along the margins of periodic lakes, and (c) in dry washes.

Rock gypsum deposits of Tertiary age occur at the north end of the Fish Creek Mountains in Imperial County; in Quatal Canyon in Ventura County; in the northern foothills of the Avawatz Mountains in San Bernardino County; in the Death Valley area, Inyo County; near Point Sal, Santa Barbara County; and at Fillmore, Ventura County.

Pre-Tertiary deposits of gypsum occur in the Little Maria, Palen, and Riverside Mountains in Riverside County.

The report gives a brief geologic description of the deposits, describes the methods of gypsum mining, and lists the uses of gypsum.

———— 1952, Gypsum in California: California Div. Mines Bull. 163, 151 p.

All known deposits of gypsum and gypsite are in the southern and southeastern parts of the State. The deposits are divided, according to a geologic classification, into pre-Tertiary, Tertiary, Quaternary, and Recent.

The pre-Tertiary deposits are found in the Little Maria, Palen, and Riverside Mountains in the eastern part of Riverside County and in the Clark Mountains in San Bernardino County. The ages of these deposits are not known, but those in the Little Maria Mountains are thought to be Silurian.

Tertiary deposits occur in the Fish Creek Mountains in Imperial County; in the Upper Cuyama Valley region of Santa Barbara and Ventura Counties; in the Death Valley region of Inyo County; in Kern, Los Angeles, San Benito, Santa Barbara, and Ventura Counties; and in the Avawatz Mountains in San Bernardino County.

Quaternary deposits are found in two places, Bristol Lake and Danby Lake, in San Bernardino County. Gypsite deposits of Recent age are found in Fresno, Kern, Kings, Los Angeles, Merced, Riverside, San Luis Obispo, and Ventura Counties.

The report contains a section on mining, production statistics, processing and marketing of gypsum, and a bibliography of the literature of gypsum. Also included is an outline map of southern California, scale of 1 inch = about 30 miles, which shows the location of gypsum deposits and a geologic map and sections of many of the deposits.

Ver Planck, W. E., Jr., 1957a, Magnesium and magnesium compounds, *in* Wright, L. A., ed., Mineral Commodities of California: California Div. Mines Bull. 176, p. 319.

Gypsum is a byproduct in the production of magnesium from sea water at Newark, Calif., by the Westvaco Chemical Division of the Food Machinery & Chemical Corp. Gypsum is precipitated by adding calcium chloride-rich liquor to the brine. The gypsum is of high purity and is used as a retarder for portland cement and in agriculture.

———— 1957b, Gypsum, *in* Wright, L. A., ed., Mineral commodities of California: California Div. Mines, Bull. 176, p. 231–240.

In 1953 the production of gypsum in California was nearly 2 million tons, which was valued at about $2.8 million. This was about 10 percent of the production in the United States.

Gypsum occurs as rock gypsum and gypsite. The deposits that have been worked in California are in rocks of Quaternary, Tertiary, and pre-Cretaceous age.

Three types of gypsite deposits are recognized: those that form caps on upturned gypsiferous beds, those that occur along the margins of periodic lakes, and those that have formed in the beds of dry washes. The largest known gypsite deposits are in the Lost Hills area, west of Wasco, Kern County. These deposits have features of both the channel and lake margin types.

Rock gypsum of Miocene age is being mined in the Fish Creek Mountains in Imperial County. The deposit is in a shallow synclinal basin that is 3 miles long and about half a mile wide.

Another deposit of Miocene age is being worked in Quatal Canyon in Ventura County. This deposit consists of a single bed of massive brown gypsum, which is 10 to 30 feet thick and can be traced for about 10 miles.

Beds of gypsum of Pliocene(?) age occur in lake beds in the foothills of the Avawatz Mountains in San Bernardino County. No production has been reported from here.

Deposits of pre-Tertiary age occur in the Little Maria Mountains in Riverside County. The gypsum beds form part of a series of slightly metamorphosed sedimentary rocks that trend west across the range for 3 to 4 miles. The gypsum occurs interbedded with limestone in persistent beds that are as much as 50 feet thick. Isolated pods that are as much as 150 feet thick also occur.

The gypsum is a coarse-grained snow-white aggregate of transparent grains. Some lenses of schist occur in the gypsum. Anhydrite is present at depth.

A deposit of pre-Tertiary age occurs at the south end of Mesquite Valley, 12 to 13 miles from U.S. Highway 91 and the Union Pacific Railroad. The gypsum is associated with black thin-bedded cherty limestone and brown shale, which are probably part of the Kaibab formation of Permian age.

Most of the gypsite is mined with carryall scrapers, which dump directly into trucks. In 1955, all the rock gypsum that was produced in California was mined by opencut methods. The maximum ratio of overburden to gypsum is about 1½ to 1.

Vine, J. D., 1956, Geology of the Stanford-Hobson area, central Montana: U.S. Geol. Survey Bull. 1027–J, p. 421, 423, 464–465.

The Stanford-Hobson area is located in Fergus and Judith Basin Counties, Mont. The gypsum which crops out in the area is in beds of the Big Snowy group of Mississippian age. These include the Kibbey sandstone and the Otter formation. An exposure of 15 to 20 feet of white gypsum is present on the south side of Black Tail Dome, near the west edge of Judith Basin County. Around the edge of the Lone Tree Dome, which is located in Judith Basin County on the west edge of the area mapped, the Heath shale contains a 20-foot bed of impure gypsum; also, a 12-foot bed in the Otter formation and a 20-foot bed of white gypsum in the Kibbey sandstone are present here. East of the area mapped, gypsum occurs in the Piper formation of Jurassic age. The gypsum is mined at Hanover on the south side of the Mocassin Mountains and at Heath, which is south of Lewiston.

Weed, W. H., 1899, Description of the Fort Benton quadrangle [Montana]: U.S. Geol. Survey Geol. Atlas, Folio 55, p. 1, 6.

The Fort Benton quadrangle includes the northwest corner of Fergus County and the eastern part of Cascade County, Mont. Workable beds of nearly pure gypsum, which is white or gray, occur in reddish sandstones of the Quadrant formations of Mississippian age near Riceville and Kibbey, Cascade County. The beds are a few inches to several feet thick and are traceable for several hundred feet along the outcrop. Gypsum is also found as thin beds and isolated crystals in clay shales in the Colorado formation of Late Cretaceous age.

________ 1904, Montana, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 74–75.

Gypsum is widely distributed in Montana on the eastern flank of the Rocky Mountains and is interbedded with a series of red and green shales and limestones of Mississippian age. The best developed deposits occur near Kibbey, Cascade County. Gypsum also occurs to the west of Kibbey in an outcrop that extends to the Missouri River and east of Kibbey along the flanks of the Big Belt Mountains.

Wilder, F. A., 1902, Geology of Webster County [Iowa]: Iowa Geol. Survey Ann. Rept. for 1901, v. 12, p. 76–77, 99–127, 138–167.

In the vicinity of Fort Dodge, Webster County, Iowa, gypsum of Permian age crops out along the Des Moines River and tributary creeks. Overlying the gypsum is glacial drift, which ranges in thickness from 1 to 100 feet. The gypsum is in a horizontal bed, which ranges from 10 to 25 feet in thickness; the upper surface of the gypsum bed is badly eroded. Of the 60 to 70 square miles in Webster County that is underlain by gypsum, at least 40 square miles can be used economically.

A geologic map of Webster County, scale 1:125,000, shows the gypsum mines, and a geologic map, scale 1:63,360, shows the region around Fort Dodge.

Wilder, F. A., 1904, Iowa, *in* Adams, G. I., and others, Gypsum deposits in the United States: U.S. Geol. Survey Bull. 223, p. 49–52.

In Iowa, gypsum is found in the vicinity of Fort Dodge, Webster County. The gypsum is confined to a single bed, which outcrops in the valley of the Des Moines River. The bed is horizontal and ranges in thickness from 10 to 25 feet. At least 40 square miles may be considered economically potential.

The gypsum is covered by glacial drift, which is as much as 80 feet thick. All the gypsum is regularly stratified.

The gypsum, which is thought to be of Permian age, is underlain by about 30 feet of red shale. The shale, in turn, lies on the St. Louis limestone of Mississippian age or, in some places, on coal measures of Pennsylvanian age.

A geologic map of part of Webster County, scale 1 inch = about 3 miles, shows the gypsum-bearing area.

——— [1923], Gypsum, its occurrence, origin, technology and uses, with special chapters devoted to gypsum in Iowa: Iowa Geol. Survey Ann. Repts. for 1917 and 1918, v. 28, p. 49–380, 468–558.

The report is a comprehensive coverage of gypsum which includes its physical and chemical properties; a discussion of the origin of gypsum; a description of deposits throughout the world, with empsasis on those in Iowa; a discussion of the technology of mining gypsum, making plasters, and plaster products; and the uses of both raw and calcined gypsum. The report also includes an extensive bibliography on gypsum and a geologic map of the Fort Dodge, Iowa, area, scale 1: 62,500, which shows the location of the gypsum mines.

Willis, Robin, 1929, Preliminary correlation of the Texas and New Mexico Permian: Am. Assoc. Petroleum Geologists Bull., v. 13, no. 8, p. 997–1031.

The report gives a tentative correlation of the Permian beds in north-central Texas, Trans-Pecos Texas, and New Mexico. The gypsum-bearing beds of north-central Texas are, from bottom to top: the Blaine, Dog Creek, and Cloud Chief formations. The Blaine is the thickest of the three formations, and consists of a gypsum, dolomite, and a red shale series, which overlies the Chickasha formation in Oklahoma and the San Angelo formation in Texas. The Blaine formation can be traced from Kansas, around the Anadarko basin in Oklahoma, and southward to San Angelo, Tex.

The Dog Creek is found in Oklahoma and just south of the Panhandle of Texas. It is composed of red sand and shale, and gypsum. Above the Dog Creek and Blaine formations is the Whitehorse formation, which is a very fine uniform red sandstone with a few stringers of gypsum. Above the Whitehorse, is the Cloud Chief formation, which is present in Kansas, Oklahoma, and Texas, and consists predominantly of red shale and sandstone, with beds and lenses of gypsum. In the subsurface of the Panhandle of Texas, the Blaine and Cloud Chief formations can be traced westward into New Mexico.

In east-central New Mexico, the Yeso formation is lower in the Permian than the Blaine formation. The Yeso formation consists of purple and red shale, with some sandstone and many beds of gypsum. The Blaine formation is equivalent to a limestone bed in New Mexico. The Whitehorse and Cloud Chief formations are equivalent to the Seven Rivers gypsum formation of New Mexico.

In Trans-Pecos Texas, Culberson County, the Castile formation includes gypsum on the surface, and anhydrite, which is overlain by salt, in the subsurface. It has been correlated with the Cloud Chief and Whitehorse formations to the east and the Seven Rivers gypsum formation to the north.

The report correlates the limestone barriers and oil-producing horizons throughout the area. Included are outcrop maps of each formation, scale 1 inch = 85 miles, and a composite geologic map of all formations, scale 1 inch = about 100 miles.

Wilson, E. D., and Roseveare, G. H., 1949, Arizona nonmetallics; a summary of past production and present operations (revised): Arizona Bur. Mines Bull. 155, Mining Tech. Ser. 42, v. 20, no. 2, 2d ed., p. 22–24.

Gypsum deposits are widely scattered throughout Arizona. The principal ones are located near Feldman and Redington, Pinal County; 5 miles east of Douglas, Cochise County; near Winslow, Navajo County; 8 miles north of Tucson and in the Empire, Santa Rita, and Sierrita Mountains in Pima County; south of Bouse, in northern Yuma County; and in northwestern Mohave County. Many of the deposits have not been developed sufficiently to indicate their size and grade.

The gypsite deposit east of Douglas was mined for plaster from 1908 to 1934. The deposits near Winslow were worked from 1909 to 1914 for portland-cement retarder. In 1946, the Union Plaster Co. (now Union Gypsum Co.) began to manufacture plaster from the gypsum quarried near Feldman. Arizona Gypsum Co. is mining gypsum east of Feldman for agricultural use.

Withington, C. F., 1955, Paradox, Colorado: U.S. Geol. Survey Quadrangle Map, GQ–72.

The map, scale 1:24,000, and accompanying text describe the geology of the Paradox quadrangle in Montrose County, Colo. The area covered by the quadrangle includes the northwestern part of Paradox Valley, an elongate collapsed salt anticline. The floor of the valley consists of the caprock, which is made up of 400 to 600 feet of gypsum, anhydrite, shale, and carbonaceous limestone.

Wright, C. W., 1907, Nonmetalliferous mineral resources of southeastern Alaska: U.S. Geol. Survey Bull. 314–C, p. 79–80.

Gypsum occurs at Iyoukeen Cove, on the east side of Chichagof Island in southern Alaska. The gypsum beds apparently overlie Carboniferous rocks; however, exposures are poor, and the contact of the gypsum with the underlying rocks is uncertain. The beds have been temporarily assigned to late Carboniferous or Permian formations. The gypsum beds that are exposed in mine workings strike east and dip north 20° to 60°. Channels, which represent old water courses, are now filled with gravel, cut the deposit in several places.

The deposit is being developed (1907) by the Pacific Coast Gypsum Co. There are two main workings: (a) a shaft 190 feet deep with 600 feet of drifts, which expose a deposit that is 200 by 150 feet; and (b) a 75-foot shaft and a drift 800 feet to the west of the first working. These workings are entirely in gypsum. The gypsum is taken by train to a wharf for shipment to Tacoma, Wash., for processing.

Wright, L. H., Stewart, R. M., Gay, T. E., Jr., and Hazenbush, G. C., 1953, Mines and mineral deposits of San Bernardino County, California: California Jour. Mines and Geology, v. 49, nos. 1 and 2, p. 228–231.

Several gypsum deposits of possible commercial interest exist in San Bernardino County, Calif., and include the Amboy, Avawatz, Red Canyon, and Clark Mountain deposits.

The Amboy deposit is on the northwest shore of Bristol Lake in a belt that is 1 mile or less wide and 6 to 8 feet thick. The gypsum occurs as a mush of selenite crystals that are mixed with salty mud.

The Avawatz deposits are on the north flank of the Avawatz Range, and 30 miles north of Baker. The gypsum is extensively exposed along a 9-mile northwest-trending belt, in a series of highly deformed Tertiary lake beds, which contain, besides the gypsum, salt and celestite. The gypsum is in layers that are as much as 30 feet thick and that are separated by layers of silt; the gypsum contains some thin shale lenses.

The Red Canyon deposits are located in the west-central part of Shadow Mountain, which is about 12 miles northeast of Baker. The deposits consist of gypsum layers, which are interbedded with yellow siltstone of Teritary age. The Tertiary strata dip vertically and strike northwest. The gypsum is irregular and sparsely distributed in beds and seams that are less than 4 inches thick.

The Clark Mountain deposits are about 10 miles north of Mountain Pass. The gypsum is interbedded with cherty and sandy limestone and shale, in rocks of the Kaibab formation of Permian age. The formation strikes N. 40° W. and dips 50° SW. The gypsum generally occurs as a white sugary aggregate that ranges from 1 inch to as much as 50 feet in thickness.

Zimmer, P. W., 1947, Anhydrite and gypsum in the Lyon Mountain magnetite deposit of the northeastern Adirondacks: Am. Mineralogist, v. 32, nos. 11–12, p. 647–653.

Anhydrite and gypsum occur in the magnetite zone at the Chateaugay mine at Lyon Mountain, Clinton County, N.Y. The anhydrite possibly was formed by hypogene acid solutions acting on limestone. The gypsum is secondary and derived from the hydration of the anhydrite. The intergrowth of anhydrite and magnetite in the absence of all sulfides suggests that the temperature range for anhydrite is greater than it was once thought.

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