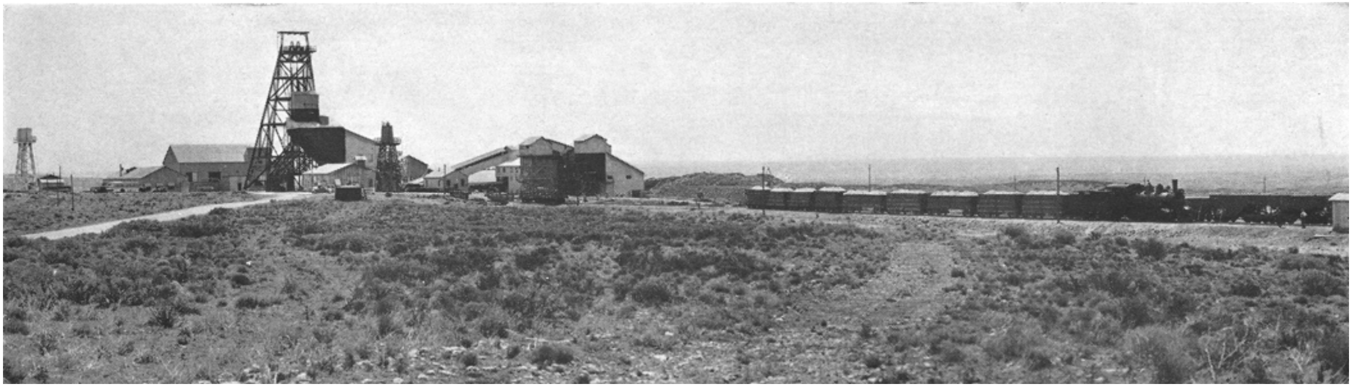
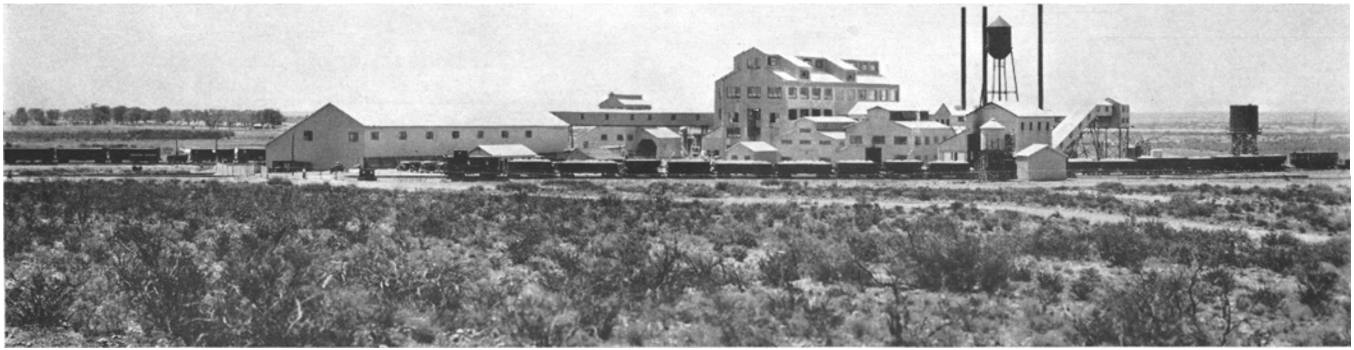


UNITED STATES POTASH COMPANY, MINE PLANT



UNITED STATES POTASH COMPANY, REFINERY

NEW MEXICO SCHOOL OF MINES

STATE BUREAU OF MINES AND
MINERAL RESOURCES

E. H. WELLS
President and Director

BULLETIN NO. 12

The Non-Metallic Mineral Resources of New Mexico and Their Economic Features

(EXCLUSIVE OF FUELS)

By
STERLING B. TALMAGE *and* THOMAS P. WOOTTON

SOCORRO, N. M.

1937

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THE STATE BUREAU OF MINES AND MINERAL RESOURCES

The State Bureau of Mines and Mineral Resources of New Mexico was established by the New Mexico Legislature of 1927. It was made a department of the New Mexico School of Mines, and its activities are directed by the board of regents of the school. Its chief object is to assist and encourage the development of the mineral resources of the State.

PUBLICATIONS

Bulletin No. 1. The Mineral Resources of New Mexico—Fayette A. Jones, 1915. (Out of print.)

Bulletin No. 2. Manganese in *New* Mexico—E. H. Wells, 1918. (Out of print.)

Bulletin No. 3. Oil and Gas Possibilities of the Puertecito District, Socorro and Valencia Counties, New Mexico—E. H. Wells, 1919. (Out of print.)

Bulletin No. 4 Fluorspar in New Mexico—W. D. Johnston, Jr., 1928. (Price 60 cents.)

Bulletin No. 5. Geologic Literature of New Mexico—T. P. Wootton, 1930. (Price 25 cents.)

Bulletin No. 6. Mining and Mineral Laws of New Mexico—C. H. Fowler, 1930. (Out of print.)

Bulletin No. 7. The Metal Resources of New Mexico and their Economic Features—S. G. Lasky and T. P. Wootton, 1933. (Price 50 cents.)

Bulletin No. 8. The Ore Deposits of Socorro County, New Mexico—S. G. Lasky, 1932. (Price 60 cents.)

Bulletin No. 9. The Oil and Gas Resources of New Mexico—Dean E. Winchester, 1933. (Price $1.50.)

Bulletin No. 10. The Geology and Ore Deposits of Sierra County, New Mexico—G. T. Harley, 1934. (Price 60 cents.)

Bulletin No. 11. The Geology of the Organ Mountains, with an Account of the Geology and Mineral Resources of Dona Ana County, New Mexico—Kingsley C. Dunham, 1935. (Price $1.00.)

Bulletin No. 12. The Non-Metallic Mineral Resources of New Mexico and their Economic Features (Exclusive of Fuels)—S. B. Talmage and T. P. Wootton, 1937. (Price 50 cents.)

Note—Bulletins 1, 2, and 3 were issued by the Mineral Resources Survey of the New Mexico School of Mines.

The Non-Metallic Mineral Resources of New Mexico and Their Economic Features

(EXCLUSIVE OF FUELS)

By
STERLING B. TALMAGE AND THOMAS P. WOOTTON

PART I. INTRODUCTION

PURPOSE AND SCOPE OF REPORT

This bulletin aims to present a summary of the available information that is related to the mineral resources of New Mexico, exclusive of the metals and mineral fuels. It is necessarily in large part a compilation of previously published information, here assembled for convenience under one cover. The compiled material has been supplemented by information obtained from interested parties throughout the State relative to occurrences not yet described in print, and by brief field examinations made by the writers at various times since June, 1931. This bulletin must be considered as distinctly a preliminary report, as several of the mineral resources mentioned herein but briefly are of sufficient extent and importance to be made the subjects for separate bulletins. Such special studies will be undertaken by the Bureau as opportunity offers.

As a vehicle of information, this bulletin aims to present a statement of all the occurrences of minerals within its scope now known in the State, with a discussion of the characteristics and uses of these minerals ; it also presents, as far as could be learned, the history of the past production of these minerals and mineral products. Production statistics are given wherever available, but are admittedly incomplete. Present activities are stated as far as seems advisable or permissible. Future possibilities are discussed, as a rule, rather cautiously; the estimation of known reserves presents no particular problem, but any prediction as to the commercial availability of those reserves is so bound up with problems of production costs, supply and demand, and fluctuating markets as to render any positive statements regarding future profits highly inadvisable.

Each mineral or mineral group is described in a general way. No attempt has been made to render these descriptions full and complete or to state in great detail determinative tests, as several excellent books are available covering these mineralogical factors. Among the most widely used texts on descriptive mineralogy are

"Mineralogy" by E. H. Kraus and W. F. Hunt (published by McGraw Hill Book Co., Inc., New York City), "Manual of Mineralogy" by E. S. Dana and revised by W. E. Ford (published by John Wiley and Sons, Inc , New York City), and the more elaborate "A Textbook of Mineralogy" by the same authors (John Wiley and Sons, Inc.). Popular books on determinative mineralogy are "A Pocket Handbook of Minerals" by G. M. Butler (John Wiley & Sons, Inc.), which deals almost entirely with recognition by characteristic physical features, and "A Manual of Determinative Mineralogy" by C. H. Warren (John Wiley & Sons, Inc.), which gives an excellent summary of chemical methods of mineral identification. "Mineralogy, Crystallography and Blowpipe Analysis" by A. J. Moses and C. L. Parsons (D. Van Nostrand Co., Inc., New York City) covers the field well in an elementary way. Special works in the field of non-metallic minerals, their production and use, are "Non-Metallic Minerals" by R. B. Ladoo (McGraw-Hill Book Co., Inc.), "The Marketing of Metals and Minerals" by J. E. Spurr and F. E. Wormser (McGraw-Hill Book Co., Inc.), and "Non-Metallic Mineral Products" by W. S. Bayley (Henry Holt and Co.).

Much of the information presented in this bulletin, especially regarding properties no longer worked, has been taken from "Mineral Resources" and other publications of the United States Geological Survey and the United States Bureau of Mines. The two principal Survey publications dealing specifically with New Mexico geology are Professional Paper 68, "The Ore Deposits of New Mexico" by Waldemar Lindgren, L. C. Graton and C. H. Gordon, and Bulletin 794, " 'Red Beds' and Associated Formations in New Mexico" by N. H. Darton; other publications are cited in their appropriate places.

IMPORTANCE OF NON-METALLIC MINERALS

The lure and romance of the search for gold have bulked so large in the public mind that when mining is mentioned one instinctively thinks of gold mining, or at any rate of metal mining. The trend of the times seems to indicate that the days of romantic mining and fortunes made by "taking a gambler's chance" are about over. The successful mining companies of recent years are those that have eliminated as far as possible the gambling element and reduced their mining operations to a manufacturing basis. As a result, more gold is now produced in the United States as a by-product from ores of the less valuable metals than as a result of direct mining for gold; and in recent years the value of the annual production of the non-metallic minerals, excluding fuels, (in the mining of which there is no chance whatever of striking a bonanza or a rich pay-streak) has approximated the value of the annual production of all the metals, gold included; the value of the mineral fuels has been more than double that of all other minerals combined.

The importance of the non-metallic minerals can hardly be overemphasized, as they enter into the arts and sciences, into engineering, agriculture and metallurgy, and abundantly into electrical equipment and many other articles used in daily life. A full list of their uses would cover many pages; the principal specific uses are listed under each mineral as discussed.

New Mexico has an abundance of many non-metallic minerals, and a superabundance of some. One of the major problems in the future development of the State is the utilization and commercial exploitation of these substances, which furnish reserves of great value. In many cases, however, this unquestioned value is a deferred asset, as the marketing factors exercise such a potent economic control as to make valueless at one time or place material that elsewhere or at some time may be of great worth.

MARKETING FACTORS

SUPPLY AND DEMAND

The successful production of the non-metallic minerals, as of any other natural resource or manufactured article, depends on the fundamental law of supply and demand. Prices may be temporarily elevated or depressed by manipulation, monopolies or legislation, but the basic facts remain that if a substance is scarce and needed the price will be relatively high, and if a substance is too abundant, or if its uses are limited, the price will be low. The price of a mineral product is in the last analysis the controlling factor of commercial production; only those mineral products can be mined profitably that will bring a price in excess of the cost of producing them and delivering them to a point where they are to be utilized. Some mineral products are so rare or so useful that it is good economy to ship them half way around the world, but others are so common or so easily substituted that they cannot bear the cost of transportation even into the next county. Local abundance may be offset by demand at a distant point, or the local usefulness of a mineral deposit may be destroyed by the shipping in of similar material from a point at which it can be produced more cheaply. Quality of material, accessibility of the deposit, and location and size of markets are thus all involved in the problem of exploiting the non-metallic minerals.

SIZE OF MARKET

The amount of any material that can be sold readily is an important factor in production. This problem is very simple in principle, but complex in its detailed application. The more of a material that can be sold in a given time, the smaller the unit profit necessary to bring in a satisfactory gross profit. Assume for simplicity that there exists a deposit of mineral that will sell for $10 a ton, and the material can be produced for $9 a ton; the profit is $1 a ton. If the local market will absorb only one ton daily, it is hardly worth the effort to operate, but if a market in another city will absorb 1,000 tons per day, the operator can afford to pay 90 per cent of his total profit in shipping charges. He will make then only 10c per ton, but his total net profit per day will be a hundred times as great as he could make in his limited local market. If the market price fluctuates, he will find that some shipments will be sold at a profit and others at a loss, and only if the market price is steady can he be assured of continued profits on a small margin.

MARGIN OF PROFIT

Assume that the same man is marketing two minerals, each bringing $10 per ton in a steady market. The one is as described, leaving a 10c unit profit on 1,000 tons, while the other brings in a $5 unit profit, but only 20 tons daily can be sold. Each mineral will bring in a gross daily profit of $100. Now assume that the price of each mineral drops 15c per ton; that is only 1½ per cent of the selling price of each mineral, but the marketing of the first mineral, which was on a margin of 10c per unit, will be changed from a substantial profit to a heavy loss, while the marketing of the second mineral, which was on a margin of $5 per unit, will bring a profit only 3 per cent less than under the former price. The exploitation of the second mineral could continue without change of method, though with slightly diminished returns, but the continued working of the first mineral would be absolutely dependent on improving methods of mining or shipping so as to bring the cost below the selling price. If the cost of mining or of shipping the first mineral could be reduced 15c per ton, it would again be as profitable as before.

Now assume that the price of each mineral rose to 15c above its original level. The second mineral, with a large margin of profit, would now bring in only 3 per cent more than at first, and only 6 per cent more than at the low price, but the first mineral, with a small margin of profit but now being produced at a lower cost due to improved methods, would bring in 150 per cent more profit than under either previous condition. This simple illustration assumes absolutely steady quantity demand. If the amount of either mineral that can be sold at either price fluctuates, the problem becomes still more complicated.

TRANSPORTATION COSTS

In the illustration just cited, it was assumed that the transportation cost borne by the first mineral amounted to 90 per cent of the total difference between production cost and selling price; yet without incurring that shipping cost the selling price could not be secured, as the material was not salable in quantity except in the specified distant market. It is obvious that a 15c per ton increase in transportation cost would have precisely the same effect as a 15c per ton decrease in price; that is, it would shift the balance from a profit to a loss. Conversely, the assumed drop in price might be met by a decreased shipping cost as well as by decreased mining cost, if a cheaper method of shipment could be devised. But in the marketing of any raw materials, this transportation cost must be met in order to get the material to the point where it can be used.

Consider for example the case of coal, which is marketed without going through any manufacturing process, and as an ideal case, consider for simplicity that costs can be expressed in round numbers. The coal is of no use to anyone while it is in the mine; its "value" in the ground is therefore wholly hypothetical, or potential. Assume that in a certain field the miners could extract the coal on a contract basis at $1 per ton, and that another dollar per ton would cover the cost of doing business at the mine. The owner then could afford to sell his coal at the mine for any price above $2.00 per ton and make a satisfactory profit on a sufficient volume of sales. But, if the principal market were in a distant city, either the producer or the buyer would have to meet the cost of transporting the coal to that market, including movement of the coal from the stockpile at the mine to the railroad cars, movement of the coal in the cars to the distant city, and movement from the cars to the wholesaler's stockpile in order to release the cars for further uses.

The coal on the wholesaler's stockpile might, therefore, have cost $5 or more per ton for transportation and handling; still it would be "run-of-mine" coal, all sizes mixed together, for which there would be small demand. In order to meet the requirements of the city market, the wholesaler would have to run all this coal over screens to separate it into such sizes as were demanded by the city customers. If the fines or slack screened out furnished an excessive amount, it might be necessary to sell this at a small loss in order to keep it from deteriorating and becoming a total loss. Customers whose furnaces were designed for burning slack coal could therefore get the benefit of a lower price, while householders who demanded that the coal be furnished in large lumps would have to pay for the coal a price that would cover the extra labor of sizing and the loss on the slack. Distribution to retailers would involve the expense of handling and transportation in large trucks, and distribution to customers would involve an additional handling and transportation in small trucks or wagons or sometimes in single bags. As a result, the consumer might have to pay $10 to $15 per ton for the coal, delivered in his bin, which at the mine was worth only about $2 a ton. Such cumulative increases of price would not necessarily involve any exorbitant profiteering anywhere along the line, but would be simply the fair cost of getting the coal to the place where it was to be used.

It would be quite absurd for the railroad company to buy its coal in the city market, when it could make its purchase at the mine and start to use that coal as soon as the train began to move. The railroad, then, would use coal bought for about $2 at the mine, to haul the same grade of coal to the $15 market.

The same principle, modified in detail, is a controlling factor in the marketing of all non-metallic minerals. Unless the producer is fortunate enough to find a buyer who will purchase his raw material on the ground, he must consider transportation expense as well as mining expense, and unless he can sell his product for more than the sum of these two expenses his venture cannot be a profitable one. Mining expenses properly include, in addition to actual extraction costs, such expenses as installation of equipment, depreciation, interest on investment and superintendence.

POPULATION

Size of market is a function of the number of consumers within a given area. Ordinarily this is directly related to the general population, but it may be modified greatly by the character of the industrial enterprises in any particular locality. Industries may be attracted to a territory furnishing abundant raw material, provided the markets are not too distant. The normal growth of cities frequently makes valuable at a later date natural resources that could not be profitably exploited when the population was smaller. For instance, sand and gravel in northern Illinois, which were relatively worthless when Chicago was a village, are now marketed profitably by the millions of tons per year on account of the large amount of concrete construction that is demanded in a large city.

Recent researches by Woolley [1] have led him to the conclusion that the most important limiting factor in population increase is water supply, and that with the industrial demands consequent on the growth of cities the demands for water always increase faster than the population, so that a large city uses more water per capita than a small town. If these conclusions are sound, as they appear to be, it seems improbable that New Mexico will ever be as thickly settled as some of the more humid states in the East, and that consequently the prospects for the development of local markets for large quantities of non-metallic minerals are not great. Except under high-pressure sales tactics, which eventually defeat their own purpose, it is useless to try to sell in a given area more of any material than the inhabitants of that area can use to advantage. Under present conditions, the beneficial use of many non-metallic minerals in New Mexico is strictly limited

[1] Woolley, Ralf R., Population trends and their relation to industrial development; and Pure water—a city's responsibility: papers presented at the 1930 meetings of the Utah Academy of Sciences.

by the relatively small and scattered population of the State. Large markets must be sought elsewhere.

MANUFACTURES

In the example of coal that was cited, the material was put to beneficial use essentially in its raw state for furnishing heat at the point of consumption. The coal was not manufactured into any other substance, and the only treatment that it received was a sorting into different sizes. Only a few non-metallic minerals can be so utilized; most of them find their principal use as ingredients in the manufacture of other substances for which there is a general or special demand.

As a simple illustration of this principle, assume that a desert lake contains abundant and pure sodium carbonate, and that its shores are made up of sand consisting of pure silica. Neither the soda nor the sand could be used while in the lake; to make them useful, they would have to be moved to a point of usefulness, as already explained. When mixed with certain other materials, they could be used in the manufacture of ordinary glass. In order to make them useful for this purpose the process of manufacture is essential. The cost of this glass delivered at the point of use involves more than mining and handling expense, as in the case of the coal that was discussed. The glass must bring a price sufficient to cover mining and handling of the raw material, plus expert labor in fabricating these raw materials into glass at the factory, plus the total cost of other ingredients of the glass, plus the cost of the fuel used for fusion of the glass (which includes carrying and handling costs of its own), plus the cost of transporting the finished product to the point of use, plus a margin for breakage and wastage of so friable a material as glass, plus the necessary business costs involved in the merchandising end of the glass industry. No one of those factors need pay any exorbitant profit, but every one of them must pay some profit, or the manufacture and sale of the glass will be a losing venture. The cost of the raw material at the point where it is extracted may thus be only a minor fraction of the total cost of the finished product. The same principle applies, with quantitative variations, to any non-metallic mineral that is used as an ingredient in a manufactured product.

VALUATION OF PROPERTIES

Most owners of small or undeveloped mineral properties are prone to overvalue them, and in most cases this overvaluation is an honest error based on a failure to recognize the principles discussed in the several preceding paragraphs. The fact that the material must pay for cost of handling, and must allow for intermediate profits, is overlooked by the small owner, who in many cases honestly believes that the raw material in his mine or on his dump is worth as much as the current price quoted in the general market. This mistake has probably delayed the development of more properties of real merit than any other single factor.

The writer recently saw a prospectus visioning the rehabilitation of a property that had been worked for silver and abandoned. The idea was advanced that the silver content was barely sufficient to pay expenses, but that the gangue, according to a reputable and accurate analysis that was quoted, contained potash and aluminum and barium and iron and sulphur and some rarer elements, which would make the ore profitable to work. The profits were estimated on the basis of the retail prices of these several substances in their refined forms, and the fact that no one of them had ever been extracted commercially from the mineral combinations that made up that gangue was entirely ignored. Projects based on this type of computation are doomed to failure from the start.

NEW MEXICO APPLICATIONS

The general laws of economics in the production of nonmetallic minerals apply in New Mexico as elsewhere. The special factors related largely to scant population and distance from principal markets may be summarized as follows:

1. Many New Mexico minerals of proved utility occur in concentrations of too low a quality or too small a quantity to be commercially worked at present. Among these are asbestos and nitrates, which have been found only in small deposits.

2. Several minerals of excellent quality and abundant quantity occur in the State, but they are located too far from lines of transportation or from large markets to be commercially exploited at present. As illustrations may be mentioned gypsum and alum. A new highway or railroad, decreased transportation charges, or an increased demand, may put any one of the deposits in this class on a commercial basis.

3. Some non-metallic minerals have a limited local market and so can be produced steadily, but on a relatively small scale. As illustrations may be mentioned the salt from Zuni Lake marketed for livestock in the western part of the State, the sand and gravel produced locally and used in Albuquerque, Roswell, Clovis and elsewhere, and the adobe and road materials occurring in many parts of the State. Under present market conditions there seems small probability of greatly expanding these enterprises.

4. Some non-metallic mineral substances in the State are available for local manufacture on a necessarily small scale as limited by population. As illustrations may be mentioned the volcanic cinder mined near Aden and used for light-weight concrete in El Paso, the concrete brick made from local material combined with imported cement and used in Hot Springs for public buildings and other purposes, and the brick clay in Bernalillo, San

Juan, San Miguel and Santa Fe counties used locally for buildings. The extension of markets for such materials depends on the creation of a demand and on low-cost transportation to the areal limits of the market.

5. Some non-metallic minerals are of rare species that can be put to special uses in a distant market, though not used at all within the State in their raw condition. As illustrations may be mentioned the kyanite that was mined for some years in eastern Rio Arriba County, and the mica of several grades from the northern part of the State. Possibly some of the sillimanite schist in Taos County may find its way into this class. The sale of such minerals is absolutely dependent on demand in a distant market, and they must be valuable enough to stand a heavy transportation cost.

6. Some non-metallic minerals can be refined in the State, and the smaller quantity of the refined product can be shipped at a reduced transportation cost. This has not yet been done extensively, but it seems to offer some possibilities for minerals that cannot be utilized otherwise. Most of the potash salt that is mined near Carlsbad is refined, and the concentrated potassium chloride is shipped a considerable distance. The possibility of grinding and otherwise treating mica in Rio Arriba County, and of refining the salt in the Estancia Valley with the extraction of epsomite have been seriously considered. The refining of other minerals for distant markets, in order to avoid the excessive cost of shipping the crude minerals, has promising possibilities.

The future progress of New Mexico non-metallic mineral production, then, would seem to offer the greatest promise along the lines of local refinement or manufacture of quality materials for which a national market exists or can be created; the lesser promise would seem to be along the lines of development of local demands and new or wider uses for raw or manufactured material produced or consumed locally. The nation-wide large-scale marketing of many of the crude non-metallic minerals must await a larger demand, higher prices, or improved or cheaper transportation, which may be delayed indefinitely and are not within the operators' control.

The specific problems of marketing non-metallic mineral products in New Mexico, although controlled broadly by the principles already discussed, are complicated by so many local or temporary factors as to make the marketing of each mineral an individual problem. With non-metallic minerals, as with all other commodities, there is no such thing as an absolutely steady market. Demand and supply do not maintain a constant relation; purchasers change, and so do prices.

In the light of these changing factors, it is not feasible to consider in this bulletin the factor of marketing under the head of each mineral as it is discussed. Neither is it feasible for the State Bureau of Mines and Mineral Resources to keep in touch with marketing developments throughout the nation. Several trade journals issue regular and up-to-date marketing lists of prices and sources, and one phase of the work of the United States Bureau of Mines is the compiling of such information. The statistical department of that Bureau, at Washington, D. C., is prepared at any time to furnish the most recent specific market information on mineral products.

The State Bureau of Mines and Mineral Resources is in receipt of frequent inquiries regarding the particular value or usability of some specific material submitted as a sample. Such value in many cases cannot be determined merely by analysis. With metallic ores, the value can frequently be determined, or at least closely approximated, by a determination of the percentage of metals present; but the value of many non-metallic minerals depends on physical characteristics more than on chemical composition, and can in many cases be determined only by special tests under working conditions. In such cases, the determination is best made by the manufacturer who may be able to use the raw material, on a sample of generous size. Laboratory tests on small lots of specimen material may be quite non-informative with regard to possible commercial use.

PART II. GEOLOGIC HISTORY OF NEW MEXICO

New Mexico is characterized at the present time by highness and dryness, but the geologist knows that these conditions constitute only one stage in the complex geologic history of this region. This history includes a remote time when rocks probably miles in thickness were removed from the surface by the eternal effort of the streams to reduce all lands to sea level; a later long time when the seacoast extended across the middle of the present State; a following time when the whole State, except a few island peaks, was submerged beneath the sea and blanketed with marine sediments; a time when the connection of this sea with the ocean was restricted and part of the State was the site of saline lakes or seas, with brines even more dense at times than those of the present Dead Sea or Great Salt Lake; a time when this shallow sea was filled up and marshy conditions existed, resulting in the formation of coal; a time of extensive deposition of desert sands and lake sediments; a time when strains in this part of the earth's crust resulted in bending and breaking of the rocks and the building of mountain ranges; a time when a succession of relatively violent volcanic eruptions buried the earlier rocks over tens of thousands of square miles; a time immediately preceding the present age when quieter eruptions permitted fluid lavas to flow from many volcanic vents and bury other large areas; all of these conditions, and others, which led up to the present in which we live, under varied conditions that are merely the result of all that has gone before.

NATURAL DIVISIONS OF NEW MEXICO

In spite of the great complexity of the geologic record, there is in nearly every region some feature that dominates to a sufficient degree to give that region an individual topographic expression. Recognition of this fact has brought about the division of the United States into seventeen recognizable physiographic provinces.[1] Similarly, but on a smaller scale, it has been observed that the State of New Mexico falls naturally into five well-defined divisions, in which the underlying geology has a characteristic topographic expression. These have been designated by Winchester [2] as the Median Area, the Southeast Area, the Northeast Area, the Northwest Area and the Southwest Area. (See map page 20.)

[1] For a discussion of the physiographic provinces of the United States, see the following:

Annals of the Assoc. of Am. Geographers, XVIII, 4, Dec., 1928.

Fenneman, N. M., Physiography of the western United States, McGraw-Hill Book Co., Inc., New York City, 1931.

Lobeck, A. K., Physiographic diagrams of the United States, the Geographical Press, Columbia University, New York City.

[2] Winchester, D. E., The oil and gas resources of New Mexico: N. Mex. Sch. of Mines, State Bur. of Mines and Min. Res., Bull. 9, p. 57, 1933.

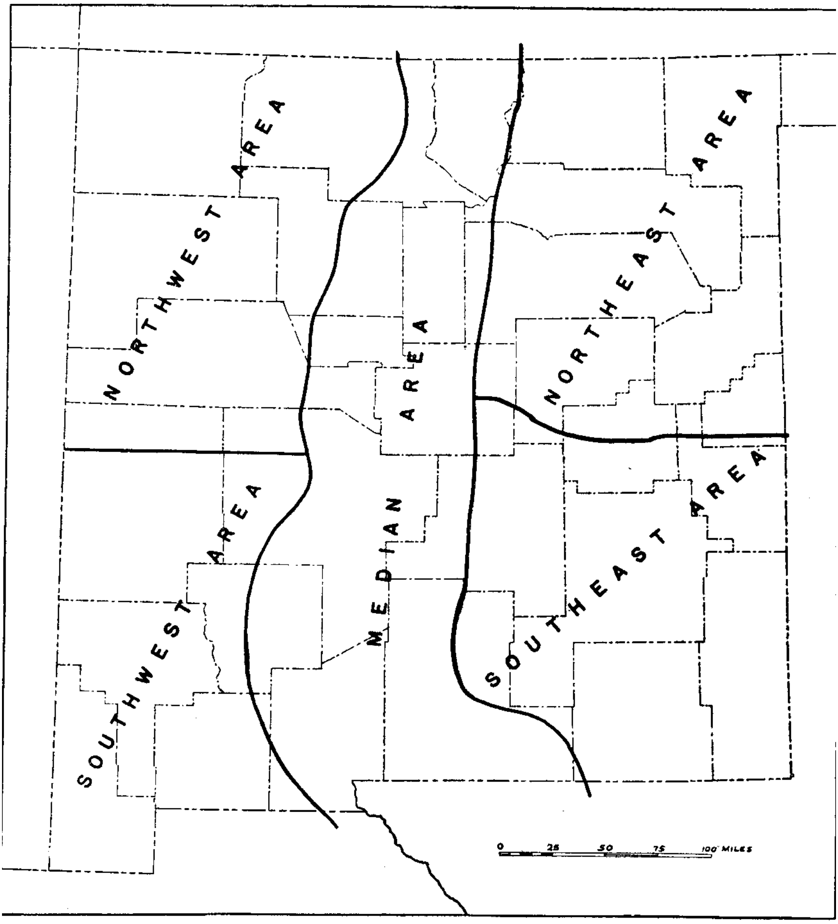

FIGURE 1.—Index Map showing Natural Divisions of New Mexico.

The Median Area is a strip averaging 75 miles wide, running from north to south through the middle of the state. It includes the Rio Grande valley and adjacent mountainous and intermontane areas on either side. North of Santa Fe, it includes the most southerly extension of the Southern Rocky Mountains province, and is prevailingly mountainous. In its southern portion it is characterized by wide desert plains flanked by northerly trending mountain ranges, and belongs to the Basin and Range province. It includes all of the great exposures of pre-Cambrian rocks in the state, except the Burro Mountains and the core of the Zuni uplift.

The Southeast Area includes that portion of the south half of the state that lies east of the Median Area. It is characterized by plains and mesas, and in its western part consists of the Chupadera formation, largely of limestone and shale, which disappears to the east under a covering of younger sediments. This is the only one of the five Areas of the state not marked by abundant evidence of igneous activity. Both this Area and the adjacent one to the north are classed as part of the Great Plains province; in their eastern parts they are typical High Plains country, but at their western edge the dissection of the mesas has made the topography in places of an almost mountainous aspect.

The Northeast Area includes that portion of the northern half of the state that lies east of the Median Area. Through most of its extent it shows at the surface sedimentary rocks of Mesozoic age from which the younger cover has been stripped by erosion. Flat-lying beds differing in hardness have been eroded unequally, and much of this area is characterized by flat lands at different levels, bounded by bold escarpments. In its northern portion the Northeast Area includes scattered tracts, totaling over 1000 square miles, of igneous rocks; most of these are extrusive, and most of them are basaltic, and all of them are of relatively late geologic age. Some of these flows are old enough to show considerable modification by agents of erosion, but others are late enough to be adjusted to the present topography.

The Northwest Area includes that portion of the state which lies north of the Datil Mountains region and west of the Median Area. More than half of this Area lies within the San Juan Basin, a broad structural trough in Mesozoic and Cenozoic sediments. In places these sediments have been punched through by numerous volcanic plugs, of which Shiprock is an outstanding example. The southern half of the Northwest Area is dominated by the effects of the Zuni uplift, in which is exposed the central core of pre-Cambrian rock, flanked by plateaus which expose, step by step, successively younger rocks as one goes outward from the center of the uplift. East of the Zuni uplift is Mount Taylor, a great volcanic pile, which is practically surrounded by one of the most extensive exposures of basalt in the state. This basalt area extends southwesterly beyond the Arizona state line. All of the Northwest Area and the Datil section of the Southwest Area are included in the Colorado Plateau province.

The Southwest Area includes the great Datil section, and the desert and mountain tracts to the south that lie between the southern Rio Grande Valley and the boundaries of the state. The Datil section consists of a complex series of igneous rocks, mostly flows of more acidic composition than the later basalts, inter-stratified with fragmental igneous tuffs and breccias, and with ordinary sediments. This section has been vigorously eroded to a mountainous aspect, except for some great intermontane plains. South of the Datil section, isolated ranges, of both old and young rocks, stand above the surface of the desert like islands in a sea of sand. The southern part of the Southwest Area belongs to the Basin and Range province.

Locally, within all of the Areas, there are departures from type; but the dominating general relations are as has been summarized.

GEOLOGIC TIME

The geologist must base his time scale on recognizable important events whose record is preserved in the rocks. He finds the year as inadequate a unit of measurement as a yardstick would be to an astronomer in measuring interplanetary space. The events that serve the geologist as time-markers were unequally spaced, and so his recognized periods are not of equal length. The geologic time table, then, is not a statistically ruled scale of equal intervals, but simply a succession of events that introduced notable changes.

The most important division point in geologic time is the one that separates the Cambrian and later periods from the pre-Cambrian. The records in the rocks of the periods following this division point are fairly clear, and the sequence of events is, in its larger phases, fairly well understood. But in the time preceding the Cambrian, comprising considerably more than half of known geologic time, there is evidence of so much alteration, of such profound modification of original characteristics of rocks, of such extensive reworking by igneous agencies deep in the earth, and of such tremendous destruction by erosion, that parts of the record of that time are lost in obscurity and must remain for the present at least matters of supposition and inference.

PRE-CAMBRIAN ERAS

During pre-Cambrian time the region that is now New Mexico was the site of extensive sedimentary deposition. Most of the pre-Cambrian sedimentary rocks have been modified by the action of solutions, heat and pressure, and consist now of quartzites and schists. Nowhere is this series exposed to its base, so there is no information available as to the foundation on which the earliest pre-Cambrian sediments were laid. There is evidence that these rocks were buried miles deep by other sediments, and they were intruded by great quantities of granite, which changed the characteristics of the sedimentary rocks. At the time of the granite intrusions or later, some of the older rocks were cut by dikes of pegmatite in which certain minerals, notably mica, were concentrated. Following this activity the processes of erosion stripped off miles of covering rocks, the record of which is completely lost, and exposed near the beginning of Paleozoic time a relatively flat, featureless surface consisting of metamorphosed sediments, granites, pegmatites and schists. This profound erosion has exposed for exploitation the deposits of mica, kyanite, lepidolite and associated pegmatitic minerals that have made an important contribution to the non-metallic production of the State.

Present exposures of pre-Cambrian rocks occupy only about 3 per cent of the area of the State; rocks of this age are covered by younger rocks in other places. The larger pre-Cambrian areas are the ones north of Taos, a southern extension of the Colorado Rockies, and in further extension the Truchas and Rincon ranges which extend a few miles south of the latitude of Santa Fe. Another exposure begins at Ojo Caliente and extends, with some breaks, 30 miles to the north and northwest. The isolated mass near Picuris is of the same type, as is probably also the larger though less mountainous Pedernal area in central Torrance County. Large cores of pre-Cambrian rock are exposed in the Zuni and Burro mountains, and smaller cores are exposed in the Ladrones and the Magdalena mountains. In the Sandia and Manzano ranges the west front presents a pre-Cambrian strip that extends unbroken for more than a hundred miles. The east front of the San Andres range shows a similar strip of greater total length, but interrupted in places. There are other northward-trending strips, but of smaller dimensions, in the Nacimiento, Oscura, Mimbres, Fra Cristobal and Sierra Caballos ranges and in the Franklin Mountains a few miles over the Texas line. There are several smaller isolated exposures in Socorro County on both sides of the Rio Grande.

The larger areas described represent part of the old pre-Cambrian basement, not greatly modified since. The long and relatively narrow strips are exposed as a result of faulting, which has brought these basement rocks up above the adjacent younger sediments.

PALEOZOIC ERA

In the Paleozoic era New Mexico was the site of extensive sedimentary deposition. During the early part of the Paleozoic the southern half of the State was submerged by the wide strait that connected the sea occupying the Mississippi Valley with the one extending from the Arctic down the present course of the western Cordillera. In later Paleozoic time the whole area of New Mexico was submerged, except for some islands in the northern part. In latest Paleozoic time all of New Mexico had emerged, excepting the southeast corner; this was in the lowest part of the basin, extending into Texas, Oklahoma and Kansas, which was connected with the ocean by a narrow strait. In this basin there accumulated, due to the evaporation of enormous quantities of sea water, what may prove to be the greatest saline deposits in North America. The rocks of this era show here no evidence of vulcanism during Paleozoic time, nor of deformation more violent than oscillations of the level of the coast line.

CAMBRIAN PERIOD

There is no record of deposition of sediments in New Mexico during early and middle Cambrian time. In the late Cambrian the sea encroached from the south and covered about the southern half of the State. In this sea were deposited sands, which were formed in part by a sorting out of the finer material from the waste that covered the land and in part from the material that was brought in by streams from the north. The gradual northward advance of this sea allowed much more time for deposition in the southern part of the state, and so this sand, now consolidated and known as the Bliss sandstone, forms a rock layer as much as 300 feet thick in the Franklin mountains, tapering gradually to only 6 feet thick in the northern San Andres Mountains and not observed farther north. This sandstone probably underlies the whole southern part of the State, but it is exposed only in the mountain ranges, where faulting and erosion have brought it to the surface. It is best shown in the San Andres Mountains, Cooks Peak, Mimbres and Florida Mountains, and in the region near Silver City.

As would be expected in a gradually deepening sea, the lower portion of this Bliss sandstone is coarser and harder, in some places now almost quartzitic, while the upper portions are finer and softer and in places contain considerable glauconite. Hummel[1] has shown that this mineral, a silicate of iron and potassium, is being deposited at present near places where warm and cold marine currents come together. Such conditions would seem quite probable in the strait that, passing across southern New Mexico, connected the two embayments, one from the Arctic and the other from the Gulf of Mexico. Some sands containing abundant glauconite, in New Jersey, have been utilized as a source of potash, and some have been used directly as fertilizer. The upper portion of the Bliss sandstone, containing the green

[1] Hummel, K., Die Entstehung eisenreicher Gesteine durch Halmyrolyse: Geologische Rundschau, Vol. 13 (1922); reviewed in Economic Geology, 18:6, p. 612 (Sept., 1923).

glauconite, has not yet been utilized for either of these purposes. Except for the upper greenish part, the Bliss sandstone is prevailingly colored in tints of brown.

ORDOVICIAN PERIOD

There is no marked break in New Mexico between the Upper Cambrian and Lower Ordovician deposits, but there was a gradual change in conditions of deposition. Apparently the waters of the early Paleozoic sea became warmer and less disturbed, and there was a definite decrease in the amount of sediments brought into them. These conditions were favorable for the development of marine animals, particularly shell-bearing types, which were so abundant in some seas of Ordovician time that their shells accumulated to form great thicknesses of fossiliferous limestones. The Lower Ordovician rock in southern New Mexico is known as the El Paso limestone. In its lower part it is sandy, grading down into the Bliss, but above that impure basal layer it is a pure light-gray somewhat magnesian limestone, in which fossils are moderately abundant. In places it is as much as 800 feet thick.

During Middle Ordovician time the sea retreated, and the top of the El Paso limestone was channeled by streams and otherwise modified by erosion. Another submergence followed, and the overlying formation, known as the Montoya limestone, was deposited in Upper Ordovician time. The encroaching sea during this time was not a strait but a bulbous bay extending eastward from the Pacific and reaching well into Texas and southward into Mexico. In its lower portion the Montoya formation consists of massive dark-colored limestone, overlain by a slabby member containing much chert. The limestone is magnesian in part.

The distribution of the Ordovician rocks is essentially the same as that described for the Cambrian; likewise, the Ordovician has its maximum thickness of 1200 feet toward the south and thins out toward the north, disappearing completely in the central part of the State. The most northerly exposure of the Ordovician, as of the succeeding Silurian and Devonian. is in the southern end of the Oscura Mountains.

SILURIAN PERIOD

During most of Silurian time, New Mexico stood entirely out of water, but during the middle part of the period another encroachment of the sea from the west covered much of the southern part of the State. In this sea was deposited the Fusselman limestone, which lies directly on the Montoya wherever it is exposed and has as its basal member in places a conglomerate containing Montoya pebbles. This conglomerate, indicating an erosion interval, together with fossil evidence, justifies the statement that the Silurian deposition in this territory occurred only during the middle portion of the period. A similar erosion interval recorded on the upper surface marks the break between the Fusselman limestone and the overlying Percha (Devonian) shale. The Fusselman limestone thins to the north and also to the east, and it is absent from the Franklin and Florida Mountains, which show some of the best exposures of earlier Paleozoic rocks. The thickness in the San Andres Mountains is as much as 220 feet. In places some of the calcium of the limestone is replaced by magnesium.

DEVONIAN PERIOD

The great Lower Paleozoic limestone series was interrupted by the deposition in Devonian time of a rock of totally different character, known as the Percha shale. This is distributed about as described for the earlier Paleozoic rocks, except that it is absent, like the Fusselman, from the Franklin and Florida Mountains and also from the small Victorio Mountains. Exposures are not sufficient to justify a definite statement as to whether the Silurian and Devonian rocks were never deposited in these areas, or whether the Fusselman and Percha formations were eroded completely before the more extensive later Paleozoic deposits were laid down.

Through most of its thickness the Percha formation consists of black and green shale, quite unlike any earlier member of the Paleozoic series. Its elastic character, as compared with the non-fragmental character of the Ordovician and Silurian rocks, suggests that during the whole time since the deposition of the Bliss sandstone the lands bordering the sea in New Mexico were lowlands, subject to deep weathering but with little erosion or transportation, permitting the accumulation of a thick soil. It appears also that the flooding during Devonian time must have been accompanied by an uplift of a portion of the shore, rejuvenating the streams and permitting this soil to be stripped off rapidly and deposited as a fine carbonaceous mud. The upper portion of the Percha contains some thin beds of limestone, suggesting the clearing of the sea when the abundant mud supply was exhausted, and a return to conditions favorable for marine life.

The deposition of the Percha shale marks the latest sedimentation that was restricted to the southern part of New Mexico. The next submergence extended farther north and culminated in a flooding of practically the whole State.

MISSISSIPPIAN PERIOD

The stratigraphic break between the underlying Percha shale and the overlying limestone of Mississippian age is not a sharp one. At one of its best exposures, at Lake Valley, the Mississippian rock, named the Lake Valley limestone from its type occurrence at this place, lies directly on the Percha shale, whose lime-bearing top member suggests a gradation upward into the Mississippian. If the Percha shale emerged at all, it was left as an extensive low-lying mud flat. It shows little or no evidence of erosion before being covered by the calcareous sediments of the Lake Valley limestone.

The waters that covered the land during early Mississippian time extended some 60 miles farther north than had any previous Paleozoic flood, as evidenced by the fact that the Lake Valley limestone occurs in the Magdalena and Ladrones Mountains. In these mountains it lies directly on the pre-Cambrian rocks, which apparently stood out of water during all the preceding Paleozoic periods. Farther south, as stated, the distribution of the Lake Valley limestone is essentially the same as that of the Percha shale.

At Kelly, in the Magdalena Mountains, the Mississippian limestone, which lies directly on the pre-Cambrian greenstone, was formerly known as the Kelly limestone. Since its definite correlation with the Lake Valley limestone has been established, it seems preferable to discontinue the use of the local term.

The Lake Valley formation is not uniform throughout. It includes a compact cherty limestone which may represent a transition to the Devonian, and a thin, coarsely crystallized light-yellow member, overlaid by blue limestones with included beds of shale. Its top is evidently an eroded surface, so the extreme upper members may be lost. In the Silver City district it is as much as 450 feet thick, and at Lake Valley and Kelly its thickness is from 100 to 200 feet.

While there is reason to believe that the Paleozoic formations already described underlie the greater part of the southern half of New Mexico, the surface exposures are limited to the mountainous tracts in the Southwest Area and the southern half of the Median Area ; within that territory less than 1 per cent of the surface shows Paleozoic rocks earlier than Pennsylvanian.

PENNSYLVANIAN PERIOD

Following the emergence which, in late Mississippian time, exposed the top of the Lake Valley limestone to erosion, and which resulted in its complete removal in places, there came in middle and late Pennsylvanian time the most extensive submergence to which New Mexico was subjected during the Paleozoic era. Practically the entire State was covered by this sea, which extended from Oregon, and later from Alaska, to the west Gulf Coast and spread over the present site of the Great Basin and the Rocky Mountains and over much of the Great Plains. Apparently a strip of dry land remained, extending from the north through eastern Colorado and western Kansas and including extreme eastern New Mexico and most of the Texas Panhandle. This land area furnished some sediments to the sea that covered all the rest of the State, except perhaps the Pedernal and Zuni areas and some other areas in the northern part of the State, in which pre-Cambrian rocks probably projected above the waters as island peaks.

The sediments laid down in this sea formed the series of rocks known as the Magdalena group or formation, which is exposed over a larger area than all the older Paleozoic rocks together. It covers between 3 and 3½ per cent of the total area of the State, mostly in the Median Area but exposed also in the mountains of the Southwest Area. It extends into Texas in the Franklin and Hueco Mountains and into Colorado in the Sangre de Cristo Range. It occurs within 3 miles of the Arizona line in the Peloncillo Range, southwest of Lordsburg. In the eastern third of the State it is completely covered by younger rocks, and its precise extension in that direction is undetermined.

In the Sangre de Cristo Mountains, as would be expected from its proximity to the old shore line, the Magdalena formation contains considerable elastic sediment, which formed gray and red sandstone and red shale, with some interbedded limestones. Farther from the shore, to the south and west, thick limestones were deposited with some interstratified sandstone and shale. In the extreme southwest part of the state the Magdelena formation thins out or disappears. In much of the state the formation is from 700 to 1200 feet thick, but it thickens in the Hueco Mountains to about 2000 feet.

In central New Mexico the Magdalena formation has been subdivided, the lower part being called the Sandia formation and the upper part the Madera limestone.

PERMIAN PERIOD

The Permian period, which closed the Paleozoic era, was a time of almost world-wide crustal disturbance and adjustment. While the deformation was far less in New Mexico than in some other parts of the country, it seems to have begun in the Pennsylvanian-Permian interval and to have tilted the eroded top of the Pennsylvanian, so that the lowest Permian beds show a slightly unconformable relation to it.

The disturbance in this region took the form of a broad down-warp that included the central and eastern portions of New Mexico. The beginnings of this Permian Basin are evidenced by the deposition and character of the lowest Permian beds, known as the Abo sandstone. This is the coarsest-grained Paleozoic rock in New Mexico above the Bliss sandstone, and represents the bottom of the great Permian series, known collectively as the Manzano group, which in its upper members consists largely of limestone, gypsum and salt. The shape of the Abo formation, thickest in the middle of the State and thinning out to the north and south and probably to the west, suggests deposition in a sinking basin, from the somewhat weathered sides of which the rock waste was carried in rapidly as the steepness of the slopes increased, due to warping. In most places where the Abo is exposed it rests on the eroded surface of the Magdalena limestone, but in the Zuni and Pedernal areas it rests directly on the pre-Cambrian. Either these two areas were islands in the Pennsylvanian sea and not submerged until carried down by the Permian down-warp, or else erosion stripped off all the earlier Paleozoic sediments, leaving the older granite and schist exposed.

The Abo is for the most part slabby red sandstone, but it includes subordinate strata of red shale. In most of the outcrops the thickness is from a few hundred to 1100 feet. The distribution of the Abo is at the upper edge of the Magdalena except in the areas mentioned above where. Abo occurs without underlying Pennsylvanian, and in the northern and southwestern parts of the State where the Magdalena group occurs without overlying Abo. The area in which the Abo outcrops is much smaller than that occupied by the Magdalena limestone.

Overlying the Abo sandstone is the Chupadera formation, the most extensively exposed sedimentary rock in the State. From the Chupadera Mesa, which includes the exact center of the State and from which this formation is named, it can be traced continuously, east to beyond the Pecos River where it disappears beneath younger beds, to the north as far as Santa Fe where it thins out, to the south beyond the State line into Texas, and to the west in the Lucero and Zuni regions, and small surface occurrences known locally as the Gym limestone in some of the mountains of Luna County. A long strip of the Chupadera formation forms the west base of the San Andres Range. It is not exposed in Grant and Hidalgo counties. In its total surface exposures the Chupadera formation covers about 13 per cent of the State.

The Chupadera formation was evidently deposited in a sinking basin; the thinnest part is near the old shore line to the north, where this formation consists mostly of gray sandstone; farther south, where the basin was deepening, the lower member of the Chupadera, called the Yeso formation, consists of variegated soft red sandstone with interbedded shale and gypsum deposits. This is overlain by the San Andres limestone, of a prevailingly gray color and also containing large amounts of interbedded gypsum. Still farther south in the Sacramento Mountains, approaching what was the center of the Permian basin, the Chupadera formation thickens to 2500 feet; and in the Guadalupe Mountains (a dissected plateau consisting entirely of the Chupadera rocks), the famous Carlsbad Cavern has been formed by the solvent action of later percolating ground waters.

A notable feature of the Chupadera formation is its abundance of gypsum and the alternation of gypsum with limestone and other sediments. This and the presence of intercalated red beds point to an alternation of marine and highly arid conditions. The distribution of the rocks suggests that the Permian sea was a large embayment connected with the Gulf of Mexico by a relatively narrow strait, through which the flow of water was interrupted several times. Such a broad, shallow body of water in an arid region would lose much water by evaporation, resulting repeatedly in a concentration of the brine to the point of saturation with calcium sulfate. The number of separate gypsum horizons in the Chupadera is large, but variable from place to place, suggesting slight warping of the bottom of the basin as well as non-continuity of the supply of sea water. When it is noted that sea water contains less than one-fifth of one per cent of calcium sulfate, it is evident that the volume of sea water that must have been evaporated during the deposition of the Chupadera formation is almost incomprehensibly large.

Such a concentration as would permit the deposition of so much gypsum would naturally lead to an enrichment of the brine in the more soluble salts. With the closing of Permian time came increased evaporation. Younger than the Chupadera formation, but lying topographically lower in the very bottom of the Permian Basin, the formation known as the Castile Gypsum was deposited. This formation in Texas consists largely of gypsum and anhydrite, with intercalated salt beds; but in the lower Pecos Valley and in the area east of Carlsbad there was deposited a bed of salt nearly half a mile thick, as the final concentrate marking the total disappearance of the Paleozoic seas in this region. Within this salt horizon, east of Carlsbad, are valuable beds of potash salts.

The formation formerly called Moenkopi consists largely of red, brown and purplish shales, but includes some beds of sandstone and conglomerate. One thin bed of conglomerate composed of limestone pebbles has been traced for over 30 miles. This formation, while uniform in its general characteristics, is quite variable in detail. It is fairly prominent in northwestern New Mexico and extends into Arizona. In the Zuni Mountains its thickness is about 1000 feet. It has not been recognized east of the Rio Grande. Recent work on correlation [2] indicates that this formation is not of Moenkopi (Lower Triassic) age, but belongs in the Permian, near the top of, or perhaps just above, the Chupadera horizon. Pending a more definite correlation this "so-called Moenkopi of previous reports" is designated as the Bluewater formation, and assigned to the topmost Permian.

MESOZOIC ERA

Conditions in New Mexico during the Mesozoic era were highly varied at different times and quite different at the same time in different places. These facts make the working out of the Mesozoic succession more difficult than in the case of the Paleo-

[2] Baker, A. A., and Reeside, J. B. Jr., Correlation of Permian deposits: Bull: Amer. Assn. Petr. Geol. 13:11, p. 1430, 1929.

zoic; correlation of separated Mesozoic formations, of the same age but differing in character, is as yet rather uncertain.

In general, it seems probable that the early Mesozoic was characterized by an irregular continuation or recurrence of the arid conditions of the Permian. In fact, for some of the red beds that are poor in fossils, the designation of the so-called Moenkopi rocks as Permian or Triassic is still uncertain. Likewise, for the sediments classed tentatively as Jurassic in age, the evidence available is not conclusive. During most of Comanchean time New Mexico stood out of water, and only a part of that period is represented in the sedimentary record. In the Cretaceous, however, the State was subjected to its last great marine invasion, and the correlation of Cretaceous beds, particularly at the base, is fairly sure. The Cretaceous sea covered the entire State, but much of the material deposited in it has been removed since by erosion. In latest Cretaceous time, while the eastern part of the State remained submerged, the western part came above the waters, and in it was instituted, probably at this time, the volcanic activity that continued on such a large scale throughout the Cenozoic era.

TRIASSIC PERIOD

During Upper Triassic time New Mexico was the site of extensive sub-aerial deposition, and sedimentation in bodies of fresh water. The rocks are largely red shales and sandstones and contain few fossils. Those that have been found include plants, the bones and teeth of land animals, and fresh-water shellfish.

In western New Mexico the Upper Triassic formations have been correlated definitely with those in eastern Arizona. The lower and middle Triassic formations are not exposed in New Mexico; the upper Triassic rocks include a basal coarse-grained member, named the Shinarump conglomerate, and an upper shale member, called the Chinle formation.

The Shinarump formation, generally called "conglomerate", is not conglomeratic throughout but in many places is a sandstone. The thickness in most outcrops is less than 100 feet. Its variability makes certain correlation difficult, but it is believed that the rock called Poleo sandstone in Rio Arriba County is the equivalent of the Shinarump. In Arizona, where it can be traced across the northern end of the State, the Shinarump is more characteristically conglomeratic.

The overlying Chinle formation is similar in general to the Bluewater formation, but it has a somewhat greater proportion of red shale and a correspondingly less amount of the coarser sediments. In the vicinity of Atarque it has a thickness of about 250 feet.

The whole Triassic series suggests a period of prevailingly desert conditions in a fiat, low-lying and perhaps irregularly sinking country, with repeated cycles of fresh-water flooding in large areas. The shallow basins were probably near sea level, but the absence of gypsum from the Triassic rocks suggests that at no time during the period was the area depressed below the sea. The continued sinking permitted brief marine flooding during the following Jurassic period.

The exposures of these recognized Upper Triassic formations west of the Rio Grande are best developed in the Zuni and Lucero uplifts, at the south end of the Nacimiento Range, and in the southern part of the Chama basin. The isolated exposures of the Lobo formation in Grant and Luna counties have been tentatively called Triassic, as judged from their position but without the support of fossil evidence.

The Triassic exposures in the eastern half of the State cover a much greater area than do those west of the Rio Grande, but the definite correlation of the eastern beds with the formations of Arizona and western New Mexico has not been made on an entirely satisfactory basis. The series of Upper Triassic red beds is known as the Dockum group and is continuous with beds of the same name in western Texas and Oklahoma. They are probably of the same age as the Chinle to the west, and the gray Santa Rosa sandstone that forms the base of the series in the northeastern part of the State may be the eastward equivalent of the Shinarump conglomerate. The strata above the Santa Rosa sandstone are largely red shales and red, brown and gray sandstones. The maximum thickness of the Dockum is about 1000 feet.

Beds of the Dockum group are exposed as far west as Carthage and as far east as the State line. There is a small area of Dockum beds in the extreme southwestern township of Lea County, and in the northeast corner of the State the Cimarron River has cut through the overlying Cretaceous rocks and exposed Dockum strata in the bed of the stream for more than 40 miles in New Mexico and beyond into both Colorado and Oklahoma. The largest single area of Dockum rocks occupies most of Quay and Guadalupe counties and extends northward across San Miguel, Mora and Harding counties, reaching to the southern boundaries of Colfax and Union counties in the valleys of the Canadian River and its tributaries. The same exposure continues southward in a long strip on the east side of the Pecos Valley to a point about 12 miles southeast of Artesia. Thus, the Dockum beds are continuously exposed for a distance of 230 miles north to south and constitute the third largest continuous sedimentary exposure in New Mexico. This area is nearly 7 per cent, and the total Triassic exposures cover more than 8½ per cent, of the area of the State.

JURASSIC PERIOD

The strata called Jurassic in New Mexico are so designated tentatively, as no fossils have been found that would serve to fix definitely the age of these rocks. There seems no good reason to doubt their Jurassic age, as in position and character they resemble unquestioned Jurassic formations in adjoining states, but the correlation is not perfect. The strata consist of massive sandstone members above and below, with a limestone-gypsum horizon between. This suggests two periods of deposition of desert sands, between which was a time of marine flooding and deposition of the thin limestone, followed by the drying up of this sea water, precipitating the gypsum. This sequence is not incongruous with known Jurassic events in the Southwest.

The lowest member of this series, called provisionally Jurassic, is known as the Wingate sandstone and is a rock that prevailingly weathers to vertical cliffs, red at the bottom and grading into yellowish at the top. Near Thoreau it is about 300 feet thick, but somewhat thinner elsewhere. It is entirely non-fossiliferous, so far as is at present known. It is capped throughout by a thin-bedded limestone, which in places is overlain by a bed of white gypsum, the two together constituting the Todilto formation with a maximum thickness of 80 feet. Above this lies the Navajo sandstone, consisting chiefly of red, yellow and gray sandstone, which also forms bold cliffs. In most of the outcrops the thickness is between 150 and 400 feet.

Jurassic rocks occupy an inconsequential fraction of the surface area of the State. The distribution of the Jurassic formations is about coincident with the upper edge of the Triassic formations already described. The Jurassic rocks form bold cliffs in the Zuni, Lucero and Chama regions, and the great escarpment on the north side of the valley of the Canadian River. This escarpment extends continuously from near Las Vegas irregularly eastward almost to the boundary of the State. These Jurassic cliffs decrease in height toward the east and the formations thin out completely in the valley of Ute Creek, about 50 miles due north of Tucumcari. Although the Jurassic disappears here, the overlying Cretaceous formations carry the cliffs several miles farther south and east, where they disappear under the Tertiary cover.

CRETACEOUS PERIOD

Formations of Cretaceous age are widespread in the Northeast and Northwest areas and are exposed in several places of smaller extent in the Median Area. Cretaceous rocks in the Southwest Area occur only in small, scattered exposures, and throughout the Southeast Area they are absent or are completely buried under younger sediments.

The geologic history of New Mexico during Cretaceous time is a record of marked instability with respect to permanence of shore lines, and great variability between areas not widely separated. This combination has led to extreme subdivisions of the Cretaceous rocks in some parts of the State and correspondingly extreme difficulty in correlating these subdivisions with precision. The Cretaceous record in its general aspects, however, is fairly clear. The Lower Cretaceous formations lie directly on the Jurassic without marked discordance, and in some places gradationally, but the succession of these rocks is far from complete. This suggests a gentle uplift without deformation near the end of the Jurassic, and general emergence but with occasional submergence during the Comanchean. This was followed by the deposition of the Dakota sandstone at the base of the Upper Cretaceous series; the Dakota is the only Cretaceous formation in the State that has been definitely correlated in all its exposures. During Upper Cretaceous time there was an intermittent sinking of the whole State, leading to complete submergence, except perhaps in the Southeast Area. The deposits of this time form a succession of sandstones, shales and subordinate limestones in alternation suggesting irregularity and non-uniformity of sinking and of deposition. Toward the end of Upper Cretaceous time the deposition caught up with the sinking, and there was a long period of extensive marshy conditions, favorable at times for the formation of coal. The coal beds are separated by sandstones and shales. In latest Cretaceous time the coal deposits were buried deeply under coarse sediments, but at the present time these later sediments are extensively exposed only in the northwestern part of the State.

The Cretaceous period was closed by the Laramide Revolution, the principal tectonic event in the forming of the Rocky Mountains. In the Median Area of New Mexico, which is in direct southern alignment with the Colorado Rockies, the effects of this disturbance are evident, in somewhat subdued degree, in the folding and faulting that affected the Cretaceous and older rocks. To the east and west of the Median Area, the effect was one of uplift without great deformation. There is some reason to believe that the Laramide Revolution developed in New Mexico the crustal weakness that provided vents for the extensive movement of magmatic material, for the first time since the pre-Cambrian. This igneous activity was the dominating feature of the succeeding Tertiary period and continued through the Quaternary and almost up to the present.

The lowest member of the series classed as Cretaceous (?) is the Morrison formation, which consists largely of shales and sandstones of prevailingly greenish-gray tint. The Morrison formation shows on the map as a narrow band between older and younger formations surrounding the Zuni uplift and in the face of the Canadian escarpment. It occurs similarly around the Chama Basin, except on the south side, and crops out as a wider area to the west and south of the Nacimiento Mountains. There is also a narrow strip on the east side of the Sierra Blanca. Its thickness as a rule is several hundred feet. This formation in New Mexico is correlated tentatively with a similar formation called Morrison, occurring in Colorado, but its exact age is not yet determined positively. It may represent a transition from Jurassic to Lower Cretaceous, or it may be, at least in its lower part in some localities, of late Jurassic age.

The top of the Morrison formation shows definite evidence of an erosional interval separating it from the beds next above. In northern and northeastern New Mexico the overlying strata are known as the Purgatoire formation and consist of sandstone and shale. At the same horizon in the Southwest Area is the Sarten sandstone, of which the rock formerly called Beartooth quartzite is probably an altered part. The Purgatoire formation does not occur in the Northwest Area, in which the Dakota sandstone rests directly on the Morrison.

The only member of the Cretaceous series that has been correlated definitely throughout its exposures in the State is the Dakota sandstone. This is one of the most widely recognized sediments in North America. It can be traced intermittently from central New Mexico into Colorado and as far north as southern Canada. It occurs along the edge of the Rocky Mountain uplift and in the rim surrounding the Black Hills, and it underlies most of the western portion of the Great Plains.

The Dakota sandstone is the principal carrier of artesian water throughout this territory. It consist of hard, compact, well-sorted sandstone and subordinate shale, with conglomerate at its base in many places. The thickness is from a few feet to 250 feet. It is generally considered to be of continental origin, but some marine fossils have been found in it in New Mexico. Its character and extent suggest that it is the basal member of the Upper Cretaceous series, and that it was formed on land, and there sorted by the advance of the great sea that submerged the entire Rocky Mountain and Great Plains areas in this period.

The Dakota sandstone forms the caprock of many of the plateaus in the northeast portion of the State. Its superior hardness enables it to act as a protective cover to the softer shales below, which weather out by undercutting, leaving bold cliffs such as characterize the Canadian escarpment. In the Northwest Area the exposures of the Dakota are limited to narrow bands, mainly in the Zuni and Chama uplifts, but it dips under the younger rocks and evidently underlies most of the whole Northwest Area, except where igneous rocks have broken through or where older formations have been uncovered by erosion. Edges of the Dakota are exposed also around the Sierra Blanca, and for a total of nearly 100 miles along the Arizona boundary near the Chuska Mountains.

Cretaceous exposures in the southern half of the State are small and scattered in the Southwest Area and entirely wanting in the Southeast Area, except for a little patch of Lower Cretaceous rocks near Portales. There is reason to believe that the

Cretaceous sea covered practically whole state but that the sediments deposited in it have been almost completely removed by erosion from the southern half of the State.

Above the comparatively uniform Dakota sandstone the sediments show great variability. Evidently the deposition in the Cretaceous sea was governed by local conditions so different as to make correlation difficult. Overlying the Dakota in the Northwest Area is the Mancos shale, with a thickness of 700 to 1800 feet, correlated with a formation of the same name in Colorado and Utah. At essentially the same horizon in the Northeast Area is the Colorado group of shales, sandstones and limestones, so named from the continuation of the formation in the Great Plains region. Next overlying is the non-marine series carrying the coal beds in the Northwest Area and known as the Mesaverde group. In the vicinity of Gallup this series is about 1800 feet thick. The Mesaverde group seems equivalent in age to part of the Pierre shale in the Northeast Area, which is considered to be the lower member of the series known in the Great Plains as the Montana group. The Pierre shale is over 2,000 feet thick in the vicinity of Raton. The lower coal in the Raton area is found in the Vermejo formation, which, with the Trinidad sandstone at its base, lies on the Pierre shale and is definitely younger than the coal-bearing beds of the Mesaverde group in the Gallup, Carthage and Sierra Blanca regions.

In the San Juan Basin the strata that are essentially equivalent in age to the Vermejo formation include the marine Lewis shale that lies directly on the Mesaverde group. Above the Lewis shale are the fresh-water sandstones and shales known respectively as the Pictured Cliffs sandstone, the Fruitland formation, which, is limited to the west side of the basin and contains some coal, and the Kirtland shale with its included member known as the Farmington sandstone. Above these is the McDermott formation, quite varied locally but notable for the abundance of included volcanic debris. In most areas these formations are several hundred feet thick, but in places they are much thicker. The McDermott is extensively developed in Colorado. Its exposures in New Mexico are limited to the west side of the San Juan basin. It is considered doubtfully to represent the extreme top of the Cretaceous series, but it may be younger. The detailed correlation of the upper part of the Upper Cretaceous in New Mexico is still far from satisfactory.

The close of the Cretaceous marked the final emergence of New Mexico from the sea and consequently the last of the marine sedimentary rocks. The Laramide Revolution resulted in an extensive uplift of the whole State, without marked deformation except in the Median Area. Later sedimentary rocks, therefore, are distinctly of the continental type, including local freshwater deposits in lake basins. If the age of the McDermott formation has been correctly judged, the beginning of the extensive volcanic activity of the State was in latest Cretaceous time. Recent field work in the area near Silver City [1] has brought to light very positive evidence of late Cretaceous vulcanism.

CENOZOIC ERA

TERTIARY PERIOD

The early part of the Tertiary period was a time of extensive accumulation of continental sediments in the northern corners of the State, of tremendous igneous activity in the Southwest Area, and of vigorous erosion elsewhere. The later part of the Tertiary was marked by the deposition of an extensive mantle of gravel and sand all along the eastern edge of the State, in common with much of the Great Plains area in adjacent states. The rest of the State was, in general, undergoing erosion, but with local deposition in valleys and lake basins.

The sediments known in the San Juan Basin as the Ojo Alamo sandstone, and in the Cerrillos area south of Santa Fe as the Galisteo sandstone, are probably equivalent and of early Tertiary age. They rest directly on the eroded surface of the earlier Cretaceous beds and are marked by coarse conglomerates in their basal parts. The Ojo Alamo sandstone is limited in its exposures to the western and southern edges of the large Tertiary area that lies mostly in San Juan and Rio Arriba counties. It is notable for the large igneous pebbles in its conglomeratic parts and for the presence of petrified logs. The Galisteo sandstone also shows locally abundant petrified logs. Both members contain some shaly beds, particularly toward the top, and both were eroded before succeeding formations were laid down. Their position suggests earliest Tertiary age. The fossil evidence confirming this suggestion is not yet conclusive, but both formations are provisionally assigned to the base of the Eocene.

In the northern part of the State, immediately east of the Rocky Mountains, an extensive area consists of the Raton formation, in which have been found fossils that date it definitely as Lower Eocene. It may be equivalent in age to the formations just described or may be somewhat younger. The Raton formation has a basal conglomerate that rests on an eroded Cretaceous surface. It is sandy with some shale in the lower part and shaly with some sand toward the top. Coal occurs in both the lower and upper parts. Later Tertiary intrusives have metamorphosed part of this coal somewhat, so that it is of better quality than most coals of Eocene age. In places this metamorphism has been sufficient to produce cokeite or anthracite.

The Raton formation seems to be equivalent in age but dissimilar in character to the lower part of the Nacimiento group

[1] Lasky, S. G., Personal communication.

in the northwestern part of the State. The rocks of the Nacimiento group are quite variable locally. Its divisions are known as the Puerco formation, overlain by the Torrejon formation in the valley of the San Juan River, and as the Tohachi shale, overlain by the Chuska sandstone in the Chuska Mountains. In the San Juan basin these rocks are capped by the Wasatch formation of light colored sandstone and shale, which belongs to the lower part of the Eocene. The maximum thickness of the Tertiary formations in the San Juan basin is about 3200 feet.

Lower Eocene sediments have not been identified elsewhere in the State, and strata of upper Eocene, Oligocene and lower Miocene ages have not been recognized anywhere in New Mexico, except as local members of minor importance in the volcanic series.

The Tertiary period was a time of the most extensive igneous action in New Mexico since the pre-Cambrian. Beginning in the Cretaceous and extending throughout the Quaternary and practically up to the present, vast volumes of molten lava were poured out on the surface of the earth. Apparently this volcanic action was intermittent over a long period of time and varied considerably in its intensity and in its quality, as beds of ash and tuff and agglomerate, with occasional thin sheets of stream-laid gravels, are found interstratified with the flow rocks. The lavas themselves are variable. Though they have not been studied in full detail, it seems probable that the same vents have given forth, in successive eruptions, lavas differing considerably in composition. The sequence differs materially from place to place. Some of the eruptions were of the quiet type, permitting spreading and long-distance flow. Others were violent, and fragments ranging from 2 feet in diameter down to fine dust were spread over considerable areas.

The intrusive igneous rocks are likewise important. Their precise age relations are difficult to determine, but they seem unquestionably to be related to the same general period of time as the flow rocks. The intrusive rocks occur as dikes, sills, stocks and small batholiths. The largest mass exposed forms the core of the Sierra Blanca. The adjacent Capitan, Jicarilla and Gallinas Mountains are closely related. The Organ Mountains, centering about 40 miles north of El Paso, and Black Mountain overlooking Cimarron Valley from the west are comparable but not so large. In the Southwest Area the intrusive rocks outcrop in the Tres Hermanas, Little Hatchet and Burro Mountains, in Cooks Range and in the Silver City region. Small intrusives are exposed in most of the ranges in the Median Area. In the Northeast and Southeast areas the intrusives are limited to the sills in the Raton region, and several long dikes. In the Northwest Area the most prominent exposure is Shiprock, an intrusive neck from which three large dikes extend outward for about 3 miles each.

There are a dozen smaller exposures, averaging a mile or less across, within 25 miles of Shiprock, and over a score of similar necks or smaller stocks between the mesa northeast of Mount Taylor and the Rio Puerco. Judging from the altitude of Shiprock, some 1850 feet above the surrounding plain, it seems probable that the areas showing numerous small vents were once buried by flow rocks, now denuded by erosion to their roots. This suggests also that similar widely scattered vents may lie below the present lava sheets, thereby explaining in part their variability of composition and difficulty of correlation, as it is extremely improbable that all these vents were active simultaneously.

The great Datil Mountains mass of early Tertiary flow rocks, covering nearly all of Catron County, the western parts of Socorro and Sierra Counties, and the northern part of Grant County, is the largest igneous exposure in the State. The ranges in Hidalgo and Luna Counties, with some exceptions, are parts of the same mass, now isolated by valley fill. Similar rocks form Mount Taylor, Sierra Grande, and Brazos Peak, and a horseshoe-shaped area between the Nacimiento Mountains and the Rio Grande. There are small exposures of this undifferentiated andesite-latite-rhyolite series scattered through the areas of later basaltic flows.

The late Tertiary igneous rocks have not been distinguished sharply from the earlier flows. The late Tertiary sediments, however, are separated from the beds of the Nacimiento group by an erosion interval that includes Middle and Upper Eocene, all of Oligocene, and Lower and Middle Miocene time. The late Tertiary sediments, therefore, are mostly of Pliocene age, with some Upper Miocene rocks at the base of the series. These rocks in the eastern part of the State are known as the Ogallala formation, and form a blanket of sand and gravel covering most of Lea County, practically all of Roosevelt and Curry Counties and the southern part of Quay County. Northward, beyond the trough of the Canadian River, the same formation extends from the State line westward into Quay, Harding and Union Counties. These areas in New Mexico form the western edge of the same formation that extends into Texas, Oklahoma, Colorado, Kansas and Nebraska. Outlying patches of the Ogallala formation, isolated by erosion, cover considerable areas in DeBaca, Guadalupe and Torrance Counties and northward.

During late Tertiary time, probably as a result of damming by lava flows and adjustment by faulting, certain portions of the Rio Grande Valley were the sites of extensive lakes, which have now been drained by the down-cutting of the obstructions at their outlets. The Elephant Butte reservoir is an artificial restoration, in a limited way, of the lake conditions that existed on a far larger scale while the Rio Grande was adjusting itself to its present course and gradient.

In these lakes were deposited extensive fresh-water sediments, of equivalent age but quite contrasted in character to the Ogallala formation of the Great Plains. These sediments, known as the Santa Fe formation, extend almost continuously down the Rio Grande Valley from the northern boundary of the State as far south as San Marcial, and smaller areas are exposed near Hatch and Rincon. Some of these sediments have been buried beneath Quaternary sediments and basalt flows. The Rio Grande has trenched deeply through the Santa Fe formation and its igneous capping, particularly in the parts of the river west of Taos and west of Santa Fe.

The Tertiary rocks, cover, about 30 per cent of the, total area of the State, distributed as follows: Eocene sediments, in northern part of State, 6 per cent; Ogallala formation, in eastern part of State, over 10 per cent; Santa Fe formation, in Rio Grande Valley, 3 per cent; intrusive igneous rocks, scattered, probably Tertiary, 1 per cent; Datil formation, of extrusive igneous rocks with interbedded tuffs and sediments, mostly in southwestern part of State, nearly 10 per cent. The Datil formation covers nearly 50 per cent of the Southwest Area.

QUATERNARY PERIOD

By the close of the Tertiary period the major topographic features of New Mexico had been definitely established in their present positions. Quaternary modification was limited to deepening of the river valleys, erosion of the uplands, deposition of bolson sediments in the intermontane valleys, and extensive flows of basalt that covered some of the softer sediments and protected them from erosion, thereby establishing the mesas so prominent in some parts of the State.

The only water-sorted sediments of Quaternary age in New Mexico are the terrace gravels, which were deposited while the streams were at higher levels but seeking their present gradient, and which have not been completely destroyed by later downcutting. Some of these gravels, particularly in the valley of the Gila River and less notably along the Rio Grande, have been named Palomas gravels and correlated tentatively with the Gila conglomerate formation in eastern Arizona.

The most extensive Quaternary formation consists of the bolson deposits of alluvium, the deposition of which has continued to the present time. This is valley fill, largely unsorted, consisting of gravels, sands and clays brought down from the mountains and deposited in the valley flats by sheet-flood erosion and torrential arroyo flows, supplemented by the action of the wind. The most typical area of this sort is probably that extending from the Franklin and Organ Mountains west to the Arizona state line. The alluvium here has formed extensive intermontane plains, burying the lower portions of the mountains, the summits of which project like islands in an alluvial sea. In the Jornado del Muerto is a similar extensive in which the streams from the mountains sink and are lost. In Tularosa and Estancia Valleys and in the Plains of San Agustin the bolson type is modified because of the former existence of temporary lakes, and in the Tularosa Valley wind action has produced an extensive covering of dune sand, part of which consists of almost pure gypsum and is known as the White Sands. Quaternary alluvium is also deposited extensively in the valleys of the Rio Grande and the Pecos River.

The igneous action that was so prominent in Tertiary time continued through the Quaternary, but with an increasing proportion of basic rocks. The Quaternary basalts formed extensive flows, mostly by eruptions of the quiet type, although some explosion craters and cinder cones have been recognized. The largest area of this basaltic flow rock is mainly south of the Zuni uplift, but extends west to the State line and northeast almost continuously into southwestern Sandoval County. Another large area of basalt extends from Colorado down the west side of the Rio Grande Valley to within 10 miles of the northern boundary of Santa Fe County. Isolated patches up to several miles across form mesas on either side of the Rio Grande throughout its length in New Mexico. Other flows of notable size occur in Mora, Colfax and Union Counties. From a point northwest of Carrizozo a basalt flow extends 40 miles southwest in the Tularosa Valley. This flow is probably quite recent. Scattered smaller areas of basalt are widely distributed, except in the southeastern part of the State.

In only one part of the State is rhyolite of Quaternary age extensively developed. In the Valle Mountain region, east of the Nacimiento Mountains and south of the Chama Basin, a central core of the Datil formation is surrounded by a roughly circular ring averaging about 30 miles in diameter, consisting of rhyolite with interbedded tuff and pumice. At its eastern edge several small tributaries to the Rio Grande have trenched through this acidic series, exposing the Quaternary basalt underneath.

The Quaternary alluvium covers about 27 per cent of the total area of the State and the Quaternary igneous rocks about 4 per cent.

PART III. NON-METALLIC MINERALS

ADOBE

Adobe is a sandy clay, generally of Recent age, which is used extensively in the manufacture of sun-dried brick. According to Miller:[1]

> The word "adobe" is used to designate a particular kind of soil and there prevails a general impression that this material is essential for the making of sun-dried brick. Most clayey loams, except those with a high clay content, are suitable, but it is not practicable to make a selection on the basis of soil analyses. Soils having a high clay content shrink or crack badly when drying, and sandy soils do not have sufficient bonding material to prevent crumbling. Neither of these soils should be used alone for brick, but a very good building material can be obtained by mixing the two soils together in proportions that will overcome the undesirable qualities of each. The best way to determine the fitness of a soil is to make a sample brick and allow it to cure in the open, protected from moisture. It should dry without serious warping or cracking. Frequently a suitable earth can be had from excavations for cellars.

Adobe clays are widely distributed in New Mexico and other southwestern states; they have been used as a building material for centuries. In many of the Spanish-American towns of New Mexico practically all of the buildings are constructed of adobe. Many adobe clays contain too much lime or alkali salts for use in making ordinary burned brick, but these impurities apparently have no ill effect on the sun-dried product.

Adobe bricks 4 by 8 by 12 inches are commonly used in Socorro, but Miller lists eight additional sizes in use in the Southwest as follows:

Sizes of Adobe Bricks

4 by 8 by 16 inches	5 by 12 by 16 inches
4 by 10 by 16 inches	6 by 10 by 20 inches
4 by 9 by 18 inches	5 by 12 by 18 inches
4 by 12 by 18 inches	6 by 12 by 24 inches

The clay is mixed with enough water to make it thoroughly plastic, and then straw, chaff or other bonding material is tramped into the mass. The mud is then pressed by hand into the molds and the molds lifted away, leaving the bricks to dry. After drying for a few days the bricks are stacked on edge and left to cure in the sun and wind for two weeks or more.

The cured bricks are laid in the wall with adobe mud or lime mortar. Exterior walls are usually 12 or 16 inches thick and interior walls are usually 8 inches. About 1500 bricks 4 by 8 by 12 inches are required for the walls of a room 10 feet square and 9 feet high. Most of the older buildings in the State have an outside coating of adobe plaster, which resists the washing action

[1] Miller, T. A. H., Adobe or sun-dried brick for farm buildings U. S. Dept. Agr. Farmer's Bull. 1720, p. 3, 1934.

[2] Op. cit., p. 4.

of rains fairly well in this semi-arid region, and which can be easily renewed. In recent years regular stucco has been used on outside adobe walls with satisfactory results.

Actual figures on the insulating characteristics of adobe have not been available until recently. Amador and Snearly[3] found the coefficient of heat transmission for 10-inch adobe walls to be 0.28 b. t. u. per hour per square foot per degree Fahrenheit temperature difference. The conductivity was found to be 3.88. The coefficient of heat transmission for 8-inch adobe walls was calculated to be 0.328; for 16-inch walls, 0.196.

The 1929 Guide of the American Society of Heating and Ventilating Engineers, as quoted by Amador and Snearly, contains the following tabulation of coefficients of heat transmission for various building materials, to which is added Amador and Snearly's coefficient:

Coefficients of Heat Transmission for Building Materials

10-inch limestone or sandstone walls 0.502	0.502
10-inch concrete wall 0.456	0.456
10-inch brick wall --------------------------------------	0.334
10-inch concrete block wall ----------------------	0.327
10-inch concrete wall with brick veneer	0.327
10-inch-adobe wall (Amador and Snearly)	0.28

Adobe dwellings have the reputation of being notably cool in summer and warm in winter, and the above data definitely prove that this reputation is justified. The greater thickness of the average adobe wall, as compared with other building materials, is an added valuable insulating feature.

It is impossible to estimate the value of adobe brick production in New Mexico, since statistics have never been gathered, but it probably exceeds the combined value of all other building materials that have been produced in the State. In Socorro the bricks can be purchased and laid on the wall foundation for $20 a thousand, if suitable adobe clay is available at the building site. If the dried bricks must be hauled any appreciable distance an additional charge of $5 to $15 a thousand is made.

ALUM

GENERAL FEATURES

Alum is the name given to the group of minerals that consist of double sulfates of aluminum and other bases. The name is also applied to manufactured salts of similar composition.

Among the natural alums are minerals containing, as the second base, iron, manganese, potash, soda, magnesium or ammonium. There are also two hydrous aluminum sulfates, not

[3] Amador, Frank J. Jr., and Snearly, James E., Study of heat transmission of adobe: Thesis prepared in the Department of Mechanical Engineering, New Mexico State College, State College, N. Mex., May, 1933.

true alums, which are used in the manufacture of refined alum salts.

Nearly all of the alum minerals are soluble in water, and consequently are easily recognized by their peculiar bitter taste. The only tasteless minerals used extensively in alum manufacture are aluminite, $Al_2O_3.9H_2O$, not reported from the United States, and alunite, $K_2O.3Al_2O_3.4SO_3.6H_2O$, which has been worked in Nevada and Utah but not in New Mexico.

Alum minerals do not occur as original constituents of fresh rocks, but are always produced by the action of sulfuric acid, formed by the oxidation of pyrite or other sulfides, on the aluminous minerals in the rock. Alum is thus found disseminated through shales, slates and clays, or in feldspathic rocks rich in pyrite. Alum minerals formed in permeable rocks may be leached out and deposited elsewhere in compact or powdery crusts. Only rarely are these crusts extensive enough to be commercially valuable. Most manufactured alum is produced by leaching the salt out of the rocks and purifying it by crystallization from solution.

USES

Alum in solution has the property of flocculating or coagulating fine or colloidal material in suspension. Consequently it is used extensively in sewage purification, in settling slimes in certain ore-dressing processes, and in clarification of water for domestic use. It is used in the paper-making, dyeing and tanning industries. Purified alum is used as a medicinal astringent, and it is an ingredient in certain low-priced baking powders.

Alum minerals do not command high prices. Manufactured alums bring from 1½c to 4c per pound, and the prices for crude alum minerals are necessarily somewhat lower.

For many purposes for which alum was formerly used, the manufactured salt known to the trade as "concentrated alum" has been substituted. This is an aluminum sulfate made from the mineral bauxite, a hydrous aluminum oxide.

NEW MEXICO OCCURRENCES

A deposit of alum-bearing rock,[1] described as one of the largest deposits in the United States, is located in Grant County on the Gila River about 25 miles north of Silver City in secs. 19, 20, 29 and 30, T. 13 S., R. 13 W. Here a portion of the volcanic rock that constitutes the great Mogollon-Datil mass has been impregnated with pyrite in small grains. This pyrite, on decomposing under atmospheric influences, has liberated sulfuric acid which, acting on the feldspars in the rock, has produced large quantities

[1] Ladoo, R. B., Non-metallic minerals, p. 26, McGraw-Hill Book Co., Inc., New York City, 1925.

Hayes, C. W., The Gila River alum deposits, N. Mex.: U. S. Geol. Survey Bull. 315, pp. 215-223, 1907.

of alum. Much of this has been retained in the rock, but some has been leached out and redeposited by evaporation on cliffs and in caves where there was a good circulation of air and protection from surface waters.

There are three possible commercial sources of alum in the Gila River deposits, as follows:

1. The alum-rock, which is present in enormous quantities. Although the alum is present in this rock in proportions of only 2 to 3 per cent, it could be readily extracted by hot water leaching and crystallization from solution. Analyses are given by Hayes.[2]

2. The incrustations on cliffs and in protected places. These consist of concentrated crude alum that has been leached and crystallized by percolation and evaporation of ground water, forming the mineral alunogen, a hydrous aluminum sulfate. These crusts are over 90 per cent pure alunogen,[3] but they occur in relatively small bodies. Most of the encrusted cliffs show coatings only a few inches thick, although crusts from 3 to 4 feet thick are reported. Some of the material in these crusts is firm, but much of it is cellular or powdery.

3. The deposits in tunnels and old mine workings. These consist of halotrichite, or iron-alum, in crusts a few inches thick in dark and moist tunnels. The halotrichite looks like green silk threads, and the crystals grow at the rate of a fraction of an inch per year. Some of this material is over 98 per cent pure. The amount is small compared to either of the other two alum minerals.

Some alunite is reported from this same territory, but no detailed information regarding it is available.

These alum deposits have not as yet been commercially exploited[4] on account of their relative inaccessibility. There seems to be little question as to the quality or quantity of material available, but on account of the low price of alum and the location of these deposits, and the fact that much of the alum bearing ground was patented many years ago, the deposits offer but little promise to prospectors.

Other occurrences of alum minerals in New Mexico, none of which has as yet proved commercial, are in Catron County 15 miles southeast of Glenwood, in Colfax County southeast of Springer, near Gallup in McKinley County, in eastern Mora County about 25 miles from Wagon Mound, in the northwestern part of Sandoval County in sandstone, in Taos County between Red River and Questa, in San Juan County in springs 10 miles northwest of Farmington, and in Union County on Ute Creek.

[2] Op. cit. (U. S. G. S. Bull. 315), p. 219.3

[3] Op. cit. (U. S. G. S. BulL 315), p. 220.

[4] As this bulletin goes to press, word is received that extensive tests of the commercial possibilities of the alum deposits are in progress, sponsored by Mr. R. H. Johnston, who controls a large acreage patented prior to 1900.

ASBESTOS

GENERAL FEATURES

A variety of amphibole, allied to hornblende and crystallizing in prisms so fine and slender that they resemble silk fibers, was recognized as a separate mineral species and originally given the name "asbestus." Later usage has altered the spelling of this term to asbestos, and has extended its scope to include several other minerals showing similar physical properties. The best asbestos of commerce is a fibrous variety of serpentine, a mineral quite different from the one originally named asbestus.

VARIETIES

The most valuable asbestos mineral is chrysotile, a fibrous variety of the mineral serpentine, which always occurs as veins in serpentine rock. These veins are made up of fine, silky fibers, usually brilliant white but in some places tinted yellow or pink, and rarely colored in deeper shades of yellow or green. Chrysotile is a hydrous magnesium silicate, $3MgO.2SiO2.2H_2O$. In veins of chrysotile asbestos the fibers lie across the vein, termed "cross-fiber," or they may lie in the plane of the vein, termed "slip-fiber." Veins of either sort are usually narrow, measuring from a fraction of an inch to a few inches across, but the veins in the commercial asbestos deposits occur near together or intersecting, in many cases forming a close network. The slip-fiber veins usually contain fibers of greater length, which is a desirable quality for weaving and spinning, but this advantage is frequently offset by the superior strength and flexibility of the cross-fiber material. Most of the best grade of asbestos occurs as the cross-fiber type, with fibers about an inch in length. Fibers less than one-half inch long, however good their quality, are much less valuable.

The fibrous varieties of several minerals of the amphibole group produce asbestos that for most purposes is considered inferior to the serpentine variety. The fibers of amphibole asbestos are generally harsh and brittle as compared with chrysotile, and usually have little tensile strength. Of the minerals of the amphibole group, anthophyllite, tremolite and actinolite occur in asbestiform varieties. Crocidolite is a rare bright-blue species.

In several occurrences of amphibole asbestos, the fibrous material is obviously an alteration product, the result of weathering. The soft fibers at the surface grade at a very slight depth into crystalline splinters and needles of unweathered amphibole; such material is worthless as a source of commercial asbestos. In other occurrences the short fibers have become matted together into tough flexible sheets, called "mountain leather", or compact masses which from their feel and texture are termed "mountain cork." No use for such materials has yet been found.

USES

The qualities that make asbestos desirable for industrial uses are its flexibility and strength, permitting spinning and weaving; its fibrous character, permitting working into desired shapes and its blending with other material; its low conductivity of heat and electricity, permitting its use for insulating and fire-resisting purposes; and its resistance to acids and other chemicals, permitting its use for industrial filters.

Asbestos has been used for hundreds of purposes, most of which fall under the general heads listed above. The best fiber asbestos is used for textiles, as it can be spun and woven into cords and cloths useful for heat-resistant packing, for heat-proof clothing, especially mittens for handling furnace tools, and in combination with other materials for such specially woven products as automobile brake bands. High-grade short-fiber asbestos is marketed loose for packing and filtering uses and is also made up by pressure into asbestos papers, plates or sheets, or even thick blocks. Mixed with some cementing material it finds use in fireproof shingles and artificial lumber, and as a heat-insulating cement for covering boilers and pipes. For chemical filtering some amphibole asbestos is superior to the fibrous chrysotile. In fact the variety of uses is so great and the variation in quality of asbestos covers so wide a range that a type of asbestos quite useless for one purpose may be entirely suitable for another.

NEW MEXICO OCCURRENCES

The only certainly identified serpentine asbestos known in New Mexico occurs in the yellow ricolite over the hill west of the main ricolite deposit, about 3 miles north of Red Rock in Grant County. (See chapter on Ricolite.) This material is a fine-quality silky-soft glistening white cross-fiber asbestos, but the veins are so narrow that the fibers are not more than one-fourth of an inch in length. This deposit has been but slightly explored. Unless future developments show larger and closer spaced veins, this material, in spite of its purity, offers little promise of commercial value.

An exposure of hornblende asbestos occurs in the north bank of the creek near State Highway 12, about a mile west of Reserve, in Catron County. This asbestos is in tough flakes without well-developed fibers in a weathered dark-colored rock. The total exposure is only a few feet across. The material appears to be a product of surficial weathering with no visible evidence of increase in quality or quantity with depth, and its physical characteristics are not much superior to those of ordinary mountain leather. It offers at present no commercial promise.

The asbestos reported from south of Stein's Pass in Hidalgo County is described as an occurrence similar to the one near Reserve, and consists of flakes of poor quality. Other occurrences reported in the State include a single mass of mountain leather, about 3 feet across, which is now in the museum at the New Mexico School of Mines; this specimen was encountered during the mining of iron ore by the Hanover-Bessemer Iron & Copper Co. near Fierro. A few other occurrences of mountain leather have been reported, without specification of locality.

As far as known exposures indicate, there seems no promise of commercial deposits of asbestos in New Mexico.

ASPHALT ROCK

GENERAL FEATURES AND USES

Asphalt rock is limestone or sandstone permeated with petroleum residue. Asphaltic sandstone has been known in two localities in New Mexico for many years. The deposit north of Santa Rosa, Guadalupe County, has been worked, and an area near Baker's Trading Post, 20 miles northeast of Gallup, McKinley County, has had some attention. The only use to which the New Mexico asphalt rock has been put is for surfacing of roads.

NEW MEXICO OCCURRENCES

GUADALUPE COUNTY

The Santa Rosa deposit, Guadalupe County, is located almost entirely within the Preston Beck, Jr., Grant, about 8 miles by road north of the town of Santa Rosa on the Chicago, Rock Island & Pacific railroad. It has been described by Winchester[1] as follows:

> The Santa Rosa sandstone (Triassic) in Guadalupe County near Santa Rosa is saturated with bituminous material over a considerable area. Recently detailed studies of this deposit have been made by the New Mexico Construction Co. and the writer is indebted to Mr. Vincent K. Jones of that company for much of the information which follows.
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> In order to determine the continuity, character and extent of the saturation, the New Mexico Construction Co. has drilled approximately 100 core drill holes covering some 3,000 acres on the Preston Beck, Jr., Grant about seven miles north of the town of Santa Rosa. These holes have proved a saturated zone from 10 to 60 feet thick. In only one hole was saturation absent.
>
> The saturated sand is a well-consolidated cross-bedded rock composed of sharp quartz grains and containing from 4 to 8 per cent of bituminous substance, about one-fifth of which, according to Mr. Jones, will evaporate at air temperature over a period of several weeks. Some parts of the sand are found to be completely saturated with asphaltic material, while other parts contain no asphaltum. The fresh material when extracted yields a very ductile asphalt which has a penetration of approximately 230 at 77° F.
>
> In some of the core holes a heavy black viscous oil which would flow at ordinary temperatures was found in pockets. In one hole a small flow of water was found trapped in such a way as to be under slight artesian pressure. Developments to date show that this particular deposit of bituminous sand contains approximately 2,000,000 tons having a residual asphaltic content of 5 per cent. The overburden, which is composed of similar sand

[1] Winchester, D. E., The oil and gas resources of New Mexico: N. Mex. Sch. of Mines, State Bur. of Mines and Min. Res. Bull. 9 p. 208, 1933.

though not saturated in this particular area, ranges in thickness from a few inches to forty feet.

> At the present time the bituminous sand deposit near Santa Rosa is being developed in a small way for paving purposes. A quarry has been opened at a point where there is practically no overburden above the saturated material and where core-hole prospecting has shown the deposits to have a thickness of fifty feet. The sand at this point has a residual asphalt content averaging 5 per cent. Approximately 1,000 tons of bituminous sand have been quarried and most of it used in pavement construction for the New Mexico State Highway Commission within the town of Santa Rosa. After mining, the rock is crushed to minus ¼-inch size and then mixed with 1 to 1½ per cent of the asphalt, together with a small amount of gasoline or naphtha, the latter being added to make the added asphalt blend with the natural asphalt contained in the rock. * * * After this treatment, the product is laid cold. Apparently one inch of this material laid on a substantial foundation is all that will be required for heavy traffic pavement.

In the summer of 1932 approximately 3,000 tons of the Santa Rosa asphalt rock was used for the construction of about 5 miles of an experimental section of U. S. Highways 66 and 85 between Belen and Los Lunas. One-half, three-quarters, and one inch thicknesses of crushed asphalt rock were rolled cold over a gravel base. Additional data on the construction of this road have been presented by Gilbert.[1]

Santa Rosa asphalt rock has also been used on highways and streets in other parts of the State and on streets in Phoenix, Ariz., Amarillo and Shamrock, Tex., and Walsenburg, Colo.

McKINLEY COUNTY

Winchester[2] also describes the McKinley deposit as follows:

> Approximately 20 miles northeast of Gallup on the north fork of the Rio Puerco, a sandstone reported to belong to the Dakota (Cretaceous) is saturated with a paraffin-base oil over a relatively large area. According to information furnished to the writer by J. M. McClave of Denver, Colo., the saturated sandstone has a thickness of not over 40 feet. The sand is coarse grained and hard. Analysis of the sand shows an oil content of as much as 24 per cent. No economic use for this sand has yet been developed.

BARITE

GENERAL FEATURES

Barite, frequently termed "barytes" or "heavy spar", is a sulfate of the metal barium. It has the chemical formula $BaSO_4$, and contains 65.7 per cent barium oxide or baryta, BaO, and 34.3 per cent sulfur trioxide, SO_3. It is the heaviest of the common non-metallic minerals, having a specific gravity of about 4.5. Its average hardness is 3, or about the same as that of calcite.

In most deposits barite occurs with other minerals. It is commonly associated with clay, limestone, fluorspar, gypsum, and quartz. In New Mexico it is common as a gangue mineral in fluorspar deposits and in the ores of certain metal-mining districts.

[1] Gilbert, A. J., Rock asphalt: *New* Mexico, vol. X, pp. 18-20, Dec., 1932.

[2] Op. cit., p. 209.

The commercial use of barite, as such, is largely dependent on the fact that it is a heavy white mineral, chemically inert and comparatively cheap.

USES

Barite enters into commerce in the following forms.[1]

1. Crude barite. This is the raw material for the manufacture of ground barite, lithopone,[2] and barium chemicals. It may be sold as it comes from the mines, or it may be washed in jigs or log washers to remove clay, iron oxides, and other impurities.

2. Ground barite. This is crude barite after it has been washed and then ground very fine. Naturally white barite, or barite intended for use where color is of small importance, needs no treatment other than grinding. Otherwise, the ground mineral must be subjected to further treatment, generally bleaching with dilute sulfuric acid. "Off-color" or "unbleached" barite is sold for use in dark-colored paints, for use as drilling mud with rotary tools in oil-well drilling, and for the manufacture of lithopone. The bleached or naturally white ground mineral is known as "prime white" or "water-floated" barite and is used as a pigment in white paints, as a filler in white paper, linoleum, rubber goods, artificial ivory, and for other purposes where a white, inert pigment or filler is desired.

Ground barite is also used in ceramics, lake colors, fireworks, glassware, phonograph records, printers' ink, heavy textiles, soap, and other articles.

3. Barium chemicals. Chemical compounds of barium are manufactured directly from crude barite, from ground barite, or from witherite (barium carbonate). The more important manufactured salts are the sulfate (blanc fixe), carbonate, chloride, nitrate, monoxide, dioxide, hydroxide, and sulfide.

NEW MEXICO OCCURRENCES AND PRODUCTION

The barite deposits of New Mexico are of two types: (a) Veins and sheetlike deposits in igneous and sedimentary rocks, and (b) concretions in sedimentary rocks. Residual deposits of barite resulting from the weathering of limestone and dolomite, such as occur in Georgia and Missouri, are not known in New Mexico.

In Bernalillo County barite occurs with fluorite and galena at the Galena King mine in the Manzano Mountains and at the Capulin Peak prospect in the Sandia Mountains. A small dump at the Galena King mine was reported by Ladoo[3] to contain 12.75 per cent barite.

[1] Santmyers, R. M., Barite and barium products; pt. 1, General information: U. S. Bur. Mines Inf. Circ. 6221, Jan., 1930.

[2] Lithopone is a pigment and filler consisting largely of barite and zinc sulfide.

[3] Ladoo, R. B., Fluorspar, its mining, milling and utilization, with a chapter on cryolite: U. S. Bur. Mines Bull. 244, p. 132, 1927.

Barite occurs in Dona Ana County[4] at Woolfer Canyon, at Tonuco Mountain, and in the Organ Mountains.

Tonuco Mountain is east of Heathdon on the Albuquerque-El Paso branch of the Atchison, Topeka & Santa Fe railway. Barite is found at the Tonuco mine of the Ore Production Co. on the west side of the mountain and at the Beal claims on the east side. The veins at both properties are fissure fillings in the pre-Cambrian rocks, and have been developed for their fluorspar content. The Tonuco vein contains 20 to 40 per cent barite in large, well-developed, platy crystals. The vein is 10 to 25 feet in width. Two hundred tons or more of barite has accumulated at the old Tonuco mill as a result of picking over the mine-run fluorspar. The Beal veins are 2 to 4 feet wide. The vein material is a mixture of barite and fluorite, grading from one to the other vertically and along the strike. In both these mines a large part of the barite is separable from the fluorite by hand sorting.

A deposit of barite has been reported near the summit of the Organ Mountains, but no information regarding it has been obtained.

In October, 1932, according to the Alamogordo News, Alamogordo, N. Mex., a carload of barite was shipped from the Stevens mine in the Organ Mountains. The material was hauled by truck to the railroad at Alamogordo. The shipment is said to have been consigned to the Mid-Continent Mud Co., Houston, Tex. This company probably used the barite in preparing a product for making heavy drilling mud for the rotary drilling of oil wells.

In the spring of 1933, Bates & Long of El Paso, Tex., shipped 12 carloads of crude barite from the White Spar mine in secs. 33 and 34, T. 23 S., R. 4 E., in the southern part of the Organ Mountains. It is reported that the vein is in limestone and that most of the barite has been taken out. The barite was hauled to La Tuna, Tex., and shipped by rail to Houston, Tex., where most of it was made into a constituent of heavy drilling mud.

Dunham[4a] mentions the presence of extensive barite reserves in the Bear Canyon district, San Andres Mountains, and in the Devil's Canyon mine in Target Range Canyon near the south end of the Organ Mountains.

Tabular crystals of barite are reported to be plentiful at the Black Hawk mine in the Black Hawk district, Grant County. The mineral is reported to be abundant in the ores of the Pinos Altos district, Grant County.

In Luna County some barite occurs in the fluorspar veins on the Duryea claims in the Little Florida Mountains, southeast of Deming. The veins average 2 feet in width and are fissure fillings

[4] Johnston, W. D., Jr., Fluorspar in New Mexico : N. Mex. Sch. of Mines, State Bur. of Mines and Min. Res. Bull. 4, pp. 61-68, 1928.

[4a] Dunham, Kingsley C., The geology of the Organ Mountains, N. Mex.: N. Mex. Sch. of Mines, State Bur. of Mines and Min. Res. Bull. 11, p. 267, 1936

in Tertiary agglomerate. The barite is associated with fluorspar and iron and manganese oxides.

It has been reported[5] that A. L. Austin, of Alamogordo, Otero County, has partially developed a deposit of barite 10 feet wide and 300 feet long. This deposit is said to be near the Warnock lead mines in the Sacramento Mountains. No other information on this deposit is available.

Barite is reported to occur as concretions and veins in the Kirtland shale and as concretions, veins, and sheets in the Puerco formation in San Juan County.[6]

A small amount of barite is found as a gangue mineral in the Nakaye, Esperanza, Harding, and other fluorspar deposits in Sierra County. A carload of crude barite was shipped from a prospect near Derry in 1918.

The ores of five districts in Socorro County are known to contain varying amounts of barite. The Lava Gap prospect, 27 miles west of Three Rivers and near the northern end of the San Andres Mountains, has considerable barite in a vein 2 to 5 feet wide. Barite predominates in the north end of the vein.

At the Hansonburg or McCarty lead mine in the Oscura Range barite is found associated with calcite, fluorspar, and galena. Considerable barite is available in this deposit, but it is too far from a railroad to be worked commercially at present.

At the Dewey mine, 5 miles east of San Acacia in northern Socorro County, barite occurs with fluorspar and quartz in a 4-foot vein containing small quantities of galena. This vein is exposed for about 4000 feet along the strike, and a 300-foot shaft has been sunk near its western end. An analysis[7] of the material mined from a shallow shaft 1500 feet east of the main shaft showed 38 per cent barite.

Barite occurs in the Magdalena district, Socorro County, especially in that part of the district north of the Atchison, Topeka & Santa Fe railway.

The silver veins of the Socorro Mountain district, Socorro County, contain barite as one of the gangue minerals. The barite constitutes about 70 per cent of the vein matter. The average width of the veins is about 2 feet, but in places a width of nearly 8 feet has been noted. The barite is generally iron stained.

In the Zuni Mountains, Valencia County, a 10-foot vein of barite is reported[8] to have been prospected many years ago for silver. A search for this vein in October, 1927, failed to disclose any barite except as a minor constituent in the vein matter of the Carnation-Columbine group of fluorspar claims.

[5] Arizona Mining Journal, vol. 14, no. 18, p. 23, Feb. 15, 1931.

[6] Bauer, Clyde Max, Contributions to the geology and paleontology of San Juan County, N. Mex.: 1, Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, pp. 274, 277, 1916.7

[7] Johnston, W. D., Jr., op. cit., p. 128.

[8] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U.S. Geol. Survey Bull. 624, p. 209, 1917.

BENTONITE

GENERAL FEATURES

Bentonite is a rock that contains 75 per cent or more of the minutely crystalline claylike minerals, montmorillonite or beidellite.[1] It is the result of the devitrification and chemical alteration of glassy volcanic ash or tuff. Ross and Shannon suggest that the name bentonite be restricted to a material derived from volcanic ash, since the inherited structure seems to have almost as great an influence on the physical properties as the mineral composition. They further state:[2]

> It is probably best to confine the name bentonite to material with at least 75% of the bentonitic clay minerals and less than 25% of sandlike or other impurities. If it contains between 25 and 75% of sandy impurities it may be called an arkosic bentonite and with less than 25% of the bentonitic clay minerals it may be called a bentonitic arkose. Shales may also contain admixed bentonitic material, but in these its certain identification is very difficult or even quite impossible.

USES

There are a great many actual and proposed uses for bentonite.[3] One of the most important uses at present is in the refining of petroleum products. An important application is in the manufacture of cleansing agents, such as soaps and beauty clays. Bentonite can replace 25 to 50 per cent of the soap substance, producing a soap equal or superior to the ordinary product.[4] In this use the bentonite is not an adulterant but actually replaces part of the soap substance and increases the lathering and detergent properties.

Bentonite is also used as a filler, binder or plastic in the paper, oilcloth, linoleum, and ceramic industries; as an adsorbent, emulsifier, or peptizer in making soap compounds; for de-inking newsprint, refining oils and fats, and in making insecticides; as a chemical agent in water softeners; and as a medicament in various drugs and antiphlogistics.

NEW MEXICO OCCURRENCES

Bentonite is widely distributed, having been reported from all the western states and several states in the eastern part of the country. It is also known to occur in many foreign countries. Bentonite and bentonitic clays have been reported from seven New Mexico counties, but data on most of the occurrences are lacking. In Eddy County bentonite has been encountered in wells drilled

[1] Ross, C. S., and Shannon, E. V., The minerals of bentonite and related clays and their Physical properties: Am. Ceramic Soc. Jour., vol. 9, pp. 77-96, 1926.

[2] Op. cit., p. 79.

[3] For detailed discussions of bentonite and its uses *see* the following:

Spence, H. S., Bentonite: Canada Dept. Mines, Mines Branch, pub. 626, 36 pp., 1924.

Davis, C. W., and Vacher, H. C., Bentonite, its properties, mining, preparation, and utilization: U. S. Bur. Mines Tech. Paper 438, 51 pp., 1928.

Bentonite handbook: Bull. 107, Silica Products Co., Kansas City, Mo., 1934.

[4] Ladoo, R. B., Non-metallic minerals, p. 96, McGraw-Hill Book Co., Inc., New York City, 1925.

for oil in the Permian strata. Similar occurrences have been reported in the West Texas oil fields. Communications to the State Bureau of Mines and Mineral Resources note the presence of bentonitic rocks near Thoreau, McKinley County.

According to Davis and Vacher,5 there are deposits of bentonite 3 to 5 feet thick in Rio Arriba County about 35 miles north of Santa Fe and near the Denver & Rio Grande Western railroad. The material is said to disintegrate rapidly in water to a soapy flocculent mass but does not remain in suspension.

Another deposit of bentonite is known near the east end of the Tierra Amarilla Grant, also in Rio Arriba County. An analysis by E. V. Shannon [8] of a purified sample of this bentonite showed the following composition: SiO_2, 51.56 per cent; TiO_2, 0.78 per cent; Al_2O_3, 13.42 per cent; Fe_2O_3, 3.22 per cent; CaO, 2.04 per cent; MgO, 4.94 per cent; K_2O, 0.38 per cent; Na_2O, 0.24 per cent; H_2O, 23.46 per cent.

The Gold Seal Products Co. of Albuquerque, N. Mex., has used some of the Rio Arriba County bentonite in the manufacture of washing powder. Bentonite deposits of unknown quality and quantity have been reported from near Hatch, Dona Ana County; Waldo, Santa Fe County; Hot Springs, Sierra County; and Ojo Caliente, Taos County. Mr. Vincent Moore of Albuquerque, N. Mex., reports that there are extensive deposits of impure bentonite on the Puebla Laguna Grant in T. 10 N., R. 6 W., Valencia County, and northeast of Grant, Valencia County.

BERYL

GENERAL FEATURES

Beryl is the name of the mineral consisting of beryllium aluminum silicate, $3BeO.Al_2O_3.6SiO_2$. The pure mineral contains 14 per cent BeO, but part of the beryllium is often replaced by calcium, iron, chromium, caesium or an alkali metal. The primary occurrence of beryl is usually in pegmatites, though it is known as a contact-metamorphic mineral in schists.

Beryl usually occurs in well-formed prismatic hexagonal crystals, commonly of a blue or yellow color but sometimes white or colorless. It may be transparent, translucent, or practically opaque. The clear white or colorless variety looks very much like crystalline quartz, but it is distinguishable from quartz by its superior hardness and by optical properties.

USES

The transparent colored crystals of beryl are prized as gem stones. The most valuable beryl is the variety called emerald, colored a deep rich green by a very small amount of included chro-

[5] Davis, C. W., and Vacher. H. C., Bentonite, its properties, mining, preparation, and utilization: U. S. Bur. Mines Tech. Paper 438, p. 7, 1928.

[6] Ross and Shannon, op. cit., p. 89.

[7] Oral communication and letter dated Oct. 3, 1932.

mium. Really fine emeralds are worth more per carat than diamonds. The light-blue beryl called aquamarine, and the honey-yellow variety called golden beryl, are popular semi-gem stones. Another semi-gem, rarer but less valuable than the two just mentioned, is the caesium beryl, of a pale pink or rose color, called morganite.

Common beryl of the non-gem variety occurs generally in opaque primatic crystals, some of which measure several inches across and a foot or more in length. Common beryl is of limited present usefulness, and the total annual production in the United States is only a few tons. Beryllium nitrate, refined from beryl, has been used as a constituent of the stiffener in incandescent gas mantles, and some experiments have indicated that beryl may be useful in the manufacture of electrical porcelain. Metallic beryllium, being lighter and stronger than aluminum, may prove of value in the manufacture of airplanes and for other uses where a very light and strong metal is required. A copper-beryllium alloy has been developed that sells for over $6 per pound, but the crude beryllium ore, even of high grade, commands only a cent or two per pound.

NEW MEXICO OCCURRENCES

Common beryl is known to occur in the pre-Cambrian rocks in the northern part of New Mexico, usually in pegmatites cutting other pre-Cambrian rocks. A little beryl has been found in the gravels derived from these rocks. Some clear, glassy beryl has been recognized in Taos and Rio Arriba counties, but most of the similar appearing material that has been sent in to the State Bureau of Mines and Mineral Resources for identification has proved to be quartz.

The production of gem beryl from New Mexico has been limited to a few crystals that have been reported from gravels in the vicinity of Santa Fe.

Beryl has not been mined commercially in the State, and future production is problematical. There seems little likelihood that gem beryl will be important in New Mexico, and as the common beryl is not abundant, even in the pegmatite dikes to which it is confined, it seems improbable that commercial deposits will be found, unless fortuitously in working the pegmatites for other minerals.

BUILDING STONES

GENERAL FEATURES AND USES

Under the heading of building stones may be considered any natural consolidated mineral aggregate (rock) which, after trimming to the desired size and shape, can be used as dimension blocks for structural purposes. Igneous, sedimentary and metamorphic rocks have all been used in important amounts as building stones.

NEW MEXICO OCCURRENCES

The quarrying of stone for building has never been an important industry in New Mexico, although many communities have utilized small quantities of local stone for various purposes. In early times, and to a large extent at present, the availability of adobe has discouraged the opening of quarries. Concrete and burned brick are important materials in modern construction, and stone is used only where it is the cheapest material at hand or where its beauty or durability make it especially desirable for a particular project.

The igneous rocks of New Mexico used for building stones are granite, rhyolite, andesite, and tuff. Basalt is useful as crushed stone, but has not been used to any extent in the form of blocks. Limestone and sandstone, especially the latter, have been quarried in several counties. Of the metamorphic rocks, only marble is known to have been developed commercially. A slate deposit a short distance southwest of the Copper Hill district, Taos County, is reported[1] to have yielded a moderate amount of slate of good quality.

Small amounts of granite and limestone have been quarried in the Sandia Mountains, Bernalillo County, for use in Albuquerque buildings. The granite was used mainly for foundations and sills. It was too hard for dressing with ordinary equipment.

Limestone and sandstone have been produced from quarries east of Roswell, Chaves County, and used in small amounts in buildings of that city.

Sandstone and andesite are among the stones found in Colfax County, but only the sandstone has been utilized so far. The stones of the Raton region suitable for building have been described by Lee[2] as follows:

> The Trinidad sandstone has furnished building stone for local use, but the demand for it is hardly sufficient to warrant its quarrying for shipment. It has been used somewhat extensively in Raton and in neighboring mining towns. It has an attractive appearance because of its even texture and light color, but its tendency to weather irregularly and scale off lessens its usefulness. Some of the massive sandstones of the Raton formation seem to be suitable for building stone, but little use has been made of them. Some of this stone would probably be more durable than the Trinidad sandstone, but its uneven rusty brown color makes it less attractive.
>
> The rock of the basaltic flows, sills, and dikes makes durable building material, although it is somewhat difficult to work. Similar rock quarried elsewhere is crushed for ballast, but little use has been made of it in these quadrangles, except locally, where volcanic cinders have been used in making footpaths and drives.
>
> The lighter-colored igneous rocks, especially the pink and blue mottled varieties that occur in the extreme southeastern part of the Raton Quadrangle, seem to be suitable for use as ornamental stone. They polish well,

[1] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U.S. Geol. Survey Prof. Paper 68, p. 90, 1910.

[2] Lee, W. T., U. S. Geol. Survey Geol. Atlas, Raton-Brilliant-Koehler folio (no. 214), p. 17, 1922.

and the colors are pleasing to the eye. The hornblende andesites of Cunningham Butte and of Towndrow Peak probably would also make excellent building stone. They are lasting and much more easily worked than the tougher basalts.

The Guadalupe County court house at Santa Rosa was constructed in 1909 of gray sandstone, with brown sandstone trim. The stone was obtained locally, probably from the quarry about 2 miles from Santa Rosa on the Las Vegas road. Several buildings in Santa Rosa are of local stone.

Most of Luna County is covered by sand and gravel deposits, but in relatively small areas of rock outcrops there are large quantities of stone suitable for building. According to Darton:[3]

> Many of the rocks in the ridges about Deming are suitable for building stone, and some of them would be of considerable value for that purpose if they were nearer to market. The granite and various other igneous rocks would dress and polish satisfactorily and there are sandstones of several varieties. Some of the limestone could be used for gray marble. The only developments are two quarries, one in the Sarten sandstone, on the main road a mile south of Fryingpan Spring, and the other in the tuff of the Florida Mountains, 2 miles northeast of Arco de Diablo. The sandstone is nearly white and is easily worked in blocks of good dimensions. The quarry was opened to supply material for the county house at Deming. The quarry in tuff is small but has exposed a large amount of excellent gray freestone in massive beds. Its color is light, and although it shows some slight mottling by dark-gray fragments its general effect is good.

Some development work has been done on a group of claims covering a deposit of onyx marble or "Mexican onyx," a variety of calcite, in the southern end of the Tres Hermanas Mountains 4 miles west of Columbus, southern Luna County. The material occurs as yellow and white banded veins as much as 4 feet in thickness in Tertiary volcanic agglomerate. The stone has been extracted from open cuts in the veins and hauled to Columbus where Mr. George Warnock formerly operated a lathe and a turning and polishing table. A few ornamental objects have been produced and sold.

McKinley County has an abundance of building stone, especially sandstone. The "pink sandstone" at the top of the Gallup sandstone member of the Mesaverde formation has been quarried at several places near Gallup and used by local builders. A quarry in the Wingate sandstone in sec. 20, T. 10 N., R. 18 W., has furnished material for several Government buildings at Black Rock.4

The only stone of Otero County known to have been used in any quantity is the marble from the Sacramento Mountains east of Alamogordo, which has been developed by the Almora Marble Co. of Alamogordo. The quarry is on the north side of Marble Canyon, 3½ miles from town. A shop for trimming and polishing the stone is maintained about one mile from town along the quarry road.

[3] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Deming folio (no. 207), p. 13, 1917.

[4] Sears, J. D., Geology and coal resources of the Gallup-Zuni Basin, N. Mex.: U. S. Geol. Survey Bull. 767, p. 51, 1925.

The present workings expose 30 feet of workable marble and 10 or more feet of worthless overburden. The quarry is on the downslope of a monocline, and the excavation has progressed up the dip. Drainage is therefore natural and excellent. The strata dip 12° to the southwest. The upper stratum of marketable stone is 6 feet thick, and blocks 7 by 15 feet can be readily cut between the fractures. This material is sold as Golden Vein marble, the "vein" being a minute crack recemented with some yellow mineral. This crack opened around the individual grains of the stone rather than through them, producing a rather attractive wavy yellow line through the blocks.

Equipment includes a power plant, several stiff-leg derricks, and a channeling machine. A large number of blocks suitable for use have been roughed out and rolled to the canyon bottom. A small quantity of blocks is kept on hand at the shop where equipment for cutting, trimming, polishing and carving is available.

The Almora Marble Co. markets dimension stone for building, polished slabs for interior decoration, polished and carved monuments, and rough blocks. The railroad companies frequently buy large blocks for the revetments of their roadbeds along arroyos. Rough stone for revetments is sold for about 25c a cubic foot, and the average price of the stone, including polished slabs, is about $2 a cubic foot. The production of the quarry totals about 300,000 cubic feet valued at $600,000.

The sandstones of Quay County have been utilized in local construction projects for many years, the court house at Tucumcari having been built of this reddish-gray sandstone in 1904. Red sandstones have been used to some extent in this county.

Sandstones and limestones are widely distributed over San Miguel County, and granite is exposed in a large area in the northwestern part. During 1935 and 1936, eleven high grade granite blocks were quarried by Hedgcock and Guy of Las Vegas, and shipped to Denver and El Paso, where they were carved for use as monuments and tombstone markers. Several quarries have been opened in the dark-red, gray and brown sandstones near Las Vegas. Several private and public buildings, including the buildings of the New Mexico Normal University, have been constructed of this rock. The "New Mexico Stone" in the Washington Monument, Washington, D. C., is a block of red sandstone from one of these quarries.

Deposits of granite, sandstone, limestone, and marble are known in Santa Fe County, but only the sandstone has been developed. A cream-colored sandstone from near Lamy was used in the construction of the Capitol Building at Santa Fe.

In Socorro County only rhyolite tuff has been used as a building stone, but deposits of limestone, marble, sandstone and granite suitable for this use are quite common. Rhyolite tuff quarried at Socorro Mountain was used in the construction of the original main building of the New Mexico School of Mines.

There is no record of the use of New Mexico stone for paving, but thinly bedded red and chocolate-colored sandstone from the Abo and Triassic “Red Beds” has been used for flagging in floors and sidewalks at Santa Fe, Socorro and other cities.

CALCITE

GENERAL FEATURES

Calcite is the name given to the mineral that consists of calcium carbonate, $CaCO_3$, and crystallizes in the hexagonal system. Calcite is the principal constituent of limestone and marble, which are discussed separately.

Calcite is an easily recognized mineral. It is rather soft, and can be scratched by a copper cent. It is the only common mineral that gives a vigorous effervescence when a drop of dilute acid is applied to it. It is abundantly distributed, but except when occurring as a constituent of building stones or in deposits of large size or exceptional purity, it is commercially valueless.

USES

Pure calcite has the following uses:

1. As the raw material for manufacturing exceptionally high-grade quicklime, for uses where an ordinary quicklime is not suitable, as in sugar refining. Considerable calcite has been used for this purpose in Utah.
2. As a fluxing material in smelting operations. Smelters working on siliceous ores and not having lime-bearing ores to mix with them, find it necessary to add calcite or limestone to the furnace charge for the production of a proper slag.
3. In certain high-grade special optical instruments. For this purpose only the very finest, purest, and perfectly transparent calcite can be used, and then only if in fairly large pieces. Such calcite is known as "Iceland Spar." No calcite of this grade has as yet been produced commercially in New Mexico.

NEW MEXICO OCCURRENCES

The only place in the State where calcite has been produced extensively is at the Aztec mine about 6 miles southwest of Hachita, in Hidalgo County. Here the calcite occurs in large milky white rhombic crystals as much as 4 inches across. None of it is of chemical or optical grade. Mr. Albert Fitch, who operated this property, reports that about 40,000 tons of this calcite was shipped as flux to the smelter at El Paso, and an additional 100,000 tons, which contained some silver, copper and bismuth, was shipped for its metal content as well as its fluxing value.

Onyx marble or "Mexican Onyx," a variety of calcite, is discussed under Building Stones, page 57.

CALICHE[1]

GENERAL FEATURES

Caliche is calcium carbonate, more or less admixed with sand and clay as impurities. Upward capillary movement of underground waters has brought the calcium carbonate in solution near or to the surface, and evaporation of these waters has caused its deposition. The resulting caliche has been deposited largely in the interstices of the surface soil. Caliche is widespread over the Southwest, where long dry seasons alternating with short periods of heavy rains are common.

OCCURRENCES AND USES

Caliche occurs abundantly in New Mexico on many of the gravel plains and mesas. It has been used for many years by the State Highway Department for surfacing roads. No other uses have been noted, but it is possible that some of the material could be used for making lime or even cement. A sample collected from a pit south of Clayton, Union County, and analyzed by A. R. Ferguson, professor of chemistry at the New Mexico School of Mines, had the following composition: $CaCO_3$, 66.05 per cent; MgO, 2.57 per cent; Fe_2O_3, 0.46 per cent; Al_2O_3, 10.61 per cent, and SiO_2, 16.63 per cent.

CEMENT MATERIALS

GENERAL FEATURES AND USES

Mineral cements may be divided into non-hydraulic and hydraulic cements. Non-hydraulic cements include lime and the gypsum products, Keene's cement and plaster of Paris. The hydraulic cements set or harden when used under water. They include natural, Portland and puzzolan cements, and hydraulic lime. These cements, except puzzolan cement, are produced by burning or calcining pure limestone, or limestone containing as naturally or artificially admixed impurities, varying quantities of silica, alumina and iron oxide. Puzzolan cement is made by finely grinding a mixture of slaked lime and volcanic ash or blast-furnace slag. Portland cement is the most important of the cements, and its chief use is in making concrete.

Some gypsum cement has been produced from New Mexico deposits; this is discussed briefly under Gypsum.

Limestones and shales suitable for the manufacture of hydraulic cements are widely distributed over the State. They are discussed separately in the chapters on Building Stones and Clays and Clay Products.

In contemplating the manufacture of any of the hydraulic cements serious consideration must be given to four important

[1] For original sense of this term, see chapter on Guano and Nitrates.

points: raw material, fuel, transportation and market. The limestone and shale raw material should be obtainable near a fuel supply and be situated near a railroad. The market area should be easily covered from the plant by rail and highway, and it cannot extend very far because of high transportation costs and competition from the many existing establishments. In New Mexico the counties most nearly meeting these conditions appear to be Bernalillo, Colfax, Chaves, Eddy and Santa Fe Counties.

NEW MEXICO OCCURRENCES AND PRODUCTION

The only cement plant ever operated in New Mexico was located near Springer, Colfax County. This plant utilized rock from a quarry in the Timpas (Cretaceous) limestone east of Springer and produced a natural hydraulic cement. According to the annual reports on mineral resources issued by the United States Geological Survey, it operated during the period from 1890 to 1899 and produced 85,500 barrels of cement valued at $89,125. Apparently market factors have prevented a resumption of oper- ations since the plant closed down about 1900.

In Bernalillo County the limestones and shales of the Magdalena formation (Pennsylvanian) outcrop in a large area in the Sandia Mountains. The area is about 20 miles east of the railroad at Albuquerque and is interesting principally on account of the possibility of developing the nearby market of Albuquerque and vicinity.

Chaves and Eddy counties are favorably situated with respect to transportation facilities and petroleum and natural gas, and they include a market area of moderate importance. Permian limestone and Triassic shale outcrop together in a narrow belt running south through the center of Chaves County and into the northern part of Eddy County. Alluvial clays are also common.

In southern Santa Fe County there are large areas of Permian, Triassic and Cretaceous limestones and shales in and around the Cerrillos coal field.

Eckel[1] mentioned the possibility of manufacturing Portland cement from raw materials occurring in the vicinity of Carthage, Socorro County. He based his opinion on a personal communication from James H. Gardner and on Gardner's report on the Carthage coal field[2] stating that Pennsylvanian limestone and Cretaceous shale outcropped together in the field and that a short railroad connected the field with the Atchison, Topeka & Santa Fe railway at San Antonio. All equipment of this road, The New Mexico Midland Railway Co., has since been removed, and there appears to be but little possibility that a new railroad will replace it.

[1] Eckel, Edwin C., Portland cement materials and industry of the United States: U. S. Geol. Survey Bull. 522, p. 271, 1913.

[2] Gardner, J. H., The Carthage coal field, N. Mex.: U. S. Geol. Survey Bull. 381, pp. 461-473, 1910.

CLAY AND CLAY PRODUCTS

GENERAL FEATURES

The term "clay" includes a great variety of substances that differ widely in chemical, mineralogical, and physical properties. No two clays are exactly alike. All of them, however, have the prominent characteristic of becoming more or less plastic when wet. Nearly all of the useful clays can be molded into shapes, will hold their form while being dried, and can be converted into a hard, rock-like substance by heat. Clay may, and in fact usually does, consist of a number of minerals, among the commonest of which are kaolinite, quartz, feldspar, mica, bauxite, calcite, and iron and manganese oxides. Organic matter is often present. Pure kaolinite, which has the formula $Al_2O_3.2SiO_2.2H_2O$, is ordinarily considered to be the parent "clay substance," but most clays contain other hydrated mixtures of alumina and silica (alumino-silicic acids) along with indefinite amounts of sand and other non-essential minerals. Even this so-called inert matter affects the plasticity, drying shrinkage, ease of drying, and final density, and at high temperatures may react chemically with the clay substance.

Clay is always of secondary origin. It results from the decomposition of other rocks, notably shales, shaly limestones, and igneous rocks containing feldspar. Sometimes the clay is found overlying the rock from which it was derived, and under these circumstances it is termed a "residual clay." Clays carried from their place of origin and deposited elsewhere are termed "sedimentary clays" or "transported clays."

Residual Clays.—These clays are widely distributed over the United States but occur principally in the southeastern part. Usually the deposits of residual clay constitute a broad mantle of considerable extent, but occasionally, as when the clay results from the decomposition of a pegmatite, the deposits occur in steeply inclined veins.

Sedimentary Clays.—According to the nature of the water body in which they have been deposited, sedimentary clays are variously described as marine, lacustrine, and stream clays. Much fine material transported by glacial action consists principally of boulder clay, which may or may not have been stratified locally or worked over by streams. Some windformed deposits, or loess, also consist of clay.

After being deposited, clay beds frequently undergo various changes. They may be folded, up-tilted, or faulted by movements of underlying rocks. Erosion likewise introduces various changes; sometimes, for example, a clay bed may be found only near the tops of various hills, the intervening parts of the bed

[1] Introductory paragraphs have been summarized from U. S. Bureau of Mines Information Circular 6155, "Clay," by Paul M. Tyler, 1929.

having been removed, or a bed originally covered by later sediments may be exposed and thus be workable only in the valleys or on the lower hillside slopes.

USES AND PRODUCTS

The different kinds of clay have so many uses that it is impracticable to list them all. The following outline indicates the great variety of products that are manufactured from clay.

Structural Products.—Common, paving, and face bricks; sewer pipe; drain tile; hollow block; terra cotta; conduits; roofing tile; flue lining and chimney pipe; floor and terrace tile; wall and fireplace tile; brick dust and crushed brick; calcined clay ; mosaic tiles.

Refractories.—Fire clay bricks and special refractories.

Pottery and Porcelain.—Tableware; kitchenware; sanitary ware; stoneware; art or garden pottery; flower pots; ollas or other porous ware; electrical insulators; porcelain specialties; and cast-iron enamel ware.

Use as Fillers.—The extremely finely divided nature of clays and their low cost make them of value as adulterants and as mineral fillers for such products as rubber, linoleum, and oilcloth. Kaolin and certain other white clays are extensively employed in the manufacture of high-grade paper, window shades, and other articles. Ochre, an iron-stained clay, is used mainly in linoleum, but the best grades are also used in paint and wall coatings. The cheaper clays find similar uses in heavy wrapping paper and cardboard and other articles where color is of minor importance. Clay competes with whiting in the manufacture of mechanical rubber goods, rubber tubing, friction tape, putty, and window shades. It is used in some paints, fertilizers, metal polishes and abrasive soaps, for rock-dusting coal mines, and in the manufacture of Portland cement.

NEW MEXICO OCCURRENCES

No extensive field investigations of New Mexico clays have been made by Federal or State organizations, and data on the various deposits are almost entirely lacking. Flood-plain clays are widely distributed and furnish the material for most adobe bricks and some fired clay products. Shales and clays weathered from them are of common occurrence in many sections of the State.

Local clay deposits have been utilized in practically every county for the manufacture of clay products other than adobes, but in only a few counties has the industry attained any appreciable importance. The refractory clays of Hidalgo and McKinley counties have been extensively mined for shipment to Arizona smelters. Fire bricks for use under boilers and in metallurgical plants were formerly manufactured in Socorro County. The shales and common clays of Bernalillo, Dona Ana, Lincoln, Sandoval, San Miguel, and Santa Fe counties have been exploited in recent years.

No discussion of the New Mexico clay industry, however brief, would be complete without some mention of the Indian pottery trade. It is impossible to even estimate the annual value of Indian-made clay products, but if this part of the industry is not the most important it certainly is the best known.

BERNALILLO COUNTY

The New Mexico Clay Products Co., operating 5 miles south of Albuquerque, manufactures bricks and tile from acequia or flood-plain clays. The plant contains standard equipment for crushing, grinding, and pugging the clay as received from the pit. The stiff mud column extruded from the mixer is cut into bricks by wires. The wet products are dried 36 hours at 150° F. before delivery to the kilns.

The company has one beehive down-draft kiln and four square up-draft kilns, each having a capacity of 100,000 bricks. A small up-draft kiln is used on some products. The kiln contents are first given a day of water smoking with wood fuel, after which the kilns are fired four or five days with crude oil for fuel.

Common brick, wire-scratched face brick, and hollow building tile are the principal products of the company, but flat and ornamental roofing tiles are made in considerable quantity. The ornamental tiles are made by hand, the workmen shaping the units over a wooden mold. Various effects are produced by pressure of the hand in the soft mud, and sometimes the wet tile is gone over with a stiff brush, giving it a very pleasing effect. Most of the products seen were salmon-colored, but deeper shades are obtained by control of temperature and firing time.

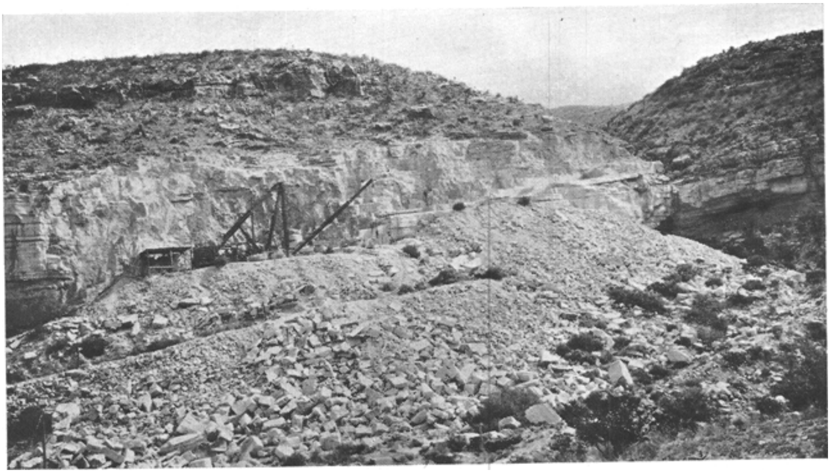
The New Mexico Clay Products Co. formerly shipped some clay from deposits in the Carthage coal field, Socorro County, for admixture with their locally available clays, but in recent years the local clay alone has been used.

COLFAX COUNTY

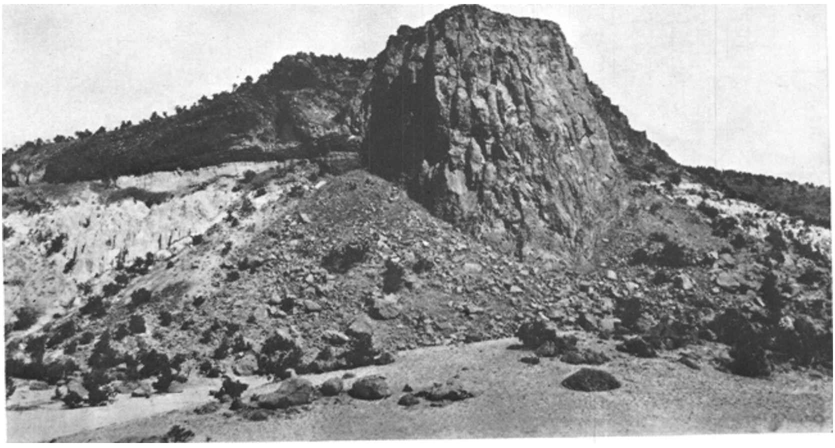
There are no clay products plants in Colfax County, but the following observations made by Lee [1] indicate that ample resources are available.

> Shale and clay for brick can be obtained in many parts of the Raton, Brilliant, and Koehler quadrangles. The shale in the Raton and Vermejo formations occurs as thin sandy layers but has never been much utilized. The Pierre formation consists chiefly of dark clay shale, which has been used near Raton in making brick for the local market. This shale occupies the lowlands of the three quadrangles.

[1] Lee, W. T., U. S. Geol. Survey Geol. Atlas, Raton-Brilliant-Koehler folio (no. 214), p. 17, 1922.



ALMORA MARBLE COMPANY QUARRY IN MARBLE CANYON, EAST OF ALAMOGORDO, OTERO COUNTY
(a)



PUMICE DEPOSIT NEAR GRANTS, N. MEX.
(b)

DONA ANA COUNTY

Massive white kaolin of the English type has been reported to occur in T. 21 S., R. 3 E., north of Organ, Dona Ana County. The deposit is found in the upper workings of an old metal mine. It is not known to outcrop. Richard reported the following results of physical and chemical tests on the Organ kaolin :

Physical Tests on Kaolin from Organ Mountains

Color (wet)	White, opaque, pearly
Color (raw)	White, smooth to touch
Foreign materials	Few undecomposed feldspar grains Few splotches of carbon Little free angular silica
Drying shrinkage	8 per cent
Slaking properties	Good
Specific gravity	2.72
Hardness	2.50
Luster when rubbed (dry)	Satiny
Macroscopic structure	Devoid of definite structure
Porosity	Absorbs water with avidity, porous
Absorption	Same as English washed kaolin
Fracture	Has no definite cleavage; on some samples shows flat breaking planes
Uses	Fine chinaware Refractory ware Paper filler
Development of Mullite on firing	Small

Chemical Analyses

SiO_2	47.23	48.25	46.25	45.20
Al_2O_3	36.85	32.40	37.55	33.60
Fe_2O_3	0.42	2.36	2.00	2.24
CaO	0.06	0.41	—	0.06
MgO	Trace	Trace	—	Trace
Na_2O	1.59	3.30	0.24	2.35
K_2O	—	—	—	0.25
TiO_2	—	—	—	0.01
SO_2	0.65	—		—
H_2O	12.80	12.28	13.86	13.00
MnO	0.10	—	—	0.09
	99.70	99.00	99.90	96.80

Firing shrinkage, 12.5 per cent; color at cone 30, gray.

Richard further states that the kaolin is plastic enough to need but little ball clay and that the fired samples compared favorably with fired English washed clay.

HIDALGO COUNTY

Fire clay has been shipped from pits 2 miles south of Pratt, on the Southern Pacific railroad in western Hidalgo County, for about 25 years. Most of the clay was shipped to the copper smelters at Douglas, Ariz., where it was ground in mud mills for use in lining furnaces and converters and for plugging reverberatory matte and slag outlets. When the smelters were oper-

[1] Richard, L. M., Note on the discovery of a kaolin deposit in New Mexico: Jour. Am. Ceramic Soc., vol. 16, pp. 632-633, 1933.

ating full time, several hundred tons of clay was consumed each year.

LEA COUNTY

The only reported clay pit in Lea County is about 2 miles southeast of Monument, about 10 miles southwest of the Hobbs oil field. According to notes furnished the writer by E. H. Wells and C. E. Needham, the pit is operated by Mr. Guy H. Hooper of Hobbs, N. Mex. Mr. Hooper has supplied more than 90 per cent of the native clay used in mudding oil wells in the Hobbs field. The clay is red and contains streaks of white and gray clay and a small amount of gypsum. It is said to be highly plastic and free from grit. It is massive and thought to be of Tertiary age. Very little overburden has been removed.

McKINLEY AND SAN JUAN COUNTIES

There are large deposits of clay shales, plastic clays and fire clays in the Cretaceous and Tertiary formations of northwestern New Mexico. These deposits have been described by Shaler and Gardner[1] as follows:

> The clay shales include in greater part the thick shale formations of the area—the Mancos and the Lewis—as well as many thinner beds intercalated with the sandstones and coal beds of the Mesaverde and Laramie (Fruitland formation and Kirtland shale) formations. All of these formations are of Upper Cretaceous age.
>
> The plastic clays include alluvial beds, adobe clays, certain unconsolidated Tertiary shales, and residual deposits derived from the weathering of clay shales.
>
> The fire clays include deposits of a semirefractory nature, the beds of which now mined are interbedded with the sandstones, shales, and coals of the Mesaverde formation. Some of these are directly associated with the coal beds and are mined in connection with them.

Crude clay and bricks have been produced from deposits in the Gallup coal district, McKinley County, for nearly 40 years. Some operators have merely mined and shipped crude and ground fireclay to the Arizona smelters, but others have manufactured bricks for shipment and for the local market.

At the present time the Gallup Clay Products Co. intermittently operates seven kilns in making common, face, and fire brick. Some salt-glazed bricks have been made and used in local buildings. The clay is mined from short drifts or slopes into the Gallup sandstone member of the Mesaverde formation and trucked to the plant at the east edge of town. The clay is prepared in a dry pan and fed to a dry-press brick kiln. The bee-hive kilns have a capacity of 65,000 bricks each. The Gallup Clay Products Co. also sells crude and ground clay.

In San Juan County the Upper Cretaceous shales and the residual clays have been exploited at several places for making

[1] Shaler, Millard K., and Gardner, James H., Clay deposits of the western part of the Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 315, pp. 296-302, 1907.

brick for local markets. Brick plants have been operated at Aztec, Farmington, Flora Vista, Fruitland, and Shiprock at various times since 1900, but no plant is known to be in operation at the present time. Several of the buildings of the Indian School and Agency at Shiprock were constructed of bricks made locally from the Mancos shale.

OTERO COUNTY

In 1931 and 1932 some exceptionally fine clay products were being produced by the tile and pottery works located at La Luz, in the canyon about five miles north and east of Alamogordo. At this plant, there was manufactured some very attractive roofing tile, but the principal product was a distinctive art pottery.

The raw material was taken from a bed of dark-colored clay, apparently a shale stratum interbedded with limestones in the Magdalena formation. This shale, when ground and pugged, formed a highly plastic, easily worked clay, with relatively slight, and very even, drying shrinkage and fire shrinkage. The nearly black color of this shale seemed to be due to included organic matter, which burned off completely during firing. The products that came from the kiln were of a light buff color, with streaks in tints of red and green; these colors, evidently due to small amounts of iron salts, could be controlled to some degree by regulation of temperature in firing. The resultant color effect was distinctly a pleasing one.

The patterns or models were even more distinctive than the colors. The designing and molding of the art pottery was done by expert Mexican artizans, who combined rare skill and taste in their designs. Many of the smaller pieces simulated native designs; but the outstanding products of this plant were the large vases called "strawberry jars"; some of these were made as much as six feet high of graceful curved designs, with apertures or lips through which vines could climb. These proved popular for garden decoration, and markets were found on estates as far away as Florida and California. The double "bean pots" and other smaller forms were made the subject of favorable comment and illustrations in New York papers and magazines.

About 1933 this plant was closed down. According to residents of the vicinity, the reason for the cessation of work here was neither failure in production nor marketing, but the sponsors of this project were said to have found it necessary to devote their attention and finances to other and larger interests. This plant was reputed to have been operated by L. M. Richard and associates.

SAN MIGUEL COUNTY

In San Miguel County there are large areas of Triassic and Cretaceous shales and residual clays. Residual clays are used for making adobe bricks, but the only recorded development of the shales is in the Benton shale of Cretaceous age.

The Las Vegas Brick Co. has been operating a plant at Las Vegas for about 30 years. This company has shipped bricks to many points in the Southwest, and they have been used in several state and municipal buildings. The bricks are salmon-colored and fairly hard and smooth.

The raw material for this plant is obtained from the Benton formation, probably the Graneros shale. The deposit outcrops on the southwest edge of Old Las Vegas. The shale is loosened with horse-drawn plows and loaded by hand into small carts in which it is hauled about one-half mile to the plant. The deposit is about 40 feet thick at the pit. The excavation extends for about 350 feet north and south and 300 feet east and west. Most of the shale has been obtained from the surface, but now an overburden 2 to 6 feet thick must be removed.

The shale is delivered to a 9-foot dry pan where it is crushed to pass a one-eighth inch mesh screen. The bricks are formed on a dry press machine which turns out 20,000 units in a shift.

The company operates three up-draft scove kilns, using coke for the water smoking and coal for the final burning. The burning process requires three weeks, and six to eight days or even more are allowed for the kiln to cool. Each kiln has a capacity of 300,000 bricks. A small test kiln having a capacity of 1000 bricks is occasionally used.

SANTA FE COUNTY

The New Mexico State Penitentiary at Santa Fe, Santa Fe County, has been operating a brick plant intermittently for many years. According to John B. McManus,[1] Superintendent, the clay is obtained from shale outcropping on leased land east of Palace Avenue. This shale is probably a part of the Magdalena group.

Bricks were first made at the institution about the time of its establishment in 1884. They were made by hand until about 1902, when machinery for preparing and making wire-cut bricks was installed. Building tiles in two sizes, 4 by 8 by 12 inches and 5 by 8 by 12 inches are also made. The product is burned in five beehive kilns in which coal is used for fuel. The kilns have a capacity of about 75,000 bricks.

During the fiscal year 1934-35 about 225,000 pieces of tile and 900,000 bricks were made. The product enters the general market of the State but most of it is sold for use in Santa Fe.

SOCORRO COUNTY

The clay resources of Socorro County consist of the typical alluvial or adobe clays ; Pennsylvanian, Triassic, and Cretaceous shales ; and residual clays resulting from the hydrothermal decomposition of igneous rocks.

There are no brick making industries in the county at present (1935), but the production of crude clay, common bricks and

[1] Letter dated November 5, 1935.

fire bricks was formerly of considerable importance at Socorro. Common bricks for use in local buildings were at one time manufactured, and the production of fire bricks for use in southwestern smelters was an important industry for some time. The common bricks were made from a mixture of alluvial clays and the fire clay. They were much softer than the fire bricks, and pale red in color.

Fire bricks were made from material obtained from two pits in the basal beds of the Magdalena formation near its contact with pre-Cambrian granite. One of the shale pits is near the head of Arroyo de la Presilla, 6 miles east of Socorro, and the other one is about 10 miles northwest of the town in the southern end of the Lemitar Mountains. Fire bricks were also made from kaolinitic material obtained at Socorro Mountain, about 3 miles west of Socorro. The kaolinitic material appears to have been derived from a rhyolite flow. It contains 40 to 50 per cent of partly decomposed grains of feldspar and quartz and some mica. Bricks made from it are buff-colored and very hard. A dark-red clay found at several places on Socorro Mountain yields a hard chocolate-colored brick. This red clay has not been used in making bricks except for an experimental batch produced several years ago.

In the Carthage coal field there are Cretaceous shales from which excellent bricks of several colors have been experimentally produced. Mr. Powell Stackhouse, Jr., had these tests made by the American Clay Machinery Co., and the New Mexico State Penitentiary brick plant. However, the only attempt at commercial development of these deposits was made a few years ago by Mr. B. H. Kinney when he made a few shipments of Carthage or Tokay clay to his New Mexico Clay Products Co. plant at Albuquerque.

A small roofing tile plant is operated intermittently at San Antonio, 11 miles south of Socorro. Most of the raw material is local adobe clay but some shale has been hauled from near Carthage and used experimentally. Only one small kiln is in use and 2 or 3 men can operate the plant. The tiles are shaped by hand over a wooden mold. The product has been used on several buildings, including the new Socorro City Hall.

OTHER OCCURRENCES

Mr. C. D. Bonney of Roswell, Chaves County, has a deposit of clay in secs. 17 and 18, T. 9 S., R. 25 E., southwest of Acme. The American Clay Machinery Co., Bucyrus, Ohio, made tests on a ton of this clay and reported very satisfactory results.

Mr. John Wake and Mr. Gus Hoagland of Artesia, Eddy County, have done some prospecting of local clay deposits. Mr. Wake has made some hand samples of bricks from his clay, but the results were not reported. The clay may be of pottery grade.

A brick kiln was operated several years ago at Silver City, Grant County, producing brick for the local market. The material was evidently obtained from the Cretaceous beds in that vicinity. Mr. Ira L. Wright of Silver City reports that some prospecting has been done on a white clay in Mangas Draw, west of the town. The nature and possible uses of this clay were not reported.

The Triassic and Cretaceous rocks of Lincoln County no doubt contain shales suitable for brick manufacture, but the only record of clay extraction in this section is Darton's[1] mention of a fire clay pit one and three-quarters miles east of Ancho.

A small quantity of common bricks has been produced from the bolson deposits of Luna County.

A brick plant was operated some time ago near Tongue, north of Hagan, Sandoval County. The raw material apparently came from Cretaceous shales.

PRODUCTION

According to figures compiled by Federal agencies, New Mexico plants have produced more than $5,370,000 in clay products, including $15,576 in Indian wares, since 1894. Most of this sum represents the value of brick and tile, since very few other products have been made. Figures for Indian wares undoubtedly are incomplete. Data for the years 1922, 1926, and 1933 are not available. A rough estimate of the production for those years brings the total value for the 40-year period to approximately $5,500,000.

During the 28-year period, 1906-1933, approximately 150,000 short tons of raw clay valued at about $315,000 was produced. Actual figures for this period amount to 142,763 short tons valued at $305,540, but figures for 1906 and 1921 are not available and an estimate for those years has been included in the above total. Most of this material was fire clay and was used in southwestern smelters.

[1] Darton, N. H., "Red Beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, p. 02 and fig. 20, 1928.

Production of Clay and Clay Products in New Mexico, 1894-1933[1]

Year	Raw Clay		Clay Products
	Short tons	Value	
1894			$ 18,235
1895			[2]45,307
1896			[2]38,444
1897			33,270
1898			41,940
1899			108,090
1900			41,898
1901			81,345
1902			68,879
1903			142,039
1904			108,764
1905			141,722
1906	([3])	([3])	152,599
1907	16,326	$ 18,446	180,284
1908	18,840	27,929	[4]140,671
1909	13,757	23,229	[4]182,755
1910	14,235	30,727	[4]129,275
1911	8,514	12,800	[4]174,651
1912	1,943	4,214	185,575
1913	3,513	9,906	176,528
1914	2,042	4,695	205,914
1915	2,568	7,320	240,847
1916	3,602	9,511	257,561
1917	2,269	8,931	257,875
1918	4,213	13,488	[5]194,533
1919	1,609	7,504	[5]235,118
1920	1,916	7,119	[5]373,600
1921	([3])	([3])	267,698
1922	1,681	6,542	([3])
1923	3,135	11,939	133,118
1924	3,596	13,603	18,611
1925	4,753	12,657	144,639
1926	2,118	10,517	([3])
1927	8,196	17,414	161,666
1928	5,338	6,597	166,351
1929	10,347	20,021	155,138
1930	6,400	10,923	181,117
1931	1,444	6,444	123,008
1932	266	1,559	60,937
1933	142	1,505	([3])
TOTALS	142,763	$305,540	$5,370,002

[1] Mineral Resources of the United States, U. S. Geol. Survey and U. S. Bur. Mines, annual.
[2] Including Oklahoma and Indian Territory.
[3] Some production but no figures available.
[4] Some pottery was produced during these years.
[5] Including Indian-made pottery as follows: 1918, $10,926; 1019. $900; 1920. $3,750.

FLUORSPAR[1]

GENERAL FEATURES

Fluorspar, also called fluorite or spar, is fluoride of calcium, CaF_2. The pure mineral contains 48.9 per cent fluorine and 51.1 per cent calcium. The accompanying table of analyses of New Mexico fluorspar shows that commercial deposits always carry a certain amount of lime, silica, barium, and other impurities.

Analyses of New Mexico Fluorspar

		1	2	3	4	5	7	8	9	10
CaF_2	73.50	98.13	95.90	91.32	91.04	86.56	92.98	88.13	86.07	84.49
$CaCO_3$	1.17	1.00	2.72	5.05	0.78		0.78	2.30	2.98	9.64
SiO_3	20.78	0.64	0.99	3.16	7.17	6.11	2.92	4.30	4.30	4.41
$BaSO_4$								3.42	8.43	
Al_2O_3 / Fe_2O_3				0.29	0.92		3.30	0.98		1.20
Totals	95.45	99.77	99.61	99.82	99.91	92.67	99.98	99.13	97.86	99.80

1. Average of 5 samples from Lida-K property, Sierra County.
2. Concentrate from mill of Fluorspar Mines of America, Sierra County.
3. Average of 4 samples from Nakaye mine, Sierra County
4. Average of 4 samples from Tortugas mine, Dona Ana County.
5. Average of 5 carload shipments from Sadler mine, Luna County.
6. Average of 8 samples from White Eagle prospect, Grant County.
7. Great Eagle mine, Grant County.
8. Carnation-Columbine prospect, Valencia County.
9. Lava Gap prospect, Socorro County.
10. Joyita prospect shaft, Socorro County.

Fluorspar is usually transparent to translucent, but dark-colored varieties may be nearly opaque. It is brittle, breaking with well-defined cleavage in four directions. Each face of a cleavage fragment of fluorite usually forms an equilateral triangle. Crystals which grew in open spaces are cubical. The color may be blue, green, rose, claret, purple, or white. It fades upon long exposure to light, and material which has been exposed in an outcrop for some time is invariably colorless or white. The hardness of fluorspar is 4, and its specific gravity ranges from 3.01 to 3.25.

USES

The steel industry is the principal consumer of fluorspar. It is used as a flux in the furnace charge in the manufacture of basic open-hearth steel, 7 or 8 pounds being required for each ton of steel produced. Small amounts of higher grade spar are required for special metallurgical processes, such as the manufac-

[1]This description of New Mexico fluorspar deposits is abstracted from "Fluorspar in New Mexico," by W. D. Johnston Jr., published in 1928 as Bull. No. 4 of the New Mexico Bureau of Mines and Mineral Resources.

ture of nickel and the reduction of bauxite. In the ceramic industries fluorspar finds use in the manufacture of opal glass and of enamels for coating steel and other metals. A small amount is occasionally used in burning cement mixtures. High-grade fluorspar is the basic material for the manufacture of hydrofluoric acid. Small amounts have other chemical uses as a flux or catalyst.

Occasionally lumps of colorless and flawless fluorspar can be sold for optical use. Pogue[2] has described in detail the properties, uses, and value of optical fluorite.

MARKETING AND SPECIFICATIONS

Fluorspar[3] of all grades is usually sold on contracts of 3 to 6 months duration. This practice was established in the Kentucky-Illinois fields and has been continued in the West. The eastern production in most cases is handled by mineral brokers who contract for the entire output of a mine. Thus it is difficult for a small producer to sell a single carload of fluorspar directly to the consumer. Usually the occasional producer sells his fluorspar to one of the larger companies which disposes of it through its broker. Small outputs are sometimes so handled in New Mexico.

Based upon its content of calcium fluoride and various impurities commercial fluorspar is graded into acid, ceramic, and metallurgical spar. Further grading is based upon the size of the particles, lump, gravel, and ground spar being recognized.

Fluorspar containing 98 per cent or more of calcium fluoride and less than 1.5 per cent of silica is of acid grade. Some consumers specify 99 per cent calcium fluoride and less than 1 per cent of silica, but such specifications are met with difficulty by western spar. Calcium carbonate should be less than 1 per cent, and the fluorspar should be free from metallic sulphides. A lower grade fluorspar can be used for acid making, but manufacturers naturally prefer the higher grade material.

Ceramic grade spar as generally specified by glass and enamel manufacturers must contain 90 to 95 per cent calcium fluoride, less than 0.12 per cent iron oxide, not over 2.5 per cent silica, and little, if any, calcium carbonate. Metallic sulphides are objectionable.

Metallurgical grade spar should contain at least 85 per cent calcium fluoride and not more than 5 per cent silica. Occasionally a lower percentage of fluorspar is acceptable. Although some steel manufacturers use spar from their own mines with calcium fluoride content as low as 75 to 78 per cent, they object strongly

[2] Pogue, J. E., Optical fluorite in southern Illinois: Ill. Geol. Survey Bull. 38, pp. 1-7, 1918.

[3] Good discussions of the marketing of fluorspar are contained in the following books:

Spurr, J. E., and Wormser, F. E., The marketing of metals and minerals, McGraw-Hill Book Co., Inc., 1925.

Ladoo, R. B., Fluorspar; its mining, milling, and utilization, with a chapter on cryolite: U. S. Bur. Mines Bull. 244, 1927.

Ladoo, R. B., Non-metallic minerals; occurrence, preparation, utilization, McGraw-Hill Book Co., Inc., 1925.

if purchased fluorspar does not meet the 85-5 specification, even though adjustment will be allowed by the shipper.

NEW MEXICO OCCURRENCES

Fluorspar in New Mexico occurs as a vein filling in igneous and sedimentary rocks and as replacement deposits in limestone. Veins in limestone are usually accompanied by some replacement of the wall rock.

The veins are variable in form and character, but without exception they appear to be fillings of pre-existing fractures. Although clean-walled fissures are most abundant, breccia cemented veins are common. Occasionally, as at the White Star and Oakland veins of the Fluorspar Mines of America near Hot Springs, simple veins pass horizontally into sheeted zones. The veins occur in many types of country rock, including granite, schist, monzonite, rhyolite, latite, shale, and limestone.

A few veins have fresh, sharp walls, but some replacement of the wall rock by fluorspar occurs in most of the veins in limestone. At the Nakaye mine, on the borders of fracture zones, certain favorable limestone beds capped by impervious clayey limestone are completely replaced by fluorspar. As the main fractures are filled with gouge impervious to ore-depositing solutions, no veins were formed. In places much secondary quartz accompanies the replacement of limestone by fluorspar. The sections of the Nakaye deposit on the outer edge of the replacement usually show a narrow band of quartz advancing into the limestone just ahead of the fluorspar. This quartz band appears to be later replaced by fluorspar.

The greatest depths to which New Mexico fluorspar veins have been followed are 320 feet at the Galena King mine and 286 feet at the Tortugas mine. In both instances no change in character of the vein filling was observed at depth. As the fluorspar veins are simple fissure fillings, their shape and extent is determined by the shape and extent of the pre-existing fractures. There is no reason to expect a consistent pinching of such fissures at depths less than 1000 feet, and mineralization can be expected to be fairly continuous to that depth at least.

BERNALILLO COUNTY

Capulin Peak Prospect.—A deposit of fluorspar at Capulin Peak in the Sandia Mountains near the Sandoval County line was opened in 1925. The deposit occupies a fault fissure in Magdalena limestone. It is 3 feet wide and consists of fine-grained purple fluorite surrounding and partly replacing fragments of the wall rock. Considerable galena and some calcite, quartz and barite are found with the fluorite. Very little development work has been done on this deposit.

Galena King Prospect.—The Galena King mine, in the Manzano Mountains 20 miles southeast of Albuquerque, was opened as a lead mine over 20 years ago. Several cars of lead ore have been shipped. The ore consists of fluorite, scattered pockets of galena, and some barite, in a fissure in pre-Cambrian granite gneiss. The vein varies in width from a few inches to 3 feet.

CATRON COUNTY

Only one deposit of fluorspar is known in Catron County. The Big Spar prospect is near the head of Little Whitewater Creek in the Mogollon Mountains, 6 miles east of Glenwood. The fluorite occurs as a cement in a 16-foot vertical zone of brecciation in rhyolite porphyry. The vein has been cut off above and below by intrusions of latite porphyry leaving a fluorspar zone of 5 feet or less in vertical extent.

DONA ANA COUNTY

The fluorspar deposits of Dona Ana County consist of deposits at a group of claims in the southern end of the Caballos Mountains, the Tonuco Mountain deposits, and the Organ Mountain deposits.

Woolfer Canyon.—The New Mexico Fluorspar Corporation controls a group of six claims in the Caballos Mountains, 7 miles east of Garfield. The fluorspar occurs as fracture zone fillings accompanied by some replacement of the limestone. One claim is on a persistent chert bed in the limestone. There has been very little development on these claims.

Tonuco Mountain.—There are two properties at Tonuco Mountain, the Tonuco mine on the west side and the Beal claims on the east side. At both properties the fluorite occurs as a fissure filling in pre-Cambrian granite and schist. The vein material is a mixture of barite and fluorite and contains considerable quartz and included fragments of country rock. Over 4000 tons has been shipped from these deposits.

Tortugas Mine.—The Tortugas mine is on Tortugas Mountain 5 miles northeast of Mesilla Park, a station on the Atchison, Topeka & Santa Fe railway 2 miles south of Las Cruces. Two veins, known as the Tortugas and Jones veins, have been developed for their fluorite content. Both veins are in limestone.

The Tortugas vein has been developed for a distance of 1000 feet along its strike and to a depth of 286 feet. It varies in width from 2 to 8 feet. Most of the 15,000 tons of fluorite produced in this area has come from the Tortugas vein. It is estimated that over 20,000 tons of fluorspar remain in this vein.

The Jones vein joins the Tortugas vein near the northern end of its outcrop. It occupies a fracture zone 15 feet or more in width. Very little development work has been done on the Jones vein, and no estimate of reserves has been made.

Hayner Prospect.—The Hayner prospect is on the west side of the Organ Mountains about 4 1/2 miles south of the town of

Organ and about 16 miles from Las Cruces. The fluorspar occurs as narrow fissure veins in Paleozoic limestone and shale. Very little development work has been done.

Bishop's Cap Prospect.—Another group of fluorite claims in the Organ Mountains is known as the Bishop's Cap prospect. This group is 16 miles by road east of Mesquite, a station on the Atchison, Topeka & Santa Fe railway, 12 miles south of Las Cruces. The fluorspar occurs with much quartz in a 6-foot fracture zone in limestone. No production has been recorded from the Bishop's Cap prospect.

GRANT COUNTY

The fluorspar deposits of Grant County are located mainly in the Gila River country northwest of Silver City, but there are a few scattered deposits west and south of Silver City and in the northern end of Cooks Range.

White Eagle Mine.—The White Eagle mine is in the north end of Cooks Range a few miles north of the Luna County line. It is 18 miles northeast of Spalding, a siding on the Silver City branch of the Atchison, Topeka & Santa Fe railway 17 miles northwest of Deming. Most of the fluorspar occurs as fissure filling in granite but one prospect has exposed a replacement by fluorite in a block of Paleozoic limestone. In some places the deposit has a width of 17 feet, but most of this material is recoverable only by milling and careful hand-sorting.

Some work has been done on a claim known as the Diamond prospect about 3 miles north of the White Eagle mine. Two veins, 4 and 6 feet in width, have been opened but the fluorspar exposed contains considerable silica.

Bound's Ranch Deposits.—Several small fluorspar veins occur in granite on Young Bound's ranch 18 miles north of Separ, a station on the Southern Pacific railway 20 miles south of Lordsburg. Some of the veins have been opened by open cuts and shafts. The fluorspar portion of the veins averages about 12 inches in width and is apparently of very good quality.

Great Eagle Mine.—The Great Eagle mine is located on the Gila River 8 miles east of Redrock and 32 miles north of Lords-burg. The fluorspar occurs as a fissure filling in veins within a wide fault zone in granite. These veins have a maximum width of 20 feet.

Over 3000 tons of metallurgical spar was produced before the mine closed down in 1921. An expensive mill was built in 1919, but it failed to handle the siliceous material. Much good fluorspar is thought to remain in the mine, but the lower grades must wait for a more efficient milling technique.

Tyrone Prospect.—A small fluorspar vein located one and one-quarter miles southeast of Tyrone has yielded several cars of metallurgical lump. The vein occurs in a fracture zone in granite porphyry.

Cottonwood Canyon Prospect.—In Cottonwood Canyon, 17 miles northwest of Silver City, some work has been done on two parallel veins in Fierro limestone. The fluorspar occurs as a filling between breccia fragments of the limestone. Very little work has been done.

Gila River Deposits.—Several fluorspar veins have been opened in rhyolite and rhyolite porphyry along the Gila River 6 to 10 miles northeast of Gila Post Office. Most of the development work in this area has been done on the Foster and Bushy Canyon mines, but neither of these properties can yield much spar except in times of high fluorspar prices. North of the Foster mine some work has been done on the Brock, Nut and Howard prospects. These veins contain from a few inches to nearly 2 feet of fluorspar.

Blue Bird Mine.—This mine is on the southwestern flank of the Mogollon Mountains in Rain Creek Canyon, 19 miles northwest of Cliff. The fluorspar occurs in a 5-foot vein in latite porphyry. About one-half of the vein is fluorspar of marketable grade. Drifts have been driven at three levels along the vein and several tons of spar has been mined. Exceptionally pure spar can be obtained by careful sorting. One hundred and eighty-nine tons of gravel spar was shipped from this vicinity in 1929.

LUNA COUNTY

The known fluorspar deposits of Luna County are confined to the northeast slope of the Little Florida Mountains and to Fluorite Ridge southeast of Cooks Range.

Little Florida Mountains.—A group of six patented claims owned by the Duryea estate is located approximately 14 miles southeast of Deming on the northeast slope of the Little Florida Mountains. The fluorspar occurs as a fissure filling in the volcanic agglomerate, associated with barite, iron and manganese oxides, and minor amounts of calcite and quartz. The veins vary in width from 1 to 3½ feet, averaging about 2 feet. Of this thickness fully half is composed of included fragments of the country rock. The claims were patented in 1925 but since that time have not been worked. Four or five cars of metallurgical lump have been shipped.

Fluorite Ridge.—These deposits occur along the axis of the ridge about 11 miles northeast of Deming. The Saddler mines are in two groups, the upper camp and the lower camp, about a mile and a half apart. They were first opened in 1909 by the American Fireman's Mining Co. and produced the first fluorspar shipped from New Mexico. One-half mile northwest of the upper camp a small amount of fluorspar is exposed in the Cox prospect.

At the lower camp the porphyry is cut by a series of fractures, many of which are filled with veins varying in width from a few inches to 20 feet. The veins are exposed in several shafts and open cuts, one shaft being 185 feet deep.

The fluorite veins of the upper camp are associated with a basalt dike in monzonite porphyry. Part of the veins are in the porphyry and part in the dike, but all the fluorspar occurs near the dike. These veins are developed by open cuts and shafts.

In 1932 the La Purisima Fluorspar Co. leased a property northeast of Deming (presumably the Saddler mines) and started production.[4] In 1933 the company [5] completed their flotation mill and produced 700 tons of ground fluorspar.

RIO ARRIBA COUNTY

A narrow vein containing some fluorspar has been prospected by the American Mines and Minerals Corp. in the Carson National Forest 3 miles north of La Madera. The property is now abandoned.

SIERRA COUNTY

The fluorspar deposits of Sierra County have been the most important in the State. They occur as fissure fillings in the Magdalena limestone as a rule, but at the Lida-K property the fluorite is in pre-Cambrian crystalline rocks. They are confined to the Caballos Mountains, most of them occurring on the western slope near the northern and southern ends of the range.

Fluorspar Mines of America.—The claims of this group are on the western scarp of the northern end of the Caballos Mountains 4½ miles from Hot Springs. Three veins, varying in width from 5 to 15 feet, have been developed since they were discovered in 1924. The vein filling is siliceous, the best grade containing 70 to 80 per cent fluorspar and 20 to 25 per cent quartz and calcite. Galena is present in some of the workings.

A mill was built in 1926 for the production of ground ceramic spar. Later, the plant was improved by the addition of Diester tables, and in 1928 the shipment of ground acid spar began. The treatment proved quite difficult, and production was later discontinued.

A considerable amount of experimental work on the flotation and gravity concentration of spar from the property of the Fluorspar Mines of America and from the Lida-K claims of the Southwestern Fluorspar Corp. was carried on in 1934 in the El Paso laboratories of the American Smelting & Refining Co. and the Texas School of Mines and Metallurgy. Although some high-grade concentrates were obtained the results were not entirely satisfactory, and the work was discontinued.

[4] Davis, II. W., Fluorspar and cryolite: U. S. Bur. Mines Minerals Yearbook, 1932-33, p. 730, 1933.

[5] Idem., 1934, pp. 993-994, 1934.

Southwestern Fluorspar Corporation.—The Lida-K claims of the Southwestern Fluorspar Corporation are located on the west face of the southern end of the Caballos Mountains, 23 miles from Hot Springs. The dikelike outcrop of the Lida-K vein has long been known to prospectors and has been assayed for gold repeatedly. It was first located by the New Mexico Fluorspar Corporation and later sold to the present owners. The first shipment was made in 1928.

The fluorspar occurs associated with quartz and galena as a fissure filling 3 to 5 feet wide in pre-Cambrian granite gneiss. The vein can be traced for 4000 feet along its outcrop. The vein material consists of 20 to 25 per cent silica intimately intergrown with fluorite, about 3 per cent galena, and 70 to 80 per cent fluorspar.

Construction of a mill was started in 1926, but the plant was not completed until 1928, when a small quantity of ground spar was produced.

Nakaye Mine.—The fluorspar deposits of the Nakaye mine are a few miles south of the Lida-K group and about 5 miles northeast of Derry. They were opened in 1918, and several thousand tons of lump spar had been shipped by 1923. A mill was constructed in 1923 and operated for about two years, producing 10 carloads of ground spar.

The fluorspar occurs as a replacement of limestone beds where they are cut by minor faults, and extends away from these faults on either side. These replacement sheets attain a maximum thickness of 12 to 15 feet near the fractures. Some fluorspar was deposited as a fissure filling along the fault planes and some occurs as vug and pipe linings in the limestone.

In general the hand-sorted fluorspar is of good grade for fluxing lump. The only impurities in the replacement material are fragments of limestone, some calcite, silica, and a very little barite. The deposit is developed by open cuts and three adits 100 feet or more in length.

In 1923 a mill was built at Derry to handle the Nakaye ore, and about 10 carloads were milled before the property was closed down in 1925. In 1930 a deposit near the Nakaye was opened and a small amount of spar produced.

New Mexico Fluorspar Corporation.—The Esperanza group of claims controlled by the New Mexico Fluorspar Corp. is located about 2 miles southwest of the Nakaye property. The deposit consists of a vein filling of fluorite with silica and small amounts of galena, and replacements along joints and bedding planes in the Magdalena limestone. Several trenches have been dug, but no commercial development has resulted.

Other Properties.—Some work has been done on several other deposits in the Caballos Mountains. The old Harding claims, which property was originally located for vanadium, were acquired in 1929 by the Velie Metals Co., and several shipments were made to Pueblo, Colo. The Cox prospect, 15 miles from Cutter, produced a carload of fluorspar in 1930. The Alamo mine near Derry made its initial shipment of fluorspar in 1931. The product consisted of gravel spar and ceramic-grade spar produced in the company's new mill.

SOCORRO COUNTY

The fluorspar deposits of Socorro County are relatively unimportant, only two of them having produced enough fluorspar to make a shipment.

Lava Gap Prospect.—This property, in the northern end of the San Andres Mountains, produced a small quantity of fluorspar in 1926. The vein contains considerable barite.

Juan Torres Prospect.—Juan Torres shipped a carload of metallurgical lump from his prospect in the Ladrone Mountains 18 miles northwest of San Acacia in 1927. The fluorspar occurs in a series of small, horizontal, quartz-lined veins in pre-Cambrian granite adjacent to a fine-grained andesite dike. The deposit is small and too far from the railroad for profitable development.

Hansonburg Lead Mine.—The old Hansonburg mine in the Sierra Oscura Range has been worked for lead, but the ore contains some fluorspar, calcite, and barite. Some lead concentrates have been produced, and at least one car of barite has been shipped, but it appears unlikely that commercial quantities of fluorspar exist here.

Joyita Hills.—Two deposits of fluorspar have been prospected in the Joyita Hills approximately 4 miles east of San Acacia and on the east side of the Rio Grande. At the Joyita prospect some fluorite occurs in a vein and in a breccia along the fault zone between pre-Cambrian granite and Tertiary lavas. The deposit is low grade, but a large quantity of the brecciated material is available. The Dewey vein contains fluorite, barite, calcite, quartz and lead. A 300-foot shaft has been sunk in a search for commercial quantities of lead, but no mineral or mineral products have ever been shipped.

VALENCIA COUNTY

Some development work has been done on a group of claims in Smelter Gulch in the Zuni Mountains, 15 miles southwest of Bluewater. Several veins containing fluorite, barite, calcite, and quartz occur in the pre-Cambrian and have been developed by Wesley Riggs and associates of Denver. A few tons of fluorspar has been mined, but no shipments have been recorded.

PRODUCTION

During 1930-1934 New Mexico produced about 2 per cent of the fluorspar shipped from mines in the United States. During the same period Colorado produced nearly 5 per cent and the Kentucky-Illinois fields over 90 per cent.

The accompanying table gives the shipments of fluorspar from New Mexico mines for the years 1909 to 1934 inclusive. Maximum production in the State was concurrent with the increase in steel production during the World War. During that period a number of properties were worked out.

Fluorspar Marketed from New Mexico Deposits, 1909-1934[1]

Year	Gravel	Lump	Ground	Totals		
	Short Tons	Short Tons	Short Tons	Short Tons	Value[2] Total	Value[2] Average Per Ton
1909				710	$ 3,728	$ 5.25
1910				4,854	26,250	5.40
1911				4,307	22,612	5.25
1912				196	1,176	6.00
1913				5,372	42,976	7.95
1914						
1915				485	3,880	8.00
1916						
1917						
1918				3,437	64,348	I18.72
1919				2,346	37,643	i16.05
1920	470	5,88		6,353	101,460	15.97
1921	1,650	991	866	3,507	60,186	17.16
1922	1,008	820	352	2,180	30,992	14.22
1923	3,540	738	50	4,328	50,861	11.75
1924	1,620	883	77	2,580	35,178	13.63
1925	1,487	939	213	2,639	40,325	15.28
1926	1,063	820	106	1,989		[3]12.98
1927	1,562	574	477	2,613		[3]14.43
1928	961	399	1,229	2,589		[4]15.40
1929	2,295	143		2,438		[5]15.57
1930	2,188	124		2,312		[5]13.71
1931	972		54	1,026		[5]13.60
1932	427	32	70	529		[5]13.56
1933	294		700	994		[5]13.27
1934	40		2,000	2,040		[6]17.49
TOTALS				59,824	$815,700	

[1] Mineral Resources of the United States, U. S. Geol. Survey and U. S. Bur. Mines, annual.

[2] Values for the years 1926 to 1934 are not available but an estimate, based on the above average prices per ton, has been included in the totals.

[3] Includes. Colorado.

[4] Includes Colorado and Nevada.

[5] Includes Nevada.

[6] Includes Nevada and California.

GEM STONES

GENERAL FEATURES

Under gem stones are included those minerals and mineral aggregates that are in general use for purposes of personal adornment. Very rarely is a mineral in its natural state used as a gem, as most gems are cut, polished, and then mounted in an appropriate setting. The qualities that make a mineral desirable for a gem stone are mainly physical; the demand may be based largely on human whims, since fashions in gems are very changeable, and exercise a potent control over demand, prices, and apparently even over definitions of beauty.

The general criteria under which a mineral may be judged as to gem quality include, according to Kraus and Holden,[1] the following: Hardness, which insures durability of the stone and of the polish; beauty, which includes purity of color, brilliance and freedom from flaws; and scarcity or demand, which is a large factor in determining prices. The appraisal of the gem quality of any stone may be modified in any one of these particulars according to the intangible temporary or local fashion, but speaking generally, the best gem stones must be hard, rare, and of good color or brilliance, or both.

The finest gems, called "precious stones", are limited to well-crystallized varieties of three mineral species. These include the diamond, which is pure crystallized carbon, the emerald, which is pure crystallized beryl with a deep green color, and the ruby and sapphire, which are the red and blue varieties of clear crystallized corundum. The minerals not so highly prized as gems, generally grouped under the name of "semi-precious stones", include a dozen or more varieties of quartz, and a large number of other species, many of which have been considered as semi-gems only locally or temporarily.

USES

In addition to their application as ornaments, some gem stones find important industrial uses. Diamonds are used in cutting-tools, and diamond dust is used where an extremely hard abrasive powder is needed. Black diamonds are used in drill bits for core-drilling rocks. All of the harder varieties of gem stones are used for bearings and pivots in watches and scientific instruments, and the dust of these stones is used in polishing and grinding operations.

The making and marketing of Indian jewelry is an industry of long standing in New Mexico. Much of this jewelry is stamped and figured silver, but many styles include the setting of some semi-precious stone. Turquoise is the mineral most widely used for this purpose; garnet and peridot are used to a smaller degree, particularly in the northwestern part of the State.

[1] Kraus, E. H., and Holden, E. F., Gems and gem materials, P. 3 ; McGraw-Hill Book Co., Inc., New York City, 1925.

NEW MEXICO OCCURRENCES

Amethyst.—Amethyst or amethystine quartz is crystalline quartz with a purple or violet color. Specimens have been obtained from the Great Republic mine in Grant County, but the mineral is not known to have been developed commercially.

Beryl.—This is a fairly common mineral in pegmatite dikes, but the gem variety, emerald, is an extremely rare mineral. Common beryl has been found in the Rio Arriba-Taos County pegmatite areas[1] but the only occurrence of gem beryl is that reported by Schrader[2] as "a few crystals of fine quality found in the gravels" near Santa Fe. No information is available as to whether these few crystals were emeralds or one of the less valuable varieties of beryl.

Dumortierite.—This mineral is a basic silicate of aluminum closely related to the sillimanite group and generally used for the same purposes as the minerals of that group. (See page 137.) However, it might be cut and polished and sold as a semi-precious gem or ornamental stone, and that is probably the only use that will ever be made of the material in the one known New Mexico deposit. It occurs in the Tres Hermanas Mountains, Luna County, about 12 miles northwest of Columbus. According to Schaller[3] this deposit was at first thought to be lapis lazuli. Schaller says:

> The ledge containing dumortierite is said be several feet wide with an outcrop of over 1000 feet. Many boulders with seams of the mineral lie on the ground. A sample sent to the Geological Survey by W. A. Casler, of Deming, N. Mex., shows a quartz rock, in part sericitized, with narrow seams a quarter of an inch wide and the same distance apart, composed of spherulites of blue dumortierite with smaller amounts of colorless spherulites of similar structure, which are formed of mica. In places the mica spherulites appear to have been derived from the alteration of the dumortierite; at other places the two minerals seem to be intergrowths. If large pieces suitable for cutting and polishing are obtainable, the occurrence should yield a striking ornamental stone, for the narrow seams of bright blue dumortierite in the white rock afford a very attractive contrast. Well-selected and cut pieces, with a narrow band of the dumortierite, might also yield cut stones of value in jewelry.

Garnet.—This is the name given to a group of minerals most of which are complex double silicates of aluminum and another base, although some double silicates of calcium and iron, lacking aluminum and with or without other bases, are known in the garnet group. The precious garnet is not a particular species but may include any one of several varieties when well crystallized, transparent, and of good color, usually a deep clear red. Garnet is a rather common contact-metamorphic mineral. Com-

[1] See chapter on Beryl.

[2] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: U.S. Geol. Survey Bull. 624, p. 209, 1917.

[3] Schaller, W. T., Gems and precious stones: U. S. Geol. Survey Min. Res. 1916, pt. II, p. 193, 1919.

mon garnets occur in several regions in the State but nowhere, as far as reported, in concentrations or varieties that seem to offer commercial possibilities as gem stones. Some garnets are found as water-worn pebbles in the gravel and alluvium on the Navajo Indian Reservation and are used by the Indians in native jewelry. There is no organized production of gem stones in this region, but casual finds are being made from time to time, and sales to tourists passing through Gallup amount to a few hundred dollars annually. First quality stones, either garnet or peridot, are worth as much as $4 a carat. Most of the garnets that now enter this Indian trade come from the Arizona portion of the Reservation.

Jasper.—Jasper is a slightly translucent cryptocrystalline quartz generally red, brown, yellow, or green. The writer has found fragments on Socorro Mountain, and a small bed containing material suitable for ornamental work has been reported by Schrader[1] from near Ancho, Lincoln County.

Opal.—Opal is hydrous silica. When it shows a play of iridescent colors it is known as fire opal or precious opal. A deposit has been prospected near Fort Bayard, and some good fire opals have been found near Santa Rita, both in Grant County. Opal has also been reported from near Cochiti, Sandoval County. Major E. W. Hubbard, U. S. A., furnished the following notes on the Fort Bayard deposit for publication by the United States Geological Survey:[2]

> The prospect is located about one-half mile from the station, and is in a very hard volcanic rock. The opal is called "button opal" in the region around, and is white, with little, if any, fire. It makes a beautiful specimen, however, since the opal is invariably outlined by a zone of black chalcedony.

J. H. Greeson, of Socorro, recently found a deposit of opalized wood near the north end of the Fra Cristobal Range on the east shore of Elephant Butte Reservoir, southern Socorro County. According to notes furnished the writer by C. E. Needham of the Department of Geology, New Mexico School of Mines, the opal is embedded in Recent sands and gravels. Opalized stems, limbs, roots, and trunks, some pieces weighing 50 pounds or more, have been found. Woody structure is well preserved. The colors are milky-white, clear or colorless, gray, brown, black, yellowish, and mottled. The smaller fragments generally yield opal of higher quality than the larger ones. Careful selection yields opal of gem quality, some of which has been sold.

Peridot.—This is the trade name given to the transparent well-crystallized variety of olivine or chrysolite, a double silicate of iron and magnesium. Olivine is a common constituent of many basic igneous rocks, but the gem variety is relatively rare. It is pale greenish-yellow in color and was formerly a very popular

[1] Op. cit., p. 215.
[2] Min. Res., 1906, p. 1227, 1907.

oriental semi-gem. Peridot is of common occurrence in the Navajo country in northwestern New Mexico and northeastern Arizona. The following notes have been abstracted from a report on that region by Herbert E. Gregory.

Olivine or peridot occurs as phenocrysts in basic dikes and plugs and frequently fills vesicles in lava. At Peridot Ridge, in Buell Park, the gems are found in place in a large mass of agglomerate composed of rounded and angular fragments of shonkinite (?), sandstone, shale, granite, quartz, and various other ingredients, set in a dark-greenish paste. Associated minerals include pyrope, diopside, calcite, limonite, ilmenite, enstatite, augite, biotite, and serpentine. The peridots are separated by erosion and are thickly spread over the slopes and flats at the southeast base of the Ridge. The gravels strewn over the surface and found in ant heaps contain from 20 to 60 per cent of peridot in sizes of four millimeters and less. Stones weighing one or two carats, particularly those of yellow-green tones, are abundant, and a few clear golden-green stones of over three carats were found. Sterrett[1] believes that a large supply of gems could be obtained by plowing favorable areas and allowing the rain to wash out the gems. He also suggests that considerable concentration could be obtained by the use of screens on the dry sandy material.

Petrified Wood.—Silicified or petrified wood, also known as fossil, opalized, jasperized, or agatized wood, is composed of opal, chalcedony, agate, jasper, or other forms of silica and is formed by replacement of the woody matter of tree trunks by silica.[2] This replacement takes place in such a way that the original structure of the wood is preserved. The material is used as museum pieces or, after cutting and polishing, as gem or ornamental stones.

Petrified wood occurs in the Shinarump conglomerate, the Chinle and McElmo formations, the Dakota sandstone and various Tertiary sediments. It is of common occurrence in the Navajo country, and small quantities are collected and sold in the tourist centers. Some is found northeast of Las Vegas, San Miguel County, and used in rock gardens. On the Sweet ranch east of Cerrillos, Santa Fe County, petrified trees are moderately abundant. There is a large quantity of this material east of Old Fort McRae at the southern end of the Elephant Butte reservoir, Sierra County. Petrified wood no doubt occurs at many other places in the State but has little value except as a local curio.

Sapphire.—Sapphire is clear corundum, aluminum oxide, generally blue but also white, pink, or yellow. Sapphires have been reported from New Mexico gravels, but some such specimens, on careful examination, have proved to be quartz.

[1] Geology of the Navajo country: U. S. GeoL Survey Prof. Paper 93, p. 146, 1917.
[1] Sterrett, D. B., Precious stones: U. S. Geol. Survey Min. Res. 1908, pt. II, p. 835, 1909.
[2] Schrader, op. cit. (U. S. G. S. Bull. 624), p. 410.

Smithsonite.—This mineral, consisting of zinc carbonate, ordinarily has no value as a gem stone, but specimens colored by copper, cadmium, or other impurities are frequently cut and sold as a semi-precious stone. The green variety, colored by a minute amount of copper, and the yellow variety, colored presumably by cadmium and called "turkey fat", have been found in the Kelly (Magdalena) district, Socorro County. Sterrett [1] describes the green smithsonite from Kelly as follows:

> Translucent, apple-green smithsonite, not only furnishing beautiful cabinet specimens but cutting pretty gems, has been found in large masses in the Magdalena mining district, New Mexico. This smithsonite occurs in the Kelly mine, which is being developed by the Tri-Bullion Smelting and Development Company. It was found in a zinc vein in a cavity or vug several feet wide and 25 feet long, which it lined and partly filled with odd shaped masses. The surface of the smithsonite masses has a mammillary structure which is drusy with the edges of many small projecting crystals. The mineral assumes odd shapes and sometimes nearly a globular form. One specimen, seen in the New York office of the Tri-Bullion Company, was roughly about the size and shape of the head and bust of a man. It had a beautiful light-green color and was covered with drusy mammillary lumps an inch or two across.
>
> This green smithsonite occurs in shells or layers, up to an inch or two in thickness, coating rough, irregular masses of typical dry bone or carbonate zinc ore. The shells of smithsonite have a columnar structure across them, with a slight radial arrangement of the columns. Ordinary smithsonite is colorless or white. This material contains variable quantities of a copper salt, which give it a beautiful green color. The copper stain is not evenly distributed through the mineral, but occurs in layers parallel with its surfaces. This smithsonite is being cut and sold as a gem in some of the Western States. It yields handsome cabochon stones similar to chrysoprase. though of course not so hard and therefore less valuable than that mineral. Mr. Hart, of Manitou, Colorado, reports that the rough mineral for gem purposes brought from $2 to $5 per pound at Magdalena.

Standard works on mineralogy and gem stones state that the gem variety has also been found in Arkansas, Greece, Sardinia, and Siberia, but all these occurrences, except that at Laurium, Greece, are the yellow or "turkey fat" variety.

Sterrett[2] also reports that Goodfriend Brothers of New York cut and sold a quantity of the green Kelly smithsonite under the name "bonamite."

Topaz.—Small crystals of topaz are occasionally found in ant hills but none are known to be of gem size or quality. The "smoky topaz" reported from the northwest part of the State is really smoky quartz.

Turquoise.—Turquoise is a complex hydrous phosphate of aluminum and copper. The color of good material ranges from sky-blue to apple-green, with a waxy luster that suggests translucency. It generally occurs in compact masses instead of in

[1] Sterrett, D. B., Precious stones: U. S. Geol. Survey Mineral Resources, 1907, pt. II, p. 825, 1908.

[2] Sterrett, D. B., Precious stones: U. S. Geol. Survey Mineral Resources, 1908, pt. II, p. 839, 1909.

crystalline form and is frequently veined with impurities. This foreign material sometimes adds to instead of detracting from the desirability of the turquoise for gem purposes, as the rich brown iron stains are often distributed in patterns that are attractively brought out in polishing. Some turquoise which appears when mined to be of first quality is not usable as gem stones because on drying it fades to an unattractive green color.

New Mexico has produced more turquoise than any other state, and the stones are noted for their quality. The output has come principally from the Cerrillos Hills, Santa Fe County; the Burro Mountains and the Little Hatchet Mountains, Grant County; and the Jarilla Hills, Otero County. Turquoise has been reported in the Nogal district, Lincoln County.

The Grant County deposits are located in the Burro Mountains 10 to 15 miles southwest of Silver City and in the vicinity of Tyrone, and in the northern end of the Little Hatchet Mountains 6 to 8 miles west of Hachita. The modern discovery of the Burro Mountains deposits dates from 1875, but turquoise ornaments, old excavations, and stone implements indicate a much earlier exploitation. These deposits have been described in several papers[1] and the following notes have been extracted from Zalinski's description of the Azure Mining Co. property.

> The turquoise was found in two forms, as vein turquoise filling cracks in the altered granite and as nuggets or concretions imbedded in kaolin. . .The Elizabeth Pocket extended from the second level to the surface, a distance of 40 to 60 feet, and the same quality of turquoise was found for 150 feet or more along the vein. The distance between walls is about 40 feet.
>
> Some good turquoise was developed on the third level and sparingly on the fourth, but here turquoise of the best quality was not plentiful and is associated with malachite and chrysocolla. It appears that an excess of copper gives the material a green color and also decreases the hardness . . . All the fine turquoise is found at depths of 100 feet or less . . . The vein turquoise fills cracks and fractures in the rock and is from one-sixteenth up to three-fourths of an inch in thickness. Most of it, however, is probably from one-eighth to three-eighths inches, but it has been found up to 1½ inches thick. Vein turquoise occurs with rounded edges and corners resembling nugget structure. The nuggets or concretions are usually in the softer portions of the vein and along seams, entirely embedded in kaolin. They have various shapes and sizes, reniform, botryoidal, etc., and make the finest gems.
>
> Vein rock from near the Elizabeth Pocket showed a medium fine to coarse-grained structure, traversed by a more than usual amount of quartz in veinlets and bands up to one-half inch or more wide; these are sometimes open and contain cavities lined with quartz crystals. Vein turquoise sometimes contains small quartz crystals penetrating the turquoise from the sides of the vein. Bordering these quartz bands is kaolinized feldspar. The quartz often gives way to bright blue turquoise, which partly or entirely fills the vein or occurs in isolated specks. Vein turquoise is often separated from the granite on one or both sides by quartz and also occurs in direct contact with the rock without quartz filling.

[1]Paige, Sidney, The origin of turquoise in the Burro Mountains, N. Mex.; Econ. Geology, vol. 7, pp. 382-392, 1912.

Sterrett, Douglas B., Turquoise (in New Mexico): U. S. Geol. Survey Mineral Resources, 1907, pt. II, pp. 828-832, 1908; and 1909, pt. II, pp. 788-795, 1911.

Zalinski, Edward R., Turquoise in the Burro Mountains, N. Mex.: Econ. Geology, vol. 2, pp. 434-492, 1907.

Other properties formerly operated in this area include the American Gem and Turquoise Co. mine, half a mile southeast, and the Porterfield Turquoise Co. mine, half a mile south of the Azure mine. Some work has been done on turquoise deposits in the White Signal district southwest of Tyrone, and on a small outcrop between Leopold and Tyrone.

The Little Hatchet Mountains deposits are in and around Old Hachita 7 miles in an air line west of Hachita and near the Grant and Hidalgo County boundary line. The first work on these deposits was done in 1885, and desultory mining was carried on for about 25 years. The turquoise occurs associated with altered trachyte and andesite and sometimes is found near the contact of the trachyte with monzonite porphyry. It varies in thickness from a paper-thin film to one-half inch. The most important properties were operated by Robinson and Porterfield, the American Turquoise Co., M. M. Crocker, and R. S. Chamberlain.

The turquoise deposits of Otero County are in the Orogrande district in the Jarilla Mountains, 2 to 4 miles northwest of Orogrande, a station on the Southern Pacific railway. The modern exploitation of these deposits began in the early nineties. Evidence of prehistoric mining is abundant. The turquoise occurs as veins and nodules in the fractures of decomposed monzonite porphyry. Most of the production came from the De Meules mine, the Alabama group of claims, the Laura claim, and a claim owned by Luna and associates.

The turquoise deposits[1] of the Cerrillos hills, Santa Fe County, are found in two main localities, 3 miles apart. The extensive workings of the ancient Indians and the Spaniards are located on Mount Chalchihuitl, 2½ miles north of the town of Cerrillos, and the modern workings are mainly on Turquoise Hill, 5½ miles north of Cerrillos. Other minor deposits have been opened up but no extensive developments made. Practically all the deposits show evidence of ancient mining.

The Mount Chalchihuitl deposits are known to have been worked by the Indians, both independently and under the rule of the Spaniards, in the seventeenth century. In 1680 a large mass of rock fell in and killed a number of Indian miners. This first recorded mining accident in the Southwest is considered to have been one cause of the Pueblo Indian uprising which resulted in the expulsion of the Spaniards from the country.

According to Johnson:[2]

> The rock forming Mount Chalchihuitl and the western and eastern ends of Turquoise Hill, and in which the turquoise occurs . . . is an altered phase of the augite andesite forming the main portion of the Cerrillos Hills . . . Those areas at Mount Chalchihuitl and at either end of Turquoise Hill are the

[1] Johnson, Douglas W., The geology of the Cerrillos Hills, N. Mex.: School of Mines Quarterly, vol. 24, pp. 173-246, 303-350, 456-500 ; vol. 25, pp. 69-98, 1903.

Sterrett, Douglas B., Turquoise (in New Mexico): U. S. Geol. Survey Mineral Resources, 1911, pt. II, pp. 1066-1071, 1912.

[2] Op. cit., p. 89.

only ones which, so far as known, contain any notable amount of turquoise. The rock is yellow or white in color, sometimes mottled or streaked with iron stains. In cases it may resemble sandstone, but remnants of the feldspar phenocrysts are generally seen in the hand specimen.

The turquoise occurs as seams throughout the rock, filling crevices formed by crushing and shearing, and as little nodules in streaks or patches of kaolin. The color varies from green through greenish-blue to pure sky-blue. Many of the specimens are marred by streaks of limonite, kaolin, etc., but some gems of rare beauty and purity have been secured, equal to the best Persian material.

Lindgren,[2] in discussing Johnson's augite andesite, points out that its composition and texture place it in the monzonite group.

Some of the more famous modern mines in the district were those owned by A. B. Renehan and by Michael O'Neill on Mount Chalchihuitl, and the Castilian and Tiffany mines on Turquoise Hill. The Tiffany mine was owned and operated by the American Turquoise Co. of New York City, and not by Tiffany & Co., as is commonly supposed. Very little work has been done in recent years.

There are many conflicting statements on turquoise production in the various statistical publications and in the literature of New Mexico turquoise. According to the U. S. Geological Survey Mineral Resources volumes, the production of gems and precious stones in New Mexico from 1890 to 1920 had a total value of $621,166; in 1890 the production was valued at $10,000; a maximum of $175,000 was reached in 1892, and in 1920 the value was only $1,315. The lowest published production was $55 in 1914. There is no record for the years 1895 to 1905, inclusive. Some production was recorded in 1915, 1917, 1919, 1921, 1922, and 1923, but the figures were not published separately. Since 1924 there has been no canvass of gem stone production. Most of the production mentioned was from the turquoise mines, but is probable that some of it represented the value of garnet, peridot, and other stones.

Governor Miguel A. Otero, in his report to the Secretary of the Interior for the year ending June 30, 1900, said, in part :

There are, as near as we can learn, some sixty or seventy turquoise claims in New Mexico, some ten or a dozen in active and profitable production.

The output of turquoise in New Mexico, as taken from official sources, was $150,000 in 1891, $175,000 in 1892, $200,000 in 1893, $250,000 in 1894, $350,000 in 1895, and $475,000 in 1896; but it is openly asserted that the true value of turquoise mined since 1890 has been greatly underestimated. As an illustration, one of these mines sold in 1893 for $250,000, and, according to the statements of a former owner, has paid a million and a half a year since that time. One single stone taken out is reported to have been bought for $6,000 in New York.

[2] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U.S. Geol. Survey Prof. Paper 68, pp. 165-166, 1910.

Zalinski[3] states that the Azure Mining Company's property "produced stones to the value of several million dollars."

GLAUCONITE

Glauconite is the name given to the amorphous dull-green mineral which is essentially a hydrous silicate of ferric iron and potash. It occurs usually as granules and coatings in marine sands. Such deposits are known as greensands, or if calcareous, as greensand marls.

During the World War some glauconite in New Jersey was utilized as raw material from which potash was successfully extracted, but this industry could not survive the drop in prices consequent on the restoration of the German potash to the world markets. It has been suggested that some greensand marls could be utilized as low grade fertilizers by applying them directly to the land. Such use has been limited and local.

Glauconite has been reported from several places in the Bliss sandstone in the southern part of New Mexico, but there has been no general or local demand to justify the exploitation of these deposits. Oh account of the limited local market for low-grade potash fertilizer, it seems highly improbable that the glauconitic portions of the Bliss sandstone will offer any attractive commercial possibilities, at least for many years to come.

GRAPHITE

GENERAL FEATURES

Graphite, also known as plumbago or black lead, is elemental carbon. It is a soft, black, lustrous mineral with a greasy feel. The hardness is 1 to 2 and the specific gravity 1.9 to 2.3. It occurs as flakes or as scaly, granular, compact or earthy masses. It is found massive in veins and disseminated as small flakes through certain rocks. Graphite may occur as the alteration product of carbonaceous material in sedimentary rocks, for example, the flake graphite deposits of Alabama and Pennsylvania; in various rocks as disseminated flakes, or as dikes or veins of obscure origin ; and as a result of the metamorphism of coal deposits, as in New Mexico, Rhode Island and Mexico.

USES

The principal uses[1] of graphite are in refractories, pigments and lubricants. In 1924 the domestic consumption of graphite was divided approximately as follows: foundry facings, 52 per cent; pigments and paint, 18 per cent; crucibles, 13 per cent;

[3] Zalinski, Edward R., Turquoise in the Burro Mountains, N. Mex.: Econ. Geology, vol. 2, p. 465, 1907.

[1] Tyler, Paul M., Graphite, pt. III, Utilization of graphite: U. S. Bur. Mines Inf. Circular 6123, p. 2. May, 1929.

pencils and crayons, 5 per cent; miscellaneous, including commutator brushes, stove polish, and lubricants, 12 per cent.

NEW MEXICO OCCURRENCES

Deposits of graphite have been reported in Bernalillo, Colfax, Grant, Taos, and Valencia Counties. At only one of these deposits—near Raton, Colfax County—has any attempt at commercial development been made.

The deposit near Raton, Colfax County, has been described by Lee[2] as amorphous graphite. It occurs as a horizontal bed in the coal-bearing sedimentary rocks in the canyon of the Canadian River. The graphite was formed by igneous metamorphism of the coal in the same bed that is mined at Van Houten. At many places in the Raton coal field the sedimentary rocks have been invaded by diabase sills. In most places this intrusion changed the coal into cokeite, but in the Canadian Canyon, where sills formed above, below and in the coal, graphite and graphitic anthracite were the principal products. The graphite occurs as irregular masses in the diabase and is more or less columnar, the columns usually standing normal to the surfaces of the igneous rock. The columnar parts are relatively pure; the non-columnar parts seem to have been formed from bony coal or carbonaceous shale.

An analysis of a sample of graphite from a 3-foot face of graphite 160 feet from the mouth of a prospect opened by the Standard Graphite Co., New York City, is as follows:

Analysis of Graphite from near Raton[a]

	As received	Air dried	Moisture free	I Moisture and ash free
Moisture	1.31	0.91		
Volatile matter	6.07	6.09	6.15	7.39
Fixed Carbon	76.11	76.42	77.12	92.61
Ash	16.51	16.58	16.73	
Sulphur	0.17	0.17	0.17	0.20

[a]Analysis by U. S. Geol. Survey. Air drying loss 0.40.

The Standard Graphite Co. in 1889 shipped 250 tons of graphite from this deposit to their plant in Pennsylvania for testing its suitability for paint manufacture. The tests were satisfactory, and the plant was being dismantled for removal to Raton when it was destroyed by fire. Nothing has since been done toward developing the deposit.

Graphite schist of pre-Cambrian age crops out in a large area near Cabresto Lake in the Sangre de Cristo Mountains in northern Taos County. No development work is known to have been done on the deposit.

[2] Lee, W. T., Graphite near Raton, N. Mex.: U. S. Geol. Survey Bull. 530, pp. 371-374, 1913.

GUANO AND NITRATES

GENERAL FEATURES

Guano, a corruption of the Peruvian term for manure, is the name applied to accumulations of animal excrement, particularly if dried in large deposits. The term is also applied to the gummy residue produced by leaching and evaporation from such deposits, and to the insoluble residue after leaching. Guano can accumulate only where a large number of animals congregate in a relatively small space for a long time. Such conditions are found on the bird islands off the Peruvian coast and in caves that have been inhabited by multitudes of bats. Occasionally small deposits of rat guano are found. Usually many of the animals die in the places where the group has lived, and their flesh and bones add their increment to the guano deposit. Such an accumulation of animal matter is exceptionally rich in nitrogen and phosphorus, which render it a high-quality fertilizer. When accumulated in large masses, guano deposits are valuable, but the prices for fertilizer are so low that small deposits of guano, even of excellent grade, may not pay to work.

Nitrates are salts of nitric acid, and nearly all the nitrates occurring naturally are readily soluble in water. The only simple nitrate minerals are niter, also called saltpeter, KNO_3, and soda niter, $NaNO_3$. Hydrous nitrates of calcium, magnesium, barium, copper and soda are known, but only as very rare minerals occurring locally and in small quantities.

The largest nitrate deposits in the world are the soda niter beds of Chile. Several features of the origin of these deposits are still in doubt, but in general they seem to have been formed in broad, flat valleys underlain by clay, in an extremely arid climate. The nitrates, formed probably by the decomposition of plant material on the surrounding hillsides, are carried in solution into the flat and concentrated by evaporation, instead of being diluted and lost in the general ground water circulation, as is normally the case in climates of average humidity. The nitrates, consisting largely of the sodium salt, form a cementing crust in the alluvium of the valley. This crusted material is known as caliche.[1] No nitrate deposits of the caliche type are known in New Mexico.

Analogous to the caliche deposits but on a smaller scale are the nitrate deposits of the playa type. In some playa lake areas, nitrates have been concentrated during the dry season in the clays near the surface. No deposits of this type of commercial richness are known, as the nitrate content of the clays is usually not over 1 per cent.

[1] This, the original use of the term "caliche", is quite different from its use in New Mexico and adjoining states, where the term is applied to crusts at or near the surface of the ground, formed similarly by capillarity and evaporation, but consisting of lime carbonate. (See page 60.)

The most widely distributed occurrences of nitrate salts are of the cave type, which includes all the deposits that have been reported from New Mexico. Such deposits, limited to arid climates, occur as incrustations on the walls of caves in porous rocks and are practically always associated with guano deposited at a higher level. The scant ground water, percolating through the deposits of animal refuse, extracts some of the soluble salts and carries them through the pores of the rocks to an exposed area, such as a cliff or the wall of a cave. Here the rapid evaporation concentrates the nitrates, and they are deposited as thin crusts or efflorescenses, with maximum thicknesses limited to a few inches. Occasionally, in a soluble rock such as a limestone, chemical interaction will produce replacements of calcium nitrate or a related salt, but generally the rock itself is simply the base on which the crusts form. Rarely are such deposits commercial, although occasionally a deposit is found which is workable, generally for its combined guano and extracted nitrate values.

USES

Formerly nitrates entered largely into the manufacture of gunpowder, and deposits of mineral nitrates were eagerly sought. Today, however, the old gunpowder has been largely replaced by more powerful explosives not requiring saltpeter. Moreover, one by-product of the manufacture of coke and coal gas is a large quantity of crude ammonia, from which nitrate salts can be easily made, and methods involving high-tension electrical discharges have been developed successfully on a commercial scale for the production of active nitrates from the inert nitrogen of the atmosphere. These factors make the demand for and the value of mineral nitrate salts much less than they used to be. It therefore seems improbable that future discoveries will reveal deposits of mineral nitrates of notable commercial promise.

During the World War the United States Geological Survey, at the instance of the War Department, instituted a thorough investigation of the nitrate resources of the United States, particularly in the arid Southwest. The results have been stated in two recent publications.[1] The following description of nitrate deposits in New Mexico is summarized largely from these publications, supplemented by observations in the field.

NEW MEXICO OCCURRENCES

Near the entrance to Bishop's Gap, in the south end of the Organ Mountains southeast of Las Cruces, is a bold overhanging cliff of tilted tuff, honeycombed with cavities from a few inches to several feet across. The undercut portions of the cliff and

[1] Noble, L. F., Nitrate deposits in southeastern California, with notes on deposits in southeastern Arizona and southwestern New Mexico: U. S. Geol. Survey Bull. 820, 108 pp., 1931.

Mansfield G. R., and Boardman, Leona, Nitrate deposits of the United States: U. S. Geol. Survey Bull. 838, 107 pp., 1932.

some of the cavities show incrustations of nitrate salts, which are reported to carry from 1.46 to 4.12 per cent of sodium nitrate, with only a fraction of 1 per cent of potassium nitrate. This deposit was examined by geologists of the United States Geological Survey, who reported it to be too disseminated for commercial promise, except perhaps by large-scale leaching in place, for which an adequate water supply is not available. Observations made during the field work for this report confirm this conclusion and indicate also that the nitrate of this deposit is derived from scattered small deposits of guano which have been formed and are still forming in the little caves above the deposits of nitrate salts. These guano caves, like the cavities containing the nitrate crusts, are too small to provide for accumulations in commercial quantities.

A deposit known as the Lyons nitrate prospect has been described and investigated by a representative of the United States Bureau of Soils; this prospect is in Dark Canyon 6 miles east of Queen, in Eddy County. The nitrate salts here are described as forming a thin efflorescence on the surface in protected places on the canyon walls, insufficient in quantity to be of commercial interest. This is in the same formation as the famous Carlsbad Cavern, which suggests that the nitrate crusts may be due to leachings from bat guano.

Similar deposits in the San Simon Valley in Hidalgo County and in the valley of Animas Creek and elsewhere were formerly interpreted as deposits of nitrate from volcanic sources. Later examination, however, led to the conclusion that these deposits are of the cave type and of organic origin, and that they only adventitiously occur on volcanic rocks. There are similar small deposits in and near small bat caves in volcanic rocks 8 miles southwest of Socorro.

The only commercial production of nitrate from New Mexico is 125 tons of potassium nitrate reported to have been shipped in about 1900 from a point 10 miles east of Lava station, in Socorro County southeast of San. Marcial. This material was mined in connection with the production of 800 tons of guano and 3333 tons of phosphate of lime. Elsewhere the total guano production from this locality is stated as 3000 tons. Mr. H. J. Bambrook, of Albuquerque, reported that 200 tons of guano was shipped from here to California about 1920, and that further work was under way in January, 1935, to fill an order for 500 tons of guano, to be shipped to the. Pacific Coast.

Other extractions of guano, limited to a few tons each, have been reported from the Carlsbad Cavern in Eddy County, from the east slope of the south peak of the Tres Hermanas Mountains in Luna County, and from the Guadalupe Mountains in Otero County. Other observed or reported occurrences, not worked, are in the Black Range in Grant County, from the Caballos Mountains in Sierra County, and in a cliff on the south side of the Plains of San Agustin in Catron County. It is probable that there are numerous small similar occurrences elsewhere.

Examinations by representatives of the United States Geological Survey, the United States Bureau of Soils, the State Bureau of Mines and Mineral Resources, and investigators for private capital have invariably led to the conclusion that no reported occurrence in the State offers commercial promise as a source of nitrate minerals. It is, however, quite possible that some deposits of guano may be worked on a small scale for fertilizer, if a local market should develop.

GYPSUM

GENERAL FEATURES

Gypsum is hydrated calcium sulfate. The pure mineral, ($CaSO_4$.2H2O), contains 32.6 per cent CaO, 46.5 per cent SO_3, and 20.9 per cent H_2O. The following analyses of New Mexico gypsum are presented for comparison with the pure material:

Analyses of New Mexico Gypsum

	1	2
Calcium oxide, CaO	34.24	30.8
Sulfur trioxide, SO_3	46.61	44.2
Water, H_2O	18.89	20.8
Iron and alumina, Fe_2O_3 and Al_2O_3		0.4
Insoluble and silicia Sift	0.18	2.7
Loss	0.08	1.1

1. Sandoval County, W. T. Schaller. analyst.
2. White Sands, Otero County, W. J. Gies, analyst.

Gypsum is a soft mineral distributed over wide areas in the United States as bedded deposits and as loosely consolidated sand and "earth". It occurs in five varieties:[1] (1) selenite, a transparent, cleavable form, usually colorless; (2) satin spar, a fibrous form with a silky luster; (3) alabaster, a massive fine-grained variety, usually white and translucent; (4) rock gypsum, a compact, granular form, coarser-grained than alabaster; (5) gypsite, an earthy, soft, impure form, non-coherent to slightly consolidated. Anhydrite has the same composition as gypsum except that it contains no water of crystallization; it may alter to gypsum by absorbing two parts of water.

Gypsum occurring as a sedimentary rock is to a large extent an alteration product of anhydrite, $CaSO_4$, as anhydrite is the usual calcium sulfate mineral formed by precipitation from dense brines. This alteration extends from the surface to a depth of hundreds of feet in places. Wells drilled for oil in the great Permian salt series of southeastern New Mexico have encountered

[1] Ladoo, Raymond B., Non-metallic minerals, p. 281, McGraw-Hill Book Co., Inc., New York City, 1925.

anhydrite in considerable quantities, but very little gypsum. Estimates of the amount of gypsum present in the sedimentary formations may be unduly large unless the transition to anhydrite with depth is taken into account.

USES[2]

The uses of gypsum extend over a very wide field. It finds application in many forms in the building industry. It is used in the arts, in the plate glass and jewelry industries, as a filler in paint and paper, for confectionery molds, dental and surgical plaster, and other purposes.

In the form of a manufactured powder free from any trace of color, gypsum is known as "mineral white" or "terra alba." The chief demand for this material is in the paper trade where it is used as a filler. It is also used extensively for finishing cotton and lace goods, and to a small extent as a substitute for lead compounds and barite in the manufacture of paint.

When ground but otherwise untreated, gypsum is used as a fertilizer, either by direct application to the soil or in alternate layers with manure. Applied in this manner, manure is said to lose only 2 per cent of its ammonia content in five or six months. Gypsum is also mixed with chemical fertilizers as a diluent to reduce the percentage of superphosphates.

Ground gypsum is used as a retarder in the manufacture of Portland cement. In the United States, and other countries except England and Germany, the amount allowed is 3 per cent; in these last two countries 2 per cent is permitted. Crude gypsum has been used to a limited extent as a source of sulfur in smelting ores, notably New Caledonian nickel ores, and a very low grade of gypsum is used to polish tin plate.

When heated to about 130° C. (266° F.) gypsum loses a part of its water of crystallization, and the product is the quick-setting cement known as "plaster of paris." In addition to the ordinary uses of plaster of paris for building it is employed extensively in the manufacture of molds, in modeling, and in the marble-working and lithographic trades. Very pure plaster of paris commands a high price. It is used as a filler for bandages in orthopedic surgery and for special purposes in dentistry.

When heated to higher temperatures gypsum becomes practically anhydrous. This product, if not heated too strongly, retains the power of setting and reverts to the hydrated form. Anhydrous or practically anhydrous sulfate of lime, obtained by burning gypsum under special conditions, is the basis of several special cements and plasters.

[2] Santmyers, R. M., Gypsum, its uses and preparation : U. S. Bur. Mines Inf. Circular 6163, pp. 3-4, October, 1929.

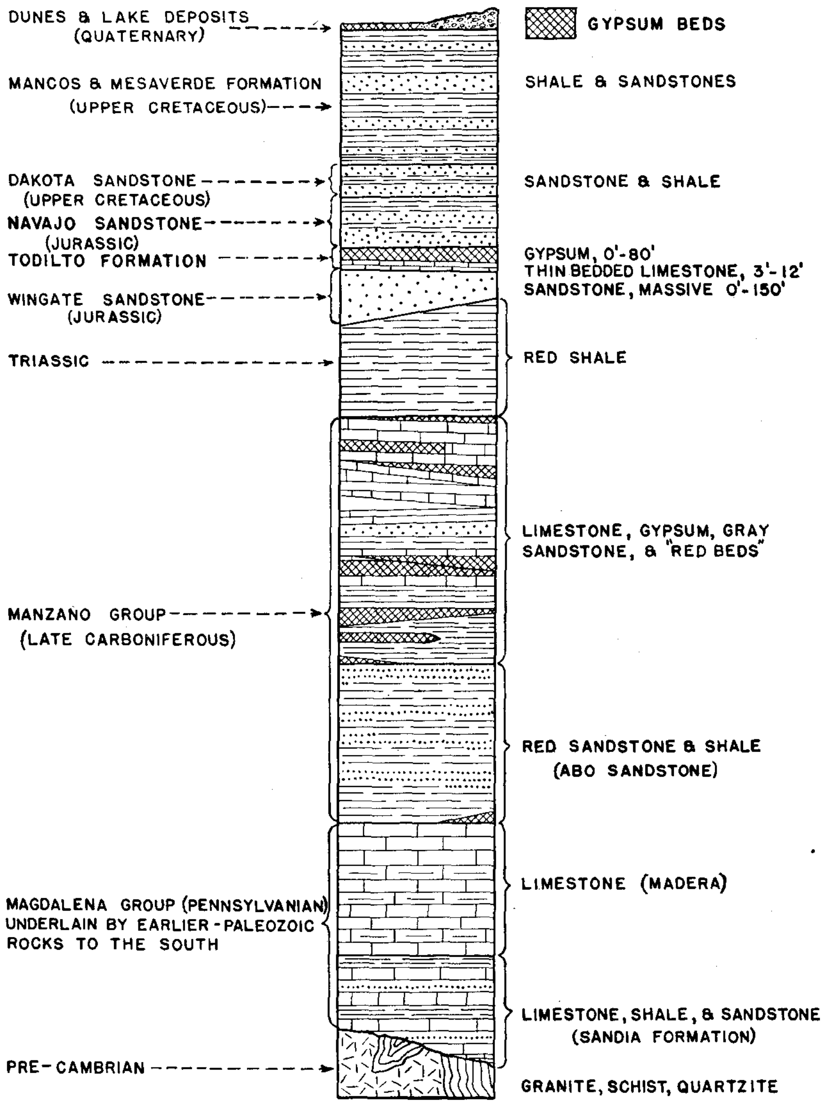


FIGURE 2.— Generalized columnar section showing stratigraphic distribution of gypsum in New Mexico.

GEOLOGIC DISTRIBUTION[1]

A very large part of New Mexico is underlain by gypsum and anhydrite, and outcrops are prominent in many districts. The beds vary in thickness from a few inches to 100 feet, much of the material being of exceptional purity. The bedded deposits are found associated with rocks of Carboniferous and Jurassic age, and a large deposit of gypsum sand in the Tularosa Basin is of Quaternary age.

The accompanying columnar section shows the principal stratigraphic relations of the more important gypsum deposits in the State.

The gypsum deposits in the Manzano group are chiefly in the Chupadera formation, consisting of the Yeso formation and the San Andres limestone. The Yeso formation consists of shale, limestone and gypsum beds, and the overlying San Andres limestone, when studied in detail, proves to be a alternation of limestone, gray sandstone, and gypsum beds as much as 100 feet thick. The Chupadera formation begins in north-central New Mexico and thickens in a short distance southward, finally attaining a thickness of 1,000 to 2,000 feet in the San Andres, Sacramento, and Caballos Mountains. The lowest formation of the Manzano group is the Abo sandstone, which consists of dark-red sandstone and shale. In the southern part of Otero County there is a bed of gypsum apparently in the lower part of this formation.

The massive sandstone that extends across western New Mexico in the Zuni uplift, where it was named Wingate sandstone, appears also in the Rocky Mountain, Nacimiento Mountain, and Sandia Mountain uplifts, and is everywhere overlain by a distinctive thin-bedded limestone and locally by a thick bed of gypsum. The southernmost exposure of this gypsum is in the Sandia uplift east of Albuquerque. It thins out and disappears in the central part of the State.

Gypsum sands of Quaternary age occur in the Pinos Wells Basin in southwestern Torrance County and in the Tularosa Basin in northwestern Otero and northeastern Dona Ana Counties.

Only a small amount of gypsum has been produced from New Mexico deposits, mainly because of long distance to large markets and the slight local demand.

NEW MEXICO OCCURRENCES

GYPSUM IN THE MANZANO GROUP

Gypsum deposits appear in the Manzano group a few miles southeast of Lamy, Santa Fe County, and they increase in thickness and number toward the south and southeast. The principal areas of outcrop are shown on the accompanying sketch map,

[1] This section is almost entirely an excerpt from N. H. Darton's report on New Mexico gypsum appearing in U. S. Geol. Survey Bull. 697, "Gypsum deposits of the United States," pp. 161-186, 1920.

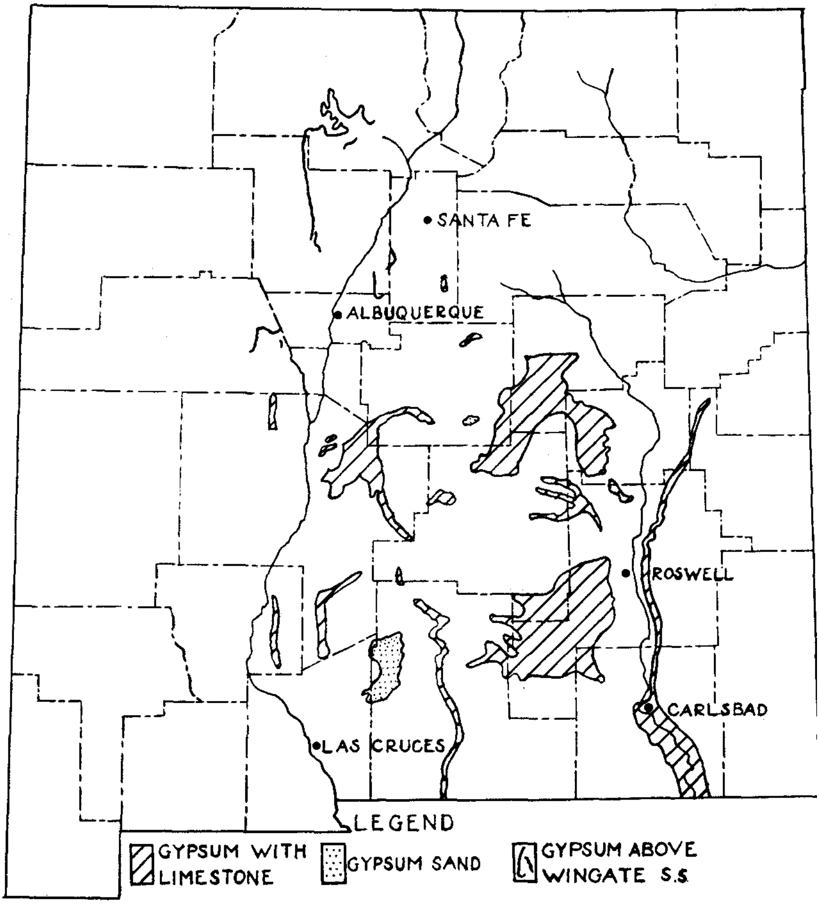


FIGURE 3.--Index map showing areal distribution of gypsum deposits in New Mexico.

figure 3, but detailed descriptions will be given only for exposures near lines of communication. A vast amount of this gypsum is high grade and easily accessible, but the beds have been worked only at Acme, Chaves County, Oriental, Eddy County, and Ancho, Lincoln County.

Chupadera Mesa.—The Chupadera Mesa occupies a wide area in the eastern part of Socorro County and extends north into the southwestern corner of Torrance County, where its northern margin is known as Mesa Jumanes. The highland is capped by limestone of the upper part of the Manzano group (Chupadera formation) dipping gently eastward. To the north, west, and southwest the mesa terminates in a line of high cliffs, in which are exposed sandstones, gypsum, and red shale with interbedded limestones of the Yeso member of the Chupadera formation.

East of Abo Pass, in Torrance County, the gypsum is exposed in the succession shown below.

Section of Gypsum and Associated Strata near Abo Siding in the Northwest Face of Chupadera Mesa

	Feet
Limestone	70+
Sandstone, gray	100
Gypsum	90
Limestone	10
Sandstone, gray	140
Limestone, hard	45
Sandstone, gray	10
Shale and soft sandstones, red, with several 10-foot gypsum beds	300+
Limestone	6
Sandstone, buff, soft	40
Abo sandstone at base of exposure	

In the north face of Mesa Jumanes, a short distance south of Willard, there is a similar succession, but the gypsum beds are much thinner.

Phillips Hills.—The upper members of the Manzano group rise on the east side of the Tularosa desert in the Phillips Hills in southwestern Lincoln County. These hills form a ridge 7 miles long lying between the railroad and the malpais southwest of Oscuro. The beds dip at a small angle, generally about 10° E. The top and most of the east slope of the Phillips Hills consist of thick beds of limestone with which are intercalated thick deposits of gypsum.

Much of the gypsum in the Phillips Hills is well situated for development and only 3 or 4 miles from the railroad. The greater part is white and evidently of good quality. The following section shows its relation to associated strata.

Section of Gypsum and Associated Strata in the Phillips Hills

	Feet
Limestone	Cap
Gypsum	20
Limestone	60
Gypsum	20
Limestone	100
Gypsum	80
Limestone	100
Gypsum, with limestone layers	100
Limestone	25
Diorite sill	60
Gypsum and limestone	50
Sandstone. yellow	20
Sandstone and shale, red	80
Gypsum	60
Limestone and gypsum	200+

Sacramento Mountains.—The great gypsum-bearing series of the Manzano group (Chupadera formation), which passes under the Tularosa desert southwest of Carrizozo and outcrops in the Phillips Hills, appears prominently in the ridges a short distance east of Tularosa. It also extends along the upper slopes of the east face of the Sacramento Range and thence south to Texas.

Vaughn Region.—Near Vaughn, in Guadalupe County, and in the wide ridge constituting the divide east of that place there are many thick beds of gypsum. In the old stone quarry half a mile north of Vaughn on the Southern Pacific railroad, there is an extensive exposure of a bed of gypsum about 20 feet thick with 15 feet of limestone above and below it. In the plains east of Vaughn there are many sink holes on the edges of which the mineral is exposed. Ledges are exposed in the railroad cut at Winkle and near Aragon and Pastura.

Gypsum undoubtedly underlies much of the plateau, which is capped by nearly horizontal limestone that extends southward from Vaughn beyond Corona, and the mineral was reported in borings at Barney and Duran. These beds appear at the surface at the foot of the south side of the plateau at Ancho.

Ancho.—At Ancho, northwestern Lincoln County, on the Southern Pacific railroad, small amounts of gypsum were at one time ground and burned in a local plaster mill. In the vicinity of the old mill the strata are considerably disturbed by flexures and cut by faults and igneous rocks.

The gypsum is extensively exposed in the slopes near the railroad, especially in the cuts east of the plaster mill, half a mile north of the railway station. There are several deposits interbedded with layers of limestone and red sandy shale and clay. The most valuable bed is 35 feet thick, and others are 10 to 15 feet thick. The principal material used in making plaster was gypsite weathered out of the main ledges. Some quarrying was done.

Pecos Valley.—A large part of the Pecos Valley has been developed in "red beds" which contain deposits of gypsum at many places from near Fort Sumner, De Baca County, to the Texas line. Some of these deposits are near the river, but most of them are in adjoining slopes or in lateral valleys. Borings show that there are thick beds of gypsum intercalated in the strata of the great Permian Basin of southeastern New Mexico and western Texas.

Much gypsum in the exposed "red beds" strata has been quarried and made into gypsum products at Acme, Chaves County, and Oriental, Eddy County.

GYPSUM OVERLYING THE WINGATE SANDSTONE

The massive Wingate sandstone of Jurassic age is locally overlain by a thin bed of limestone, above which in places is a bed of gypsum 50 to 100 feet in thickness. These two beds are known as the Todilto formation. Outcrops of the gypsum bed are known in Bernalillo, Rio Arriba, Sandoval, Santa Fe and Valencia Counties.

Sandoval County.—From Gallina, Rio Arriba County, where a small quantity of gypsum has been quarried for local use, the outcrop of the great gypsum bed of the Todilto formation extends 45 miles nearly due south along the west slope of the Sierra Nacimiento. Its thickness ranges from 50 to 100 feet, gradually increasing toward the south. At Senorita the gypsum bed is 54 feet thick and outcrops extensively just west of the post office. Coal has been developed in this vicinity. The outcrop of the gypsum passes over the Nacimento uplift where the axis of the fold pitches down at Rio Salado, a few miles southwest of Jemez Pueblo.

In part of this area the gypsum extends along high slopes or caps buttes, as in the extensive area 3 to 4 miles southwest of San Ysidro, but farther up Rio Salado it extends down to lower lands and could be easily mined over a large area. Small wedge-shaped masses appear in slopes 4 miles northwest of Jemez and along the fault 1½ miles west of San Ysidro. The southern extension of this fault cuts off the gypsum 3 miles south-southwest of San Ysidro, and it does not appear again between that point and the San Jose Valley at Suwanee.

This area is served by the Santa Fe Northwestern Railroad and the Cuba extension of that line. These railroads extend northwestward into central Sandoval County from the main line of the Atchison, Topeka & Santa Fe Railway at Bernalillo.

Santa Fe County.—The "Red Beds" that come to the surface on the great monocline west of Los Cerrillos in Santa Fe County contain a thick bed of gypsum which outcrops very conspicuously along the bank of Galisteo Creek. This locality is about a mile east of Rosario siding on the Atchison, Topeka &

Santa Fe Railway. The exposure extends along the side of the railroad for nearly half a mile and then trends off to the north, finally passing under the Santa Fe formation. The gypsum bed is 60 feet thick.

Valencia County.—A high cliff of gypsum extends along the north slope of the San Jose Valley in the vicinity of El Rito Pueblo near Rito siding on the Atchison, Topeka & Santa Fe Railway. It extends along the north side of the railroad track for some distance. The relations of this bed of gypsum to adjoining rocks are shown in the following section.

Section of Gypsum and Associated Strata near El Rito Pueblo Feet

Shale, gray, greenish, red; some sandstone	200
Sandstone, gray, massive	50
Sandstone, red	140
Gypsum	80
Limestone, thin bedded	10
Sandstone, gray above, red below (Wingate)	140
Shale, red, at base of exposure	

This bed of gypsum crosses the San Jose Valley a short distance west of the Pueblo but thins out a few miles south of El Rito. On the north slope of the valley it gradually rises to the east and outcrops for 16 miles to a point 5 miles north of Suwanee, where a great north-south fault, which drops on the east side, cuts off all the beds.

THE WHITE SANDS[1]

"The White Sands" is the name given to the remarkable accumulation of finely divided gypsum in dunes that occupy the lowest part of the Tularosa Basin. The Tularosa Basin is a broad valley, without exterior drainage, extending from the Chupadera Mesa northwest of Carrizozo southward into Texas. Shore-line features show that this basin was once occupied by a saline lake having an area of from 1600 to 1800 square miles; at the present time, however, the basin contains no permanent lakes, and no streams except at the margins. The intermittent streams entering the basin from adjacent mountain ranges sink into the gravels near the canyon mouths, and the water seeps underground toward the center of the basin. Soluble salts, notably calcium sulfate, sodium sulfate and sodium chloride, are carried by these seepage waters, and concentrated by evaporation ; in consequence, there are short-lived saline playa lakes in the lower part of the basin during the wet season, and as these lakes dry up their beds show a layer of crystalline gypsum, halite and mirabilite.

[1] The general information on the White Sands is compiled from various sources, notably U.S. Geological Survey Bulletins 697 and 794, private reports by E. H. Wells, State Geologist, and others, and observations made on the ground by representatives of the State Bureau of Mines and Mineral Resources.

The area of playa lakes known as the Alkali Flats lies at the east base of the San Andres Mountains, in a roughly triangular tract covering about 164 square miles. East of this flat, covering about 270 square miles, is the area of gypsiferous dunes known as the White Sands. These dunes are remarkable for their extent, and for their composition, which varies from ordinary quartz sand with an unusually high content of gypsum, as found west of Tularosa, to almost pure gypsum, which forms the dazzling white dunes southwest of Alamogordo. These dunes, in general, range from 10 to 30 feet high, though heights of about 70 feet have been reported. They support a scant growth of desert vegetation in parts of the area, which fixes the dunes in place; the younger and still active dunes, near the southeast margin of the White Sands area, are spectacular in their brilliant whiteness, and are slowly moving eastward, as is shown by several roads that are now buried in part under the advancing edge of the dunes. The rate of movement has not been determined with accuracy, and is probably quite variable from time to time, and from place to place.

The White Sands contain gypsum of a quality as high as any that is now worked commercially anywhere in the United States. The price of gypsum is low, the cost of transport is relatively great, and the location of the White Sands is far from large markets; consequently, there has been as yet no large-scale commercial working of these deposits.

The thickness of the White Sands has been variously estimated as averaging 15 to 20 feet. Assuming the correctness of the lower figure as representative for the whole area of 270 square miles, the total volume of gypsum sand would be 113,000,000,000 cubic feet. Allowing 25 cubic feet for a ton of gypsum sand, the total gypsum in this deposit has been computed at about 4½ billions of tons.

In January, 1933, a considerable portion of the White Sands area, including more than 200 sections, in Tps. 17, 18 and 19, S., Rs. 5, 6, and 7 E, has been designated as a National Monument; these lands were chosen to include those portions of the dunes showing the most spectacular scenic effects, excelling in a way anything else of that type on the North American continent. The National Monument lies immediately adjacent to State Highway 3, and can be reached in a half-hour's drive from, Alamogordo on U. S. Highway 54, or in about two hours from El Paso, by turning east through the Organ Mountains at Las Cruces.

Outside of the area withdrawn as a national monument, there is enough gypsum of good quality to supply, at the present rate of utilization, all the demands of the United States for several centuries to come. The value of this material, however, must be considered as potential rather than actual, since commercial development must await the establishment of more favorable circumstances of marketing or of transportation.

Origin of the White Sands.—Several suggestions have been advanced to explain this remarkable occurrence. The most widely accepted idea seems to be that the gypsum, derived from the Chupadera formation underlying the valley or in the mountains to the west, has been leached out by circulating ground waters, brought to the surface in the lower part of the valley by capillarity and precipitated due to evaporation, and then swept into piles by the wind.[2] This explanation has been questioned recently, on the basis of field investigations made by the State Bureau of Mines and Mineral Resources.[3] These investigations disclosed the following facts and relations:

The lowest part of the Tularosa bolson is occupied by a playa lake, which disappears during the dry season. This lake was formerly much larger and deeper, as is evidenced by the unquestionable shore-line features to the west of the present lake. During the shrinkage of this lake to its present size, its dissolved salts, including gypsum, were concentrated by evaporation; this was probably repeated many times.

The more soluble of these salts would remain in solution until the last stages of the evaporation. This fact explains the present potential value of these waters as a source of sodium sulfate.[4] The less soluble constituents, such as the gypsum, would precipitate out long before the brine reached its maximum density. Apparently a major part of this gypsum was deposited as large crystals of selenite within the silt that formed the sides and bottom of the lake, rather than as a crust on top of the silt. Just west of Lake Lucero, and again at Baird's Wells 12 miles farther north, silt banks some tens of feet high are now undergoing destruction by wind and water, and are exposing countless thousands of gypsum crystals more than a foot long, with occasional exceptional crystals reaching maximum dimensions exceeding 4 feet. These giant crystals are embedded in the fine silt, and contain enough of the silt as inclusions to give them a distinctly brown or yellow color. Although these crystals are oriented at all points of the compass, all of them seem to be embedded with their cleavage faces vertical; this fact, and some other peculiarities of crystallization[5] have been noted, but not yet studied in sufficient detail to justify an explanation.

On the east side of the playa lake are found dunes consisting of material that evidently came from the disintegration of the large gypsum crystals on the opposite shore. These dunes are

[2] Darton, N. H., "Red beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, p. 59, 1928.

[3] Talmage, S. B., The origin of the gypsum sands of Tularosa valley: Bull. Geol. Soc. of America, 43:1, p. 185 (abstract) 1932.

[4] See chapter on Salines.5

[5] Needham, C. E., A rare habit for gypsum: Science, N. S., vol. 76, p. 542, 1932.

yellow, not white. Their constituent particles are cleavage fragments of larger gypsum crystals; some of these fragments measure as much as a quarter of an inch across. The prevailing grain size is smaller than this, but much larger than the grains that form the white sands proper, some miles farther to the east.

On the surface of these dunes, and in the bed of the playa lake in the dry season, fresh gypsum crystals are forming, but these are invariably gray in color, instead of yellow; this seems to prove that the gypsum deposited seasonally in the playa lake cannot be the main source of the material in the coarse-cleavage dunes. The destruction of the coarse-cleavage dunes by the wind results in a sorting, and a building farther east of yellow dunes of finer and more evenly graded grains, which, however, are still recognizable as cleavage flakes. Some of these fine-cleavage dunes are now undergoing destruction, and show some excellent sections for study.

East of the cleavage dunes is a belt of gypsite hills, which, from their size and distribution, appear to be old dunes that have been compacted and cemented by the action of ground water. These are prevailingly gray instead of yellow, and compact instead of granular; they furnish exactly the result that would be expected if the formation of the fresh gray crystals, noted on the surface of the coarse-cleavage dunes, worked through the entire mass. Many of the gypsite hills are covered with desert vegetation, which probably had some effect in directing the recrystallization. The included silt in these gypsite hills is dull gray instead of yellow, probably due to a reduction of the iron oxide that gives the yellow color to the silt and to the large crystals of selenite.

These gypsite hills are, in turn, being destroyed by the action of surface agencies, and may be observed in all stages, from the beginning of their disintegration to almost complete destruction. In the process of breaking down, two materials are produced. The gray silt is liberated as a fine powder, which is winnowed out and carried away, even by gentle breezes. The gypsite proper breaks down to fine grains, free from silt and perfectly white, which are carried farther east by the stronger winds and piled up into the dazzling white mounds most characteristic of the White Sands proper. The best of the White Sands, therefore, are found farthest from the source, at the southern and eastern edges of the area, in dunes that are slowly migrating still farther south and east.

The strips designated as the zones of cleavage dunes, of gypsite hills and of white sands proper are not sharply separated, but overlap to a considerable degree. This indicates merely that there are in the area dunes of several generations, and that the whole process of selective winnowing and recrystallization is still operative. The sequence of events appears to be clear, and suggests that the older ideas, that the white sands are formed from gypsum brought to the surface by present circulating ground waters, or from crystals precipitated in the playa flats, are inadequate to explain satisfactorily the phenomenon of the White Sands.

LIME

GENERAL FEATURES AND USES

Lime is calcium oxide, CaO, and is obtained by the complete calcination or burning of limestone. Since limestones produced in commercial quarries vary in composition from nearly pure calcium carbonate, $CaCO_3$, to nearly pure dolomite, $CaCO_3.MgCO_3$, the resulting burned product will vary in composition accordingly. These commercial limes are classified as follows:

High-calcium limes, 90 per cent or more CaO.

Calcium lime, 85 to 90 per cent CaO.

Magnesium lime, 10 to 25 per cent MgO.

High-magnesium lime, 25 per cent or more MgO.

The uses of lime are too numerous and diverse to be listed in any but a special work on the subject. The three principal uses in the United States are agricultural, building, and chemical. Under chemical uses there are many classifications, including metallurgical lime, refractory lime (generally high-magnesium), and lime for water purification and for the paper and pulp industry, etc. In 1935, according to preliminary figures issued by the U. S. Bureau of Mines, the United States consumption of lime by the three main uses was, agricultural, 275,000, building, 677,000, and chemical, 2,000,000 short tons, having a total value of nearly $22,000,000.

NEW MEXICO LIME KILNS

Limestones suitable for the manufacture of lime are widely distributed in New Mexico and are to be found within a reasonable distance of practically every center of population. Rock formations of Ordovician, Silurian, Mississippian, Pennsylvanian, Permian, Triassic, Jurassic, and Cretaceous ages contain important limestone beds. Limestone for the manufacture of lime has been quarried in at least nine counties of the State, and it is probable that small quantities for local use have been mined at other places.

A kiln was formerly operated at Silver City, Grant County, the product being used in local construction and in the milling and smelting plants in that region. Some lime has been produced at Watrous, Mora County, from stone obtained at a nearby quarry.

Edmund Thurland of Kirtland, San Juan County, intermittently operates a small plant producing building lime for the local supply. The stone apparently comes from the numerous lenses of impure limestone occurring in the Lewis shale (Cretaceous) .

The Canyon Lime Co., Las Vegas, San Miguel County, has been operating a lime kiln and crushed stone plant on the Gallinas River near Montezuma College since about 1910. The stone is obtained from a quarry in a 20-foot bed of Carboniferous limestone and trammed to a bin above the kiln. From the bin the stone goes through a screening and crushing plant. The coarser material is burned and the refuse is further sized and sold as crushed stone. The kiln is 30 feet high and 12 feet in outside diameter. A mixture of wood and bituminous coal is used for fuel. The capacity is 15 tons of lump quicklime a day and the product is sold for construction and chemical use. The lime is shipped to southern Colorado, Kansas, and western Texas as well as to points in New Mexico.

In Santa Fe County the New Mexico Penitentiary occasionally operates a small pot kiln in making lime for the local market: Bituminous coal is used for fuel. The stone is obtained from a quarry in Carboniferous limestone east of the City of Santa Fe.

Small shaft and pot kilns have been operated in Socorro County in the past near Carthage, Magdalena, and Socorro. The output from the Carthage plant was shipped to various points in the Southwest, but the other two plants were small and for local building lime only.

Limestone from the Chupadera formation has been quarried near Bluewater, Valencia County, for many years. The stone has been used for crushed stone and mine dusting as well as for lime manufacture. According to a press dispatch in January, 1936, Mr. W. A. Thigpen of the Bluewater Commercial Co., planned to erect a lime hydrating plant during the year. This plant, if erected, would be the only lime hydrating plant in New Mexico.

PRODUCTION AND CONSUMPTION

Lime production from New Mexico plants during the period from 1904 through 1933 amounted to about 55,000 short tons valued at approximately $455,000. Figures for the years 1908, 1914, 1918, 1929, 1931, and 1933 are not available, but an estimate of the production and value for those years was included in the above totals.

It is estimated that during the five-year period from 1929 to 1933 New Mexico producers sold approximately 5000 short tons of lime in the State. During this same period about 45,000 tons of lime was shipped into the State, making an available supply of about 50,000 tons. These figures indicate that only about 10 per cent of the State's lime supply is produced locally. Of the total available lime supply during this period about 6500 tons, or 13 per cent, was hydrated lime, none of which was produced in the State.

LITHIUM MINERALS

GENERAL FEATURES

The principal occurrence of lithium is in minerals of complex but variable composition, as the lithium stated in the formula for the pure mineral is frequently replaced in part by another element of the alkali metal group, generally sodium. The actual lithium content of such minerals is considerably below the theoretical content of the pure mineral.

There are nearly a dozen lithium-bearing minerals, but of these only three are important industrially for their lithia content. These minerals, with their theoretical formulas, are amblygonite, $2LiF.Al_2O_3.P_2O_5$; lepidolite $3Li_2O.2K_2O.3Al_2O_3.12SiO_2.8F$; and spodumene, $Li_2O.Al_2O3.4SiO_2$.

Amblygonite is the richest of the minerals that are mined for their lithia content. The pure mineral contains over 10 per cent of lithia, but the actual minerals may contain as little as 3.5 per cent. The amblygonite as mined generally averages about 9 per cent lithia, and that running below 8 per cent is hardly salable, as unit cost of extraction is too high on lower grade material. In its outward appearance and hardness it resembles feldspar, from which it can be distinguished easily by its ready fusion before the blowpipe and the red coloration that it gives to the flame.

Spodumene has been mined extensively for its lithia content, particularly in the Black Hills of South Dakota. The ordinary variety looks to the untrained eye like feldspar or amblygonite, but is slightly harder and more lustrous. It fuses before the blowpipe but not so readily as amblygonite, and also colors the flame red, but this color is frequently masked by the yellow color due to sodium. Spodumene often occurs in very coarse crystals. The largest crystal ever found in North America was of spodumene. It was uncovered in the Etta mine in South Dakota and measured 42 feet in length and 3 by 6 feet in cross-section. Nearly all the spodumene mined is treated in the chemical works at Mayfield, New Jersey. Spodumene contains less lithia than amblygonite, averaging from 4 to 7 per cent.

Lepidolite, known also as lithia mica or purple mica, contains on the average only 4 per cent of lithia, although its formula indicates a content of nearly 6½ per cent. It was formerly used as a source of refined lithia salts, but lately most of it has been used in the manufacture of special grades of glass and enamels. It occurs usually as fine-grained aggregrates of tiny purple scales.

The lithia minerals, in their commercial occurrences at least, are confined to pegmatite dikes. They are generally accompanied by coarsely crystallized quartz and feldspar, often by mica, tourmaline and apatite, and sometimes by beryl or other rare pegmatite minerals.

USES

Lithium salts are used for the preparation of lithia water and other medicinal compounds, as lithium hydroxide in Edison storage batteries, and on account of the red flame coloration some lithium salts are used in fireworks. All of these, formerly the main uses of lithia, are now subordinate to the use of lithium compounds in the manufacture of special glasses, such as Pyrex ware and shatter-proof glass for automobiles, which are tougher, less brittle, more resistant to rapid temperature changes, more brilliant and less subject to corrosion than ordinary glass.

NEW MEXICO OCCURRENCES AND PRODUCTION[1]

The only commercial occurence of lithium minerals in New Mexico is at the Harding mine in Taos County 7 miles east of Embudo, where shoots bearing lepidolite and spodumene compose part of a large pegmatite. The deposit occurs in a belt of pegmatites and hypothermal veins about 4 miles long bordering the Dixon granite, which outcrops along the Rio Pueblo.

During the decade 1920-1930, about 12,000 tons of lepidolite and spodumene approximating 3.5 per cent Li_2O was shipped from the Harding mine. In the early part of this period the rock was shipped in lump form to Wheeling, W. Va., where it was ground and sold to the glass trade. In the later part of the decade a grinding mill was built at Embudo, and grinding was done before shipment. Operations ceased in 1930.

The pegmatite at the Harding mine is the only place in this district where lithium minerals have been found. Several outcrops bearing lepidolite and spodumene occur on the property, and it is possible that further development would result in the discovery of other lithium-bearing shoots. Under present conditions of market, transportation and development, this deposit appears to be practically worked out.

Smaller deposits containing lithia minerals have been reported from the vicinity of Las Tablas, Rio Arriba County.

MAGNESITE AND DOLOMITE

GENERAL FEATURES AND USES

Magnesite is the natural carbonate of magnesium, $MgCO_3$, and contains, when pure, 52.4 per cent CO_2 and 47.6 per cent MgO. Dolomite is a carbonate of magnesium and calcium, the pure mineral containing 47.7 per cent CO_2, 21.9 per cent MgO, and 30.4 per cent CaO. Calcite, $CaCO_3$, and brucite $Mg(OH)_2$, are frequently found associated with magnesite.

[1] For a more extended discussion of lithium minerals, mica and other minerals in the pre-Cambrian pegmatites, and their mineralogic and geologic associations, see Just, Evan, "Geology and economic features of the pegmatites of Taos and Rio Arriba counties, New Mexico": N. Mex. Sch. of Mines, State Bur. of Mines and Min. Res. Bull. 13, (in preparation).

The principal use of magnesite is as a refractory material for furnace linings, but large amounts are used in building materials and in the chemical industries. Dolomite and high-magnesium limestones find similar application, and are also used in paper and glass manufacture, as a flux, fertilizer, filler, and in ceramics. They are also used as dimension and crushed stone.

NEW MEXICO OCCURRENCES

High-magnesium limestones are widespread over southern and central New Mexico in Lower Paleozoic and Permian formations. The Fusselman, Montoya, and El Paso limestones of the Lower Paleozoic contain many dolomite and dolomitic beds, some of which are many feet thick. The Chupadera formation (Permian) is known to contain a large amount of magnesia. Many of the oil wells in Chaves and Eddy counties were spudded in dolomite or passed through thick beds close to the surface.

Only three deposits of magnesite are known in the State. Two are in Dona Ana County, one near the south end of the Organ Mountains, the other on the southwest side of the San Andres Mountains north of Organ Pass. The third deposit is in Grant County on Ash Creek, about 30 miles north of Lordsburg.

Dona Ana County.—The principal Dona Ana County deposits are in the southern end of the Organ Mountains in the southeast part of T. 23 S., R. 4 E., in South and Target Range Canyons. The magnesite occurs in dolomite xenoliths contained in a quartz monzonite intrusive. The deposits have been described by Dunham[1] and briefly mentioned by Taft.[2] The following notes have been extracted from Dunham's report:

> Metamorphism of the dolomite xenoliths by the quartz monzonite converted them into periclase marble consisting essentially of periclase and calcite * * * at a later stage, periclase and forsterite were in part converted into brucite and serpentine. Later still, the xenoliths were invaded by solutions, probably rich in carbon dioxide, which were able to convert the marble into magnesite. * * * Development of the property has not proceeded sufficiently to show what form the magnesite bodies take, but the excavations which have been made show magnesite in places more than 4 feet thick. * * * The xenoliths are exceptionally large, and, while they are by no means wholly converted into magnesite, yet the slight developments so far made are sufficient to indicate that large quantities of the material exist, apparently as replacements of certain beds in the dolomite. * * * The developments in South Canyon consist of five open cuts and a number of shallow pits. The magnesite in these varies from 1 to 5 feet in thickness.
>
> In Target Range Canyon, east of the Devil's Canyon mine, bodies of magnesite of identical character have been found in the metamorphosed dolomite. * * * Analyses of magnesite from South Canyon and Target Range Canyon are given below:

[1] Dunham, Kingsley C., The geology of the Organ Mountains, N. Mex.: N. Mex. Sch. of Mines, State Bur. of Mines and Min. Res. Bull. 11, pp. 236-237, 1935.

[2] Taft, H. H., Magnesite in Dona Ana County, N. Mex.: Eng. and Min. Jour., vol. 137, p. 137, 1936.

Analyses of Magnesite

	I	II	III	IV	V
SiO_2	1.74	2.51	0.13	0.86	1.01
R_2O_2	0.57	0.74	0.71	0.76	0.36
CaO	3.28	0.96	2.00	5.35	4.95
MgO	43.18	44.48	44.77	41.76	42.19
Loss on ignition (CO_2 & H_2O)	51.23	51.31	52.39	51.27	51.49

I-IV, from Target Range Canyon.
V, from South Canyon.
Analyst, H. C. Lee, University of Ohio.

Taft, in the paper cited above, mentions the deposit north of Organ Pass, but does not describe it except to say that it is probably smaller than the others.

Grant County.—Since the Grant County deposit has never been visited by a member of the Bureau Staff the following paragraphs are quoted in full from the only known description:[1]

A deposit of magnesite that crops out on a steep hillside west of Ash Creek two miles above its junction with Gila River, about 30 miles north of Lordsburg, N. Mex. was examined by R. W. Stone in May, 1920. The general alignment of the outcrops might indicate that it is a continuous body, 1000 to 1500 feet long and 30 feet thick, in limestone, but close examination shows that the limestone occurs as a number of detached blocks, none of them more than a few rods long, inclosed in granite and cut by dikes and sills of diabase older than the granite.

The magnesite has replaced certain beds of limestone. At one place where the deposit has been prospected and has since caved there appears to be a total thickness of 20 to 30 feet of magnesite and limestone. The best exposure shows only seven feet of magnesite in a limestone block 5 or 6 rods long, in which the beds stand vertical. Not all the limestone blocks contain magnesite. The small quantity of magnesite available and the distance of the deposits from a railroad render them of little present commercial interest.

The magnesite is hard, amorphous, and pure white, resembling the variety common in California. It is believed to have been derived from the diabase.

An analysis of the Grant County magnesite published in the Mineral Resources volume for 1918 was as follows: Silica, 0.60 per cent; oxides of iron, 0.38 per cent; calcium carbonate, 4.03 per cent; and magnesium carbonate, 94.99 per cent. This analysis was made by Regis Chauvenet & Bro., St. Louis, Mo.

MEERSCHAUM

GENERAL FEATURES AND USES

Meerschaum, also known as sepiolite, is a hydrous silicate of magnesia whose composition is represented by the formula $2MgO.3SiO_2.2H_2O$. It is a compact, finely granular white mineral, so light in weight that when dry it floats on water, from which character comes its name, signifying in German

[1] Yale, Charles G., and Stone, Ralph W., Magnesite: U. S. Geol. Survey Mineral Resources, 1919, pt. II, p. 234, 1922.

"sea-foam." In some respects it resembles physically a high-grade white clay.

Meerschaum is invariably an alteration product of magnesian rocks or minerals, generally magnesite or serpentine. Its principal use is in the manufacture of tobacco pipes, for which its light weight, its absorbent property enabling it to take a rich brown color from the smoke, and its ease of working, make it especially suitable. The best meerschaum occurs without admixed impurities in blocks from which pipes can be carved, sometimes very elaborately. Lower grade material is freed from impurities and molded or pressed into shape.

NEW MEXICO OCCURRENCES

Two deposits[1] of meerschaum from the same general locality in New Mexico have been described, one about 12 miles northwest and the other about 24 miles north of Silver City. The meerschaum is described as occurring in veins in Tertiary igneous rocks. The veins carried the meerchaum in nodules or in blocks, some of them several feet across, but few if any of these nodules or blocks were clear and free from impurity. Nearly everywhere the meerschaum was shot through with crystals of quartz or calcite, so that grinding and washing were necessary to eliminate these crystals. Several shipments were reported to have been made some years ago, part of the material being used for pressing into tobacco pipes and part used as an absorbent for nitroglycerine.

No detailed information is available as to the extent or success of the use of New Mexico ground meerschaum for these purposes, nor as to costs and prices at the time the deposits were worked. Either the quality of the material was too low, or more probably the cost of extraction and shipment was too high, to justify the continued production of this material, as the properties have been idle for many years.

MICA[2]

GENERAL FEATURES

Mica is the general name given to the group of minerals characterized by splitting readily into thin sheets that are elastic or springy. The minerals of the mica group are soft but relatively tough, and most of them are highly resistant to heat and to the passage of electricity. In composition the micas are complex and variable hydrous silicates of aluminum and other bases, which generally include iron and magnesium and may include potash, soda, lime, fluorine, titanium, lithium or vanadium, with other substances sometimes found as impurities.

[1] Sterrett, D. B., Meerschaum in New Mexico: U. S. Geol. Survey Bull. 340, pp. 466-473, 1908.

[2] See footnote, page 110.

The more important varieties of mica are:

Muscovite, or potash mica. This is generally colorless or faintly tinted in brown or yellow. Thin cleavage plates appear transparent and colorless. In thicker sheets the mineral shows a distinctive luster resembling mother-of-pearl.

Biotite, known also as black mica, or iron mica. This is deep black and opaque, except in very thin sheets, which appear translucent and dark brown.

Phlogopite, known also as bronze mica, or magnesium mica. This has a characteristic lustrous bronze-yellow color, somewhat deeper than the color of yellow muscovite.

Lepidolite, or lithia mica. This usually is recognized readily by its characteristic color, which is between lilac and pink. It generally occurs as an aggregate of tiny scales and is found in large sheets much more rarely than the other varieties. (See Lithium Minerals, pages 109-110.) Some mica originally mistaken for lepidolite, has proved on test to be the rare but valueless purple muscovite.

Other minerals of the mica group are relatively rare, of little commercial importance, and not known to occur in New Mexico.

Commercial deposits of high-grade mica are limited almost entirely to pegmatite dikes, except for phlogopite, which occurs characteristically in metamorphosed limestones and has been developed commercially only in Canada. The value of mica depends on the size of the sheets, the larger pieces bringing a much higher price per pound than the smaller ones.

In their characteristic occurrences in pegmatite dikes, the mica crystals are embedded in a mixture of quartz and feldspar, often with some rare minerals intergrown. The mica crystals are generally incomplete and partially cleaved, and are called "books" from the appearance of the edges. Mica is generally separated from its associated minerals by hammering, either hand or machine, which breaks up the brittle minerals and leaves the tougher mica relatively undamaged.

USES

Most of the sheet mica produced is used in the electrical industry, principally as an insulator in light sockets, condensers, dynamos and spark plugs. It is also used as a heat insulator, for furnace sight holes, lamp chimneys and protective goggles. Formerly much sheet mica was used for the fronts of parlor stoves, and this is still the principal use outside the electrical industry. Sheet mica is also used in resonators for phonographs and sounding devices and formerly was used for telephones, military lanterns, compass cards, decorative purposes and windows subject to heavy vibrations or shocks. For most of these purposes muscovite is preferred to biotite on account of its lack of color and superior transparency. Phlogopite is the best mica for insulation in electrical commutators, which is its sole important use.

For many purposes where transparency is not required, mica board is used instead of sheet mica. Mica board is built up from thin cleavage scraps pressed together with an adhesive. Ground mica mixed with shellac is molded into insulators of various forms. Ground mica is also used for producing a glistening surface on wall paper and prepared roofing, as a constituent of lubricants, as a filler in certain rubber and paper products, for tire powder and for various decorative uses. For most of these purposes mica ground from clean scrap is required, but for surfacing roofing a considerable amount of impurities is permissible. Some powdered mica is produced by the grinding of micaceous schists.

Recent prices for sheet mica range from 4c to 10c per pound for sizes smaller than 1½ inches and as much as $5 to $8 per pound for sheets 8 by 10 inches. Quality as well as size affects the price, the clear and flawless grades being more valuable. Ground mica was quoted recently at from $18 to $75 per ton, but during the World War the first quality ground mica, carefully prepared, brought as high as $200 per ton.

NEW MEXICO OCCURRENCES AND PRODUCTION

The occurrence of mica of industrial quality in New Mexico is confined entirely to the pre-Cambrian rocks, and the only commercial developments have been in the Rocky Mountain area in the north-central part of the State. The major production has been from the Apache mine in Rio Arriba County, which according to the statement of Mr. C. L. Johnson, the present owner, has been operated intermittently for more than 80 years. Jones[1] says that the mining of mica from the mountains near Santa Fe was mentioned by Lieutenant Pike as early as 1807. In the early working of this property, the mica was packed on burros to Santa Fe and to Alamosa, Colo., and the mine is reported to have produced 72,000 pounds of sheet mica prior to 1926.

The Apache mine is located in Apache Canyon, 3 miles west of Petaca, in T. 26 N., R. 8 E. Four pegmatite dikes have been worked at this property. The mica occurs in medium to coarse books, which are distributed much more abundantly near the hanging wall of the dike than near the foot wall. The mica here is a good quality muscovite, nearly white, and quite colorless in thin sheets. It was reported by Mr. Johnson, that 50 per cent of the sheet mica produced will cut as large as 3 by 3 inches. At the time of the writer's visit in 1931, the property was not being operated, except to keep up assessment work, as it was explained that market conditions did not justify extensive operation. Plans were reported under way for producing some finished mica products on the property instead of shipping the raw mica, in

[1] Jones, F. A., New Mexico mines and minerals, p. 260, 1904.

order to reduce the ratio between freight costs and total selling price. The discontinuance in 1931 of railroad service to La Madera further hampered shipment from this district, necessitating trucking across the mountains to Servilleta on the Denver & Rio Grande Western railroad.

Under the same ownership as the Apache mine are reported mica properties at Cribbenville, 2 miles west of the Apache, and 13 claims in Alamos Canyon in secs. 25 and 26, T. 26 N., R. 8 E. These mines were reported as also idle. In fact, the only production in the district during 1931, aside from mica produced from assessment work, was from small individual independent Spanish-American operators. About 60 of these men were reported to be working intermittently extracting mica from the numerous small dikes that occur in the region. This mica, mostly scrap, was purchased from the individual miners by Mr. Johnson, and formerly by Sargent and Wilson, the proprietors of the store at La Madera, and shipped as it accumulated in carload lots. Shipments during 1931 were reported to average about 60 tons a month, of which only about 300 pounds was of sheet or plate grade, and the rest was scrap for grinding.

Near the Apache mine is the property described in the posted location notice as the Conquistador claim belonging to P. S. Hoyt and situated 2 miles west of Petaca. This has been opened by an incline following down a pegmatite dike for at least 200 feet. This pegmatite consists largely of very coarse feldspar crystals, many of which are from one to two feet across. The mica, most of which is biotite, is distributed abundantly in coarse books in the upper portion of the dike but is scant toward the bottom. There are two cobbing cribs near the opening of the mine, which at the time of the writer's visit contained numerous plates of black biotite free from flaws and from 6 to 8 inches across. This mine was formerly equipped for mechanical operation, but the hoisting machinery is now dismantled.

About a mile to the east of the Conquistador is a prospect that has been opened to a depth of a few yards in a very steep pegmatite dike. This dike has a very irregular edge, apparently due to apophyses extending into the surrounding rock. The mica here, which is biotite and muscovite in small books, is confined to the edges of the main dike and to the apophyses. Along the borders of these dikes the rock is a micaceous schist.

About 15 miles to the south, but in the extension of the same area of pre-Cambrian rocks, is the property owned by J. S. Stanko and Charles Springer (deceased) , situated in a canyon west of the road about 2 miles north of Ojo Caliente. At this mine the coarse pegmatite dikes consist largely of feldspar that is prevailingly red, in contrast to the dikes referred to above in which the feldspar is prevailingly white. The dike at this property is the largest observed by the writer in the district, and the mica seems also to be more abundant and in larger sheets than at any other property that was visited. The mica here is all biotite of the deep black iron-rich variety. As at the other occurrences, it is more abundantly distributed near the hanging wall of the dike.

In a separate area of pre-Cambrian rocks, centering about 25 miles southeast of the district just described, is the Harding mine, at which a moderate amount of the lithia mica known as lepidolite has been mined and marketed. The deposit is described under Lithium Minerals.

Although the commercial deposits of sheet mica are restricted to the pegmatite dikes, mica in small flakes is a frequently occurring minor constituent of many igneous rocks as well as a major constituent of mica schists. Only rarely and under exceptionally favorable circumstances are deposits of this sort of commercial interest. It seems probable that most of the reported but unverified occurrences in Socorro, Santa Fe and Colfax Counties are of the same sort and of no commercial importance.

According to E. H. Wells,[1] a pegmatite pipe in the pre-Cambrian rocks of Little Burro Peak, at the north end of the San Andres Mountains, Socorro County, contains some mica. This nearly vertical pipe, which is about 200 feet in largest diameter, consists mainly of quartz, but in places there are bodies of nearly pure feldspar amounting to several tons. Adjacent to one of the segregations of feldspar is a nearly solid mass of muscovite mica several feet across. The mica books are not over 2 inches long, and most of them are bent or broken; they do not constitute high-grade material.

Mica has been reported from the Florida Mountains, southeast of Deming. The occurrence here is merely as scattered flakes in a disintegrated granitic rock. Deposits of mica in small scales, described as bran-mica or as micaceous rotten shale, have been worked in a small way near Mora and southwest of Las Vegas, in the southern extension of the Rincon Range.

Mica is more resistant to weathering than many of its associated minerals and so may form a conspicuous constituent of disintegrated igneous rocks or of the sands derived from such. Several specimens of sand bearing flakes of mica, especially the bronze-yellow phlogopite, have been sent to the State Bureau of Mines and Mineral Resources for identification or assay, under the mistaken impression that the glistening yellow flakes of mica were gold. Mica in such an association is worthless.

The total published production of mica from New Mexico mines from 1900 to 1932 is 160,285 pounds of sheet valued at about $40,000, and 7,218 short tons of scrap valued at about $123,000. These figures do not include the production during the years from 1903 to 1922, and in 1931, and include only scrap mica during the years 1927 and 1930.

[1] Private report.

MINERAL PAINT

GENERAL FEATURES

The materials properly classed as natural mineral paints are limited to colored earths. The coloring matter is usually an oxide of iron, other natural pigments being relatively rare. Many other mineral substances, such as barite and prepared salts of lead and zinc, enter into the manufacture of certain paints, but these are not considered here. Graphite and barite, which are used as ingredients in paint, are described separately in this report. The only mineral paints of interest here are included in the group known as ochers.

Ocher may be broadly defined as a clay stained with oxide of iron. The term includes all varieties, from red ocher, consisting of hematite with only a small percentage of clay, to pale yellow ocher, consisting of clay with a very small amount of limonite. There are numerous intermediate shades of reds and browns, and a few ochers described as orange, depending on quantity and proportional mixtures of the two iron oxides.

Hematite is the oxide of iron with composition expressed by the formula Fe_2O_3. In color it ranges from red through dark brown to black, but the powdered pure mineral is always a rich red. In ochers the hematite is finely divided, and it is the principal coloring ingredient of all the red earths or clays that are in use as pigments. Some deposits of relatively pure hematite, of iron ore grade, have proved most valuable when ground for paint.

Limonite is the name given to the mineral formerly described as consisting of hydrous iron oxide, $2Fe_2O_3.3H_2O$. It is now known that much that has been called limonite consists of a mixture of several hydrated iron oxides, which may include goethite, $Fe_2O_3.H_2O$; hydrogoethite, $3Fe_2O_3.4H_2O$; turgite, $2Fe_2O_3.H_2O$; xanthosiderite, $Fe_2O_3.2H_2O$, and others, often with accompanying minerals related to jarosite, $K_2O.3Fe_2O_3.4SO_3.6H_2O$. It seems advisable to retain the term limonite as a general name for the group or mixture. All these minerals, when occurring finely divided as in ochers, are colored in shades of yellow and brown, some of them being darkened by the presence of manganese compounds. Some limonitic ochers may have the color enriched and reddened by strong heating, which drives off part of the water from the hydrous iron minerals and transforms them to hematite.

USES

Low-grade ochers are used extensively as combined fillers and coloring agents in the manufacture of linoleum and oilcloth. Medium-grade ochers find their most extensive use as protective paints for exposed metal surfaces, barns, freight cars, etc. The better ochers are used in making high-grade paints in shades of red, brown, and yellow, for general use. Only rarely is ocher found of a quality sufficiently high to use in artists colors. Another use of ochers that is growing in importance is as a coloring medium in concrete and plaster. The finely ground pigment is mixed in varying proportions with the cement or plaster and gives the finished product any one of a great range of color tones. Iron oxides prepared for these uses are sold as "mortar colors."

NEW MEXICO OCCURRENCES

Jones[1] reports the existence of a deposit of ocher in Bernalillo County in the Sandia Mountains east of Albuquerque near Coyote Springs. He describes the deposit as being a bed several feet in thickness and of beautiful red and yellow colors. No attempts have been made to develop this deposit.

The only mineral paint deposit in the State that has been worked regularly for its value as a pigment is located about 10 miles north-northwest of Farmington, in San Juan County. It is worked as an intermittent one-man side-line industry by Mr. William Scott. The market is entirely local, and the total value of the paint produced averages only about $150 a year.

The paint deposit outcrops near the bottom of a broad canyon as a dark red ridge, trending nearly east and cut by north-easterly fissures in which are springs with a small flow of alum water. The rock containing the pigment material consists of sandstone and conglomerate. It is probably part of the Farmington sandstone member of the Kirtland shale formation of late Upper Cretaceous age. This rock contains streaks of stained clay, and some of the conglomerate has a clay cement. From one-fifth to three-fourths of the rock in the best horizons is said to be good raw material for paint. The colors range from red through browns to yellow.

Mr. Scott extracts the "paint ore" streaks separately and subjects the material to a long treatment in the open air, including weathering or "seasoning", repeated washing and settling, with alternate drying, and blending when desirable. This treatment is reported to fix the colors, which change somewhat during preparation. The pigment is sold at retail by hardware stores in Farmington. The prevailing price for the dry pigment is 6c a pound, with special grades in small quantities bringing as high as 25c a pound.

The location and size of this deposit and the preparation required for producing a serviceable pigment, make it seem improbable that any large expansion of the industry would be commercially successful.

Near Glorieta, Santa Fe County, there are three or more outcrops of iron ore referred to by Mr. V. Carl Grubnau[2] as "mineral brown." The ore is hematite, and shipments are said to

[1] Jones, F. A. New Mexico mines and minerals, pp. 264-265, 1904.
[2] Personal communication.

have been made to the blast furnaces at Pueblo, Colo. The deposits are covered by three patented claims in secs. 14, 15, 22, and 23, T. 15 N., R. 11 E., about 6 miles southeast of Glorieta. They are about 4 miles from the Atchison, Topeka & Santa Fe Railway at Fox siding. Mr. Grubnau states that he had tests made on the material and it proved to be suitable for use as a brown pigment. Mr. Grubnau kindly furnished a copy of a report by Mr. Frank F. Trotter, Jr.,[3] dated January 16, 1923, from which the following notes have been abstracted.

The iron mineral is a dark brown hematite occurring in a yellow sandstone 3 to 5 feet thick, underlying a series of shales capped by a coarse sandstone or conglomerate. One bed of shale has enough iron oxide to give it the appearance of an iron ore. There are about 600 feet of workings on the Iron King claim, and the ore has been uncovered for a distance of 40 feet on the Monator claim. Trotter mentions no outcrops or workings on the third claim, the Iron Queen. At no place was the thickness of the ore reported to be more than 5 feet. The ore is said to pinch out in the drifts extending to the west. Trotter estimates the ore left in pillars at about 1000 tons and says that an additional 15,000 tons could be developed at a cost of about $3000.

According to Lindgren,[4] several thousand tons of iron ore was shipped from these deposits to smelters at Socorro, N. Mex., and El Paso, Tex., for use as flux.

Jones[5] mentions another deposit of mineral paint in Santa. Fe County near San Pedro but gives no details of its occurrence.

According to Dunham,[6] some of the jarosite from the Organ Mountains has been mined and used successfully as a pigment.

POTASH MINERALS

GENERAL FEATURES

The term "potash" originally was applied to the caustic solution obtained from the leaching of wood ashes and was therefore practically synonymous with "lye," or crude potassium hydroxide, KOH. Later chemical usage restricted the term "potash" to the oxide of potassium, K_2O, and this usage is still current in reporting "potash content" (recalculated to K_2O) of potassium-bearing compounds.

Ordinary usage, however, has extended the meaning of the term "potash" to cover most of the compounds of potassium occuring in nature, and the term "potash salts" is firmly established commercially as descriptive of those potassium-bearing minerals that are soluble in water.

[3] Private report to V. Carl Grubnau.

[4] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U.S. Geol. Survey Prof. Paper 68, p. 112, 1910.

[5] Op. cit., (N. Mex. Mines and Minerals) , p. 265.

[6] Dunham, K. C., The geology of the Organ Mountains: N. Mex. Sch. of Mines, State Bur. of Mines and Min. Res., Bull. 11, P. 244, 1936.

Potassium is an element that is widely distributed in many combinations. It occurs in orthoclase, the most abundant mineral in granitic rocks, in some micas, and in several other common rock-forming minerals, but from these it cannot be extracted commercially on account of their insolubility. It is also a constituent of about thirty rare minerals, which are not sufficiently abundant to make them commercially important for their potash content.

The chief minerals from which the refined potash salts and compounds can be manufactured on a commercial scale are:

Sylvite, potassium chloride, KCl.

Carnallite, hydrous double chloride of potassium and magnesium, $KCl.MgCl_3.6H_2O$.

Kainite, hydrous compound of potassium chloride and magnesium sulfate, $KCl.MgSO_4.3H_2O$.

Polyhalite, hydrous triple sulfate of potassium, magnesium and calcium, $K_2SO_4.MgSO_4.2CaSO_4.2H_2O$.

These potash minerals are usually white or colored in various shades of red. With the exception of polyhalite they are water-soluble, so they can generally be recognized by their peculiar slightly bitter taste. When mixed with halite, which is always associated with them, the potash flavor is masked by the stronger taste of the common salt and may be recognized only as a bitter after-taste. The magnesium-bearing salts, such as carnallite, are particularly bitter with a flavor resembling that of epsom salts.

USES

Potash salts are used for a wide variety of purposes, but in the United States more potash has been used for fertilizer than for all other purposes combined. Certain crops, notably cotton, tobacco and citrus fruits, extract from the soil large quantities of potash, which must be replenished if production of these crops is to be maintained. For fertilizer purposes some of the crude potash salts, known as "manure salts," may be used directly or mixed with packinghouse refuse or other nitrogenous or phosphatic material. Such a mixture supplies not only potash but other desirable ingredients to the soil.

The principal market for manure salts has been in the South Atlantic states where the cotton has demanded more potash than any other single crop in this country. Crude manure salts for fertilizer purposes have sold in normal times at prices of from $10 to $25 per ton, depending on grade. During the World War prices were much higher, and salts richer in potash commanded a correspondingly better price.

There are many other uses of potash compounds. Refinement of the potash minerals results in the manufacture of about

40 chemicals containing potash, which are used for a wide variety of purposes. Among the potash compounds that are used medicinally may be mentioned potassium bromide, KBr; potassium iodide, KI; potassium chlorate, $KClO_3$; potassium permanganate, $KMnO_4$; several potassium tartrates, including cream of tartar, KHC_4H_4O, Rochelle salts, $KNaC_4H_4O_6$, and tartar emetic, $KSbO.C_4H_4O_6.H_2O$. Important industrial compounds include potassium hydroxide, or caustic potash, KOH, used in the manufacture of high-grade soaps and in electroplating; potassium carbonate, K_2CO_3, used in making first-quality glass; potassium bichromate, $K_2Cr_2O_7$, potassium ferricyanide, $K_4Fe(CN)_6$, and other compounds used in the dyeing and tanning industries; potassium cyanide, KCN, used in metallurgy and in electroplating; potassium chlorate, $KClO_3$, used in the manufacture of matches and explosives; and potassium nitrate, KNO_3, used in the manufacture of gunpowder. A score or more of other potash compounds are important chemical laboratory reagents.

DEPOSITION OF POTASH SALTS

The large deposits of potash salts were formed, directly or indirectly, by the evaporation of sea water in enclosed basins, and as a result common salt or halite is generally present in far greater quantity than any other substance. The solubility of these various salts is high, and several of them show great variation in solubility with change of temperature. Moreover, the presence of one salt may affect the solvent power of the water with respect to some other salt. Consequently, the actual formation of bodies of potash salts is probably due to a very complex process, involving repeated solution and redeposition by ground and surface waters, either warm or cold. As a result of these processes, which are not yet fully understood, there are, within rock-salt deposits, concentrations of potash salts of considerable magnitude. There is some evidence suggesting that these concentrations may have been formed, or at least enlarged, by selective replacement after the solidification of the main mass consisting mostly of rock salt.[1]

The best-known deposit of this type and the one from which most of the world's potash to date has been extracted, is in the Stassfurt region of Germany. Here is a rock salt series, interbedded with anhydrite, clay, and complex salts, with a total thickness of over 3300 feet. The only part of this series in which rock salt is not predominant is a zone about 140 feet thick, lying about 900 feet below the surface. This is known as the "carnallite zone," and contains about 55 per cent of carnallite, from which the potash, averaging over 9 per cent of the total mixture, is extracted. All of the commercial potash produced at Stassfurt

[1] Schaller, W. T., and Henderson, E. P., Mineralogy of drill cores from the potash field of New Mexico and Texas: U. S. Geol. Survey Bull. 833, pp. 66-70, 1932.

comes from this zone, the salts other than carnallite being present in only small quantity.

Another important European deposit is in Alsace, France, and was discovered in 1904. Here the potash occurs as a mixture of halite and sylvite in about equal proportions. This mixture is called sylvinite,[2] or better, halo-sylvite, and is a richer source of potash than the Stassfurt carnallite, the workable parts of the deposit averaging 22 per cent potash.

The two areas mentioned above contain enough potash salts to supply the world's needs for more than twenty centuries to come at the present rate of consumption, and until recently they had almost a monopoly in the potash markets of the world.

The occurrence of potash in the Suria district in Spain has been known since 1912, but no production was recorded until 1925. The three operating companies produce nearly half a million tons of crude potassium salts annually. Since Spanish domestic consumption is small, practically all the salts produced enter the world market in competition with potash from other sources.

DEPOSITS IN THE PERMIAN BASIN

The southeastern part of New Mexico lies in the "Permian Basin," an area that in Permian time was flooded by incursions of the sea from the Gulf of Mexico. This basin extended eastward into Texas and northward into Oklahoma and Kansas. (Plate III). Apparently this broad, relatively flat basin was connected with the gulf by a narrow strait running through Mexico. There is evidence that the evaporating power of the southwestern sunshine was fully as great then as now, and the water evaporated from the broad expanse of the Permian embayment was replaced by inflow through the strait, which thus maintained what was essentially a one-way current. These conditions naturally led to an increase in the saline content of the embayed waters, which repeatedly became supersaturated with calcium sulfate, and deposited the gypsum and anhydrite beds that form so prominent and abundant a part of the older Permian sediments throughout New Mexico.

The lowest part of this basin was in the vicinity of the southeast corner of New Mexico, and here were collected the intensely saline brines, concentrated by evaporation, in the closing stages of the history of the Permian basin. The salt series here has a maximum thickness of over half a mile. The salt is interspersed with beds of anhydrite, which indicate intermittent influxes of sea water during the closing stages of dessication, and also indicate that the evaporated waters were high

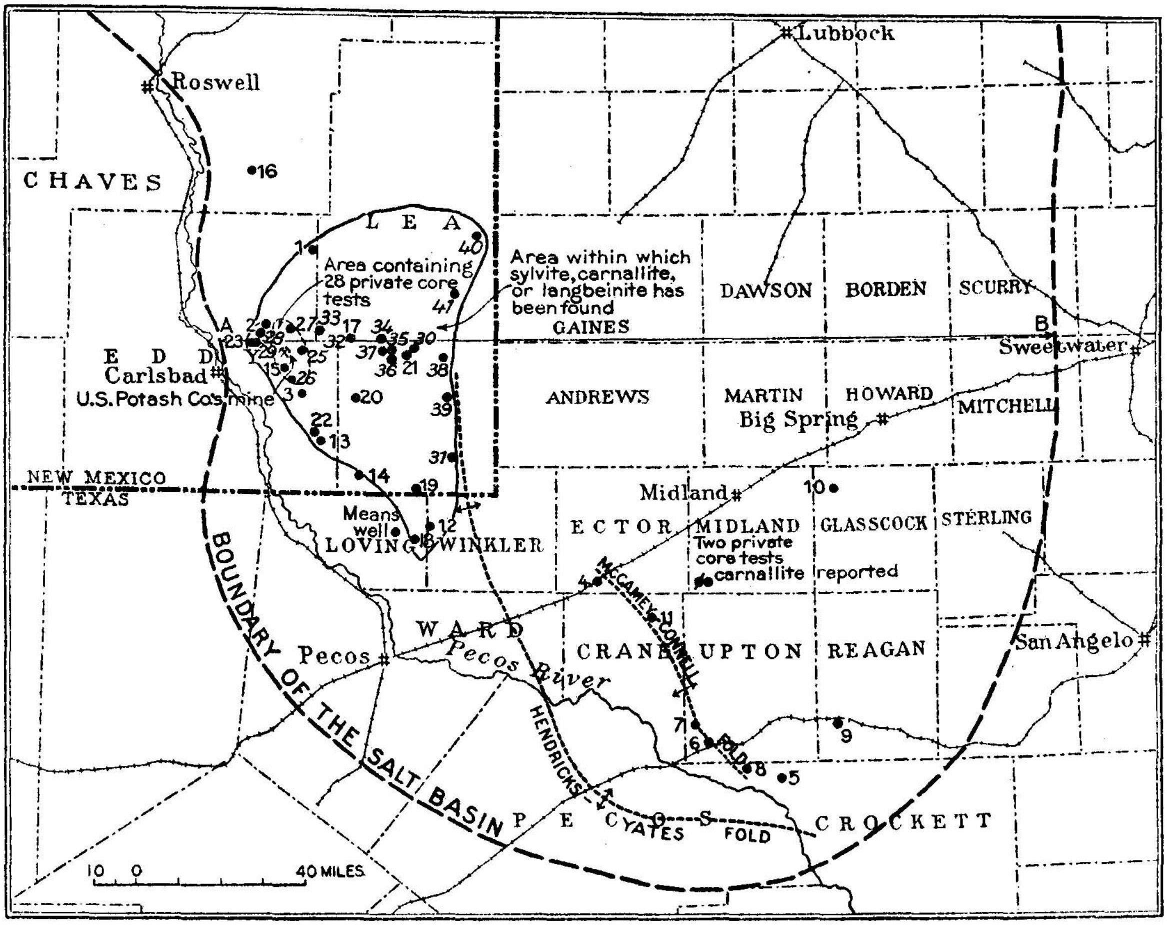
[1] The term "sylvinite" is highly objectionable; first, on account of being nearly indistinguishable from "sylvanite," a recognized mineral species containing gold, silver and tellurium; and second, because the application of a mineralogical name to a mixture of two separate minerals in varying proportions is quite unsound. The term "halo-sylvite," suggesting halite and sylvite, is far preferable.

in saline content, otherwise gypsum instead of anhydrite would have been deposited. At intervals the drying up of this water body was almost complete, as indicated by the occurrence within the rock-salt series of horizons bearing the very soluble potash salts, which could be deposited only under conditions of maximum concentration. There is some evidence, however, that the potash salts were not deposited just as they are found at present, but that they have been reconcentrated or redistributed by replacement, or by resolution and redeposition within the rock salt series.

In the New Mexico potash area, there is nothing on the surface to indicate the presence of this great series of salt beds. Their discovery was accidental in the course of drilling for oil. The recognition of certain potash-bearing horizons has stimulated further drilling by private parties and by the United States Geological Survey and the United States Bureau of Mines. A summary of the work done by these Federal organizations appears on pages 125-130. The results of this drilling have demonstrated that the potash-bearing beds extend over thousands of square miles in southeastern New Mexico and western Texas, and also that the potash bearing horizons are irregularly distributed through the salt formation and cannot be correlated over any great distances.

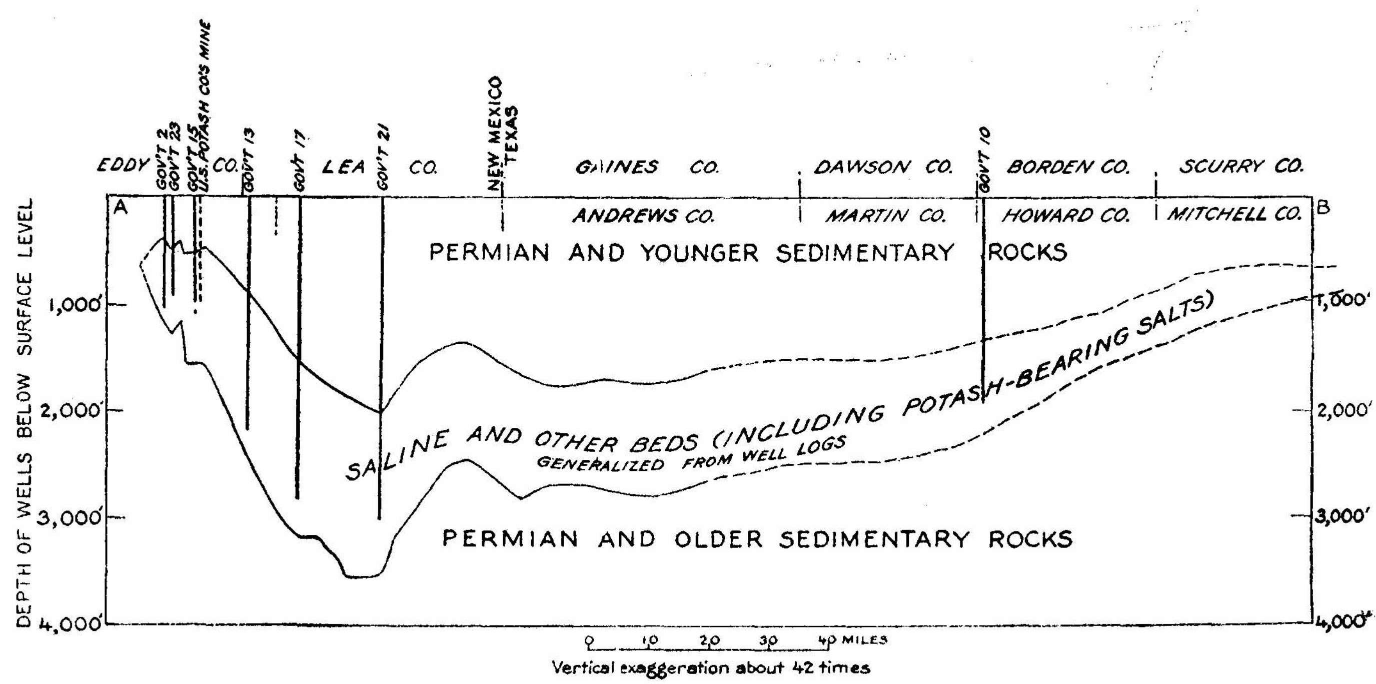
According to early reports, it seemed probable that the principal potash values in this territory would lie in the polyhalite, which was encountered in the early drilling more frequently and in greater quantity than any other potash salt. Shafts and drill holes have passed through several beds of polyhalite, one of which is reported to be as much as 10 feet thick. This material occurs as an aggregate of very small relatively lusterless crystals, so that in its general appearance it ordinarily resembles a light-colored red brick; one horizon of pure white polyhalite has been encountered. This salt, like the carnallite, would be an entirely satisfactory source of potash if nothing better were available, but the halo-sylvite bed furnishes material so much superior that the polyhalite horizons have not even been explored. In fact, they are timbered off in the shafts, and not now accessible. They furnish, however, a further valuable reserve.

Some other beds have been encountered that might be worked commercially if it were not for the superior quality of the sylvite in the bed that is being explored. On the fourth level of the mine of the United States Potash Co., a bed of carnallite is exposed, with a thickness of 9 feet. The carnallite is a dark brownish-red salt, lacking both the brilliant color and the luster of the halo-sylvite. It is also very deliquescent, and so the workings where it is exposed are uncomfortably wet. Compared with published descriptions of the European salts, this salt seems to be of a quality equal to the best potash source at Stassfurt. It is concentrated in a single bed large enough to be mined without



POTASH-BEARING WELLS SHOWN ON MAP

Nos. 1-23. Government core tests
Nos. 25-41. Churn-drilled wells that ave yielded sylvite, carnallite, or langbeinite
25. S. & M. McNutt No. 1
26. Ohio-Workman
27. Marland-Hale No. 1
28. Getty-Nicolas No. 11
29. S. & M. Lawrence ..o. 1
30. Empire-State 1-C
31. Gypsy-Humphreys No. 1
32. Empire-Martin No. 1
33. Texas-Humphreys No. 1
34. Texas-Lynch No. 1
35. Snowden McSweeney-State No. 1
36. merada-State No. 1
37. Cranfill & Reynolds State 1-D
38. Continetal-A. E. Meyer No. 1
39. Continental-Wm. Meyer No. 1
40. Barnsdall-Bronson No. 1
41. National Securities-T. A. Linam No. 1



MAP AND PROJECTED SECTION OF PERMIAN POTASH FIELD IN TEXAS AND NEW MEXICO
Showing areas in which sylvite, carnallite, or langbeinite has been found

DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY
1932

extraneous material, and so could furnish carnallite even better than the run-of-mine Stassfurt salt. The refining of carnallite, however, is a much more complicated and costly process than the refining of halo-sylvite, and so, until the lower sylvite horizon is worked out, this upper carnallite bed will probably be held in reserve. If the demand for metallic magnesium should increase materially, the carnallite might prove valuable as a magnesium ore, as well as for its potash content. At present the carnallite bed has been explored for only about 30 feet from the shaft.

GOVERNMENT CORE TESTS

Under date of May 9, 1932, the Department of the Interior issued a press bulletin, summarizing the results of the Federal five-year program of potash exploration. From this press bulletin, the following paragraphs have been taken:

The Department of the Interior today announced that the Geological Survey had recently completed the study of the cores from the twenty-first, twenty-second, and twenty-fourth Government test holes drilled by the Bureau of Mines under the act which provided for joint explorations by the Department of the Interior and the Department of Commerce in search of potash. The site of the twenty-first test is in Lea County, New Mexico; the twenty-second in Eddy County, New Mexico; the twenty-fourth in Grand County, Utah. The potash-bearing mineral polyhalite was encountered in each test hole, sylvite in the twenty-second and twenty-fourth, and carnallite in the twenty-first.

General Results.—Under the total appropriation for the five-year period ending June 30, 1931 ($500,000 in all) twenty-four core tests have been made. The Bureau of Mines directed the drilling, and the Geological Survey selected the drilling sites and made the necessary mineralogic, petrographic, and chemical studies of the cores obtained. Of the test wells 13 are in New Mexico, 10 in Texas, and 1 in Utah. As an indirect result of this core-drilling program and of the 15 years of preliminary exploration, chiefly by the Geological Survey, whereby the oil companies and the public generally became "potash-conscious," private companies have drilled 30 additional core test holes-2 in Midland County, Texas, and 28 in Eddy County, New Mexico.

Seventeen of the 24 Government tests bave revealed more than 50 intersections of polyhalite beds that may be considered as having possible economic interest. These beds range in thickness from 2 to about 10 feet and in potash content from 10 to nearly 15 per cent. Most of the private core tests bave also cut comparable beds of polyhalite. Commercial interest in many of these polyhalite beds is no doubt remote. Nevertheless, it should be borne in mind that the viewpoint of the Government toward mineral resources is somewhat different from that of industry. Whereas industry seeks an immediate or early return upon invested capital the Government must foresee and provide for our future requirements in mineral raw materials. Polyhalite contains magnesium and calcium as well as potash. If industrial uses for magnesium alloys should develop along certain anticipated lines the polyhalite beds in New Mexico and Texas should prove abundant sources for this metal, and by-product potash could probably be produced very cheaply.

Summary.—The Federal five-year program of potash exploration, together with events which preceded it, has stimulated private exploration and actual exploitation of potash salts in the Permian basin of New Mexico and Texas. It has demonstrated the presence of great reserves of polyhalite and of at least one rich body of sylvite in the same general region. By improved methods of study applied to both oil-well cuttings and cores it has outlined a broad area in which the occurrence of sylvite is known and in which by further exploration it may be possible to locate additional commercial bodies of that mineral. It has also eliminated certain areas as being improbable sources of potash.

In the same press bulletin, the results for all of the 24 holes drilled by the Federal agencies were tabulated. The parts of this tabulation related to holes drilled in New Mexico are given below.

In this table, the symbols in the column headed "Minerals Present" indicate the finding of salts as follows:

A, anhydrite, $CaSO_4$.
C, carnallite, $KCl.MgCl_2 6H_2O$.
Cl, clay.
H, halite (common salt) NaCl.
K, kieserite, $MgSO_4 H_2O$.
Ka, kainite, $MgSO_4.KCl.3H_2O$.
L, langbeinite, $K_2Mg_2 (SO_4)_3$.
Le, leonite, MgSO4.K2SO4.4H2O.
M, magnesite, $MgCO_3$.
P, polyhalite, $2CaSO_4.MgSO_4.K_2SO_4.2H_2O$.
S, sylvite, KCl.

Summary of Government Potash Tests in New Mexico

Tests marked have yielded sylvite, carnallite, or langbeinite.

Number of test	Location	Beds of possible commercial interest: Thickness Ft.	In.	Approx. depth to top of bed Feet	K_2O Per cent	Minerals present	Remarks
1†	NW.¼ sec. 13, T. 17 S., R. 31 E., Eddy County, N. Mex.						Carnallite zone 838 to 1228 (?) ft.; sylvite at 906 ft No commercial beds.
2†	Sec. 14, T. 20 S., R. 29 E., Eddy County, N. Mex.	2	8	486	10.05	P, A, H, K	Sylvite at 392-394, 502-505, 511-515 ft.; carnallite at 440-441, 445-448 ft.; no commercial beds.
		2	5	810	13.94	P, H, Cl, M	
3	SW. ¼ sec. 34, T 22 S., R. 30 E. Eddy County, N. Mex.	3	2	868	13.50	P, H, Cl	No carnallite, sylvite, or langbeinite recognized in this test. Percentage of core recovery (82) lowest for Government tests. Unrecovered portions of core may have contained soluble potash salts.
		2	3	951	13.13	P, A, H	
		3	7	1,012	12.86	P, (white) A, H	
		2	4	1,200	12.88	P, H	
		3	3	1,333	12.06	P, H	
		8	10	1,466	11.08	P, H, A	
13†	Sec. 5, T. 24 S., R. 31 E., Eddy County, N. Mex.	2	1	829	13.25	P, H	8 ft. bed contains 3 ft. 3 in. P (15.10% K_2O) at 1,408 ft. Sylvite and langbeinite zone between 1,631 and 1,723 ft.
		2	2	1,099	10.02	P, H, A, M	
		2	10	1,189	11.78	P, H	
		2	1	1,382	11.40	P, H, M, Cl	
		8		1,406	12.02	P, H, M Cl, A	
		2	5	1,476	12.80	P, H, M	
		2	4	1,600	10.61	P, A, H, M	
		3	3	2,202	12.05	P, A	
14	SW. ¼ SE.¼ sec. 1, T. 26 S., R. 32 E., Lea Co. N. Mex.	2	2	1,533	12.01	P, H	The 6 ft. 5 in. bed includes at 1,662 ft. 4 in. a 2 ft. 3 in. bed P (14.03% K_2O). No sylvite.
		6	5	1,658	12.04	P, H, A, M, Cl	
		3	10	1,741	13.43	P, H	
		3	2	1,786	11.19	P, H, A, M	
		2	6	1,865	10.21	P, A	
		3	3	2,027	12.89	P, H, Cl	

Summary of Government Potash Tests in New Mexico—Continued

Number of test	Location	Beds of possible commercial interest					Remarks
		Thickness		Approx. depth to top of bed	K_2O	Minerals present	
15	NE. ¼ sec. 34, T 21 S., R. 29 E. Eddy County, N. Mex.	2	7	941	10.70	P, A	2 ft. 9 in. P (9.45% K_2O) at 712 ft. Numerous other poorer beds P. No sylvite, etc.
16	SE. ¼ sec. 12, T. 14 S., R. 28 E. Chaves County, N. Mex.	2	8	373	12.10	P, H, Cl, K	No sylvite.
17†	SW. ¼ NE. ¼ sec. 28, T. 20 S., R. 33 E., Lea Co. N. Mex.	4 2 7 3 2	 7 10 10	2,356 2,385 2,407 2,523 2,610	11.35 10.32 9.12 11.40 13.85	S, H, P, C, Cl P, H, A, S H, C, Cl L, H, P, Cl P	The 4 ft. bed includes 2 ft. S, H, P, C (15.25% K_2O); the 3 ft. bed includes 11 in. L (20.63). Carnallite ranges through 721 ft. from 1,736 ft.; sylvite ranges through 191 ft. from 2,279 ft.; langbeinite ranges through 26 ft. from 2,514 ft.; 3 ft. L, H, etc., at 2,523 ft. contains 11.40% K_2O.
19†	Sec. 31, T. 26 S., R. 35 E., Lea County, N. Mex.						Carnallite zone of 300 ft. beginnng at 1,485 ft.; 4 ft. bed H, P, C., etc. (6.98% K_2O) at 1,788 ft.; 3. ft. white P etc. (7.76) at 1,986 ft.; sylvite at 1,611 ft.

Number of test	Location	Beds of possible commercial interest: Thickness		Approx. depth to top of bed	K_2O	Minerals present	Remarks
20†	Sec. 3, T. 23 S., R. 32 E., Lea County, N. Mex.	2		1,832	12.93	P, A, H, Cl	Carnallite traces at 1,372 (?) and 1,723 ft.; 3 ft. 4 in P, etc. (6.62% K_2O), at 1,947 ft.; 2 ft. 6 in. P, etc. (6.08), at 1,996 ft.; 2 ft. 4 in. P, etc. (9.17), at 2,008 ft.; 3 ft. P, etc. (9.80), at 2,088 ft.; 3 ft. P, etc. (7.43), at 2,135 ft.; 8 ft. 3 in. P, etc. (5.95), at 2,178 ft.
		3		2,284	13.08	P, H	
		4	3	2,298	9.55	P, Cl, A	
21†	SE. ¼ sec. 11, T. 21 S., R. 34 E. Lea County, N. Mex.	5		2,553	8.89	P, H	Carnallite occurs at intervals through 230 ft. of beds below 2,225 ft. At 2,739 ft. a 2-ft. bed contains P, Le, L, K, with H and Cl. K_2O content 4.44%
		2	8	2,760	13.42	P, A	
		2	7	2,763	12.20	P, H	
		6		2,760	11.54	(includes 2 beds above)	
		2	5	2,814	12.20	P	
22†	SE. ¼ sec. 36 T. 23 S., R. 30 E. Eddy County, N. Mex.	2		638	10.65	P, H	The 4 ft. 2 in. bed at 1,175 ft. includes a 2 ft. 4 in. bed (11.65% K_2O). Upper sylvite zone (20 ft.) at 1,215 ft. The 3 ft. 9 in. bed at 1,219 ft. includes 9 in. with 21.90% K_2O; lower sylvite zone (30 ft.) at 1,409 ft. contains langbeinite throughout.
		2	7	682	12.63	P, H, Cl	
		2	1	1,152	13.62	P, H	
		4	2	1,175	10.91	P, A, H, Cl	
		3	9	1,219	17.72	H, S, Cl, Ka Le	
		2	11	1,308	10.70	P, A, M, H, Cl	
		3		1,363	11.60	P, A, H	
		2		1,501	12.43	P, H	
		2	1	1,565	11.48	P, H, Cl	
23†	NW. ¼ sec. 35, T. 20 S., R. 29 E., Eddy County N. Mex.	6		623	11.52	P, A, H	Zone containing carnallite and sylvite ranges through 197 ft. from 517 ft.
		5		686	8.80	H, S	
						H, S	
		5		691	30.75		

Oil Wells in New Mexico, Cuttings from which have yielded Sylvite, Carnallite, or Langbeinite

Name of well	Location
Snowden & McSweeney McNutt No. 1	NE. ¼ SW. ¼ sec. 4, T. 21 S., R. 30 E., Eddy County.
Ohio-Workman No. 1	SW. ¼ sec. 13, T. 22 S., R. 29 E., Eddy County.
Marland-Hale No. 1	Sec. 11, T. 20 S., R. 30 E., Eddy County.
Getty-Nicholas No. 1	Sec. 25, T. 20 S., R. 29 E., Eddy County.
Snowden & McSweeney No. 1	Sec. 35, T. 20 S., R. 29 E., Eddy County. Lawrence
Empire-State I-C	Sec. 12, T. 21 S., R. 34 E., Lea County.
Gypsy-Humphreys No. 1	NW. ¼ SW. ¼ sec. 25, T. 25 S., R. 36 E., Lea County.
Empire-Martin No. 1	SW. ¼ SE. ¼ sec. 28, T. 20 S., R. 33 E., Lea County.
Texas-Humphreys No. 1	Sec. 18, T. 20 S., R. 32 E., Lea County.
Texas-Lynch No. 1	Sec. 34, T. 20 S., R. 34 E., Lea County.
Snowden & McSweeney State No. 1	NW. ¼ sec. 1, T. 21 S., R. 33 E., Lea County.
Amerada-State No. 1	NW. cor. lot 10, sec. 1, T. 21 S., R. 33 E., Lea County.
Cranfill & Reynolds State No. 1-D	SE. cor. lot 6, sec. 3, T. 21 S., R. 33 E., Lea County.
Continental A. E. Meyer No. 1	SW. ¼ SW. ¼ sec. 17, T. 21 S., R. 36 E., Lea County
Continental-Wm. Meyer No. 1	Sec. 28, T. 22 S., R. 36 E., Lea County.
Barnsdall-Bronson No. 1	SE. ¼ sec. 28, T. 16 S., R. 38 E., Lea County.
National Securities-T. A. Linam No. 1	Sec. 33, T. 18 S., R. 37 E., Lea County.
Marland Gardner No. 1[a]	Sec. 24, T. 23 S., R. 31 E., Eddy County.

[a] This well was not checked in time to be shown on the map, but it falls within the area outlined.

NEW MEXICO OCCURRENCES

THE UNITED STATES POTASH COMPANY

At the operating property of the United States Potash Co., situated about 20 miles east of Carlsbad and about a mile south of the Carlsbad-Hobbs highway (U. S. Highway 62), the potash-bearing series has been explored best to date. The main working shaft is situated in the SW. ¼ of sec. 12, T. 21 S., R 29 E. It was located on the basis of drilling results that showed some particularly favorable features in this portion of the area. A second shaft has been sunk in the NW. ¼ of sec. 13, T. 21 S., R. 29 E. The total thickness of the salt series here is about half a mile with several horizons of potash-bearing salts within the upper half of this series. The promise extended by the drilling has been more than realized in the development.

This property has been opened by two vertical shafts about 1000 feet deep. The best potash-bearing horizon, and the only one that has been worked for production to date, is near the bottom of the shafts, where there was found a bed of halo-sylvite averaging about 8 feet thick, lying nearly horizontally and without conspicuous irregularities. The size and attitude of this bed permitted its development by the standard room-and-pillar method of mining. A consistent campaign of development and exploration has shown that this horizon maintains its essential continuity for a total distance exceeding 4000 feet north and south, and 800 feet east and west; these figures represent extreme limits of exploration in June, 1934, the fully developed ground at that date being well within those stated limits. Detailed figures on production and reserves are not available; but it is safe to say that there has been produced, and marketed a total of several hundred thousand tons of potash salt, and that there has already been developed enough halo-sylvite, in this one horizon, to supply the total needs of the United States for many years to come.

The salt mixture in this horizon consists of an intergrowth of halite or sodium chloride (common rock salt) and sylvite or potassium chloride, intimately interlocked, in crystals averaging approximately half an inch on a side. Most of these crystals are cubes, though other forms have been noted. Some of these crystals are white, and others are colored red by inclusions of microscopically fine particles of iron oxide, giving the halo-sylvite mixture the general appearance of a coarse-grained red granite. An interesting feature regarding the distribution of the iron oxide is that it is restricted to the outer margins of the crystals, both of halite and sylvite, the centers being clear, white, and free from iron.[3] The reason for or the significance of this distribution of iron has not been determined. The iron oxide is present in such small amount that when the mixture is crushed its color is a very pale pink. The iron oxide is also heavy and quite insoluble in water, so that in refining it separates easily as a heavy red sludge.

This halite-sylvite mixture is exceptionally pure, containing only 3 to 4 per cent of substances other than the sodium and potassium chlorides. The impurities include the iron oxide mentioned above, a little admixed clay, and traces of calcium and magnesium salts. The halite-sylvite ratio is fairly constant, the halite making up slightly more than half of the total mixture. The potash value, or content recalculated to K_2O, averages from 26 to 27 per cent, rarely, going below 22 or above 32 per cent, except in small local concentrations of either salt.

THE POTASH COMPANY OF AMERICA

The Potash Company of America is operating under State and Federal leases on several sections located some 10 miles north of the property just described. As a result of the information developed by 17 core tests, supplemented by some churn drill tests, this company began, in February of 1933, the sinking of

[3] Smith, J. P., U. S. Potash Co., oral communication.

a shaft near the center of sec. 4, T. 20 S., R. 30 E. ; this shaft has been carried to about 100 feet below the halo-sylvite horizon, which was encountered at nearly 1000 feet below the surface. The halo-sylvite bed in the vicinity of this shaft ranges from 4 to 11 feet thick, and maintains its essential horizontality, although it has shown somewhat greater irregularities than were encountered in the early work in the area farther south.

This company is building for permanence. A block 1000 feet square is being left around the shaft, beyond which it is intended to operate by the standard room-and-pillar method of mining. The main haulage ways accommodate extra large mine cars, with electric locomotive haulage, and the shaft, 8 by 28 feet with three compartments, is equipped with large skips. At the time of the writer's visit, in June 1934, the development for permanent operation was still under way, and no production had been attempted beyond the material that was removed in the development work. This material, totaling some hundreds of carloads, was being crushed at the mine and shipped crude. Later, this company plans to build a refinery near the mine. A standard-gauge spur track connects this property with the Atchison, Topeka & Santa Fe railway at Carlsbad.[1]

THE TEXAS POTASH CORPORATION

The Texas Potash Corp., incorporated in Colorado, has done some exploratory work east of Artesia and also east of Carlsbad. In their earlier work, two holes were drilled, one in sec. 7, T. 17 S., R. 29 E., and the other in sec. 34, T. 17 S., R. 30 E. Both of these holes are reported to have found the bottom of the salt about 900 feet below the surface, and to have encountered over 100 potash-bearing horizons, none of which were of commercial size; the maximum thickness of the potash beds here is reported as 10 inches, and the maximum potash content is stated as 13 per cent.

This company has abandoned the section of the field east of Artesia, and has sunk two other tests east of Carlsbad, one in sec. 1, T. 22 S., R. 29 E., and the other in sec. 7, T. 22 S., R. 30 E. The results of these tests are reported as "very satisfactory," but no details have been made public. In June 1934, this company was proceeding to sink about six more test holes to prove up the balance of their leased holdings, which total 15,000 acres. Plans for further operation naturally are dependent on the results of this drilling campaign.

[1] As this bulletin goes to press, information is received that the refinery of the Potash Company of America was put into operation during 1936, and that a successful separation of sylvite from halite is being made by a process of froth flotation in a saturated brine.

MARKETING AND REFINING

In the early stages of its development the United States Potash Co. marketed all of its material in the crude form, with no treatment other than crushing. Such material as this, known in the trade as "manure salts" is mixed in varying proportions with packing house refuse, ammonium salts and phosphate rock, and applied directly to the land as fertilizer; proportions of the

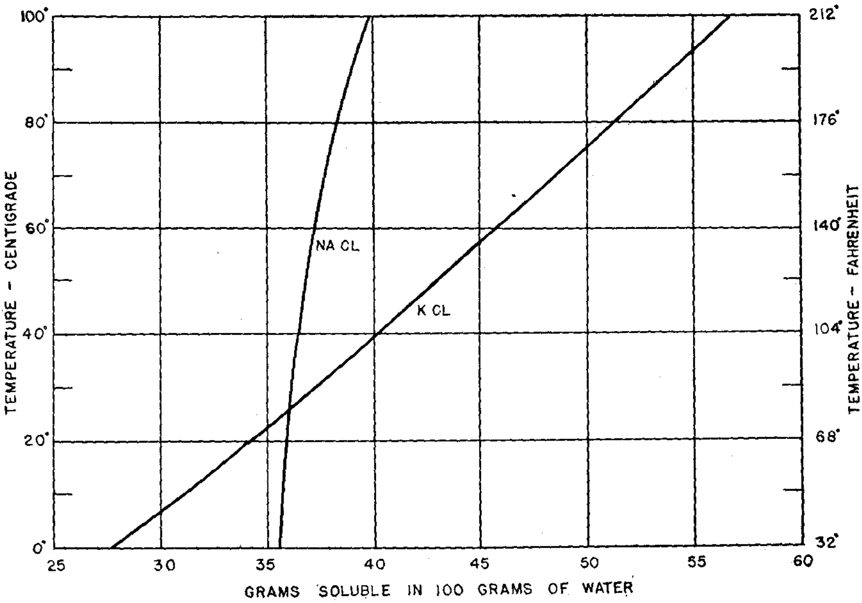


FIGURE 4.—Chart showing relative solubility of potassium and sodium chlorides.

various materials depend on varying requirements of soils in different localities. Apparently the large amount of common salt present in this run-of-mine material is not detrimental, as the amount of fertilizer applied at one time is not sufficient to bring about a damagingly high concentration of salt.

The United States Potash Co., since September, 1932, has also been producing a refined potassium chloride, known to the trade as "muriate of potash." The refining plant of this company is located on a 2000-acre tract in T. 23 S., Rs. 28 and 29 E. The Atchison, Topeka & Santa Fe Railway Co. has built a spur track from Loving to the refinery, and the company operates its own narrow-gauge railroad between the refinery and the mine.

The process of refining the halo-sylvite and producing the high-grade potassium chloride is based on principles of selective solution and fractional crystallization. Sodium chloride varies only slightly in its solubility with respect to temperature, whereas the solubility of potassium chloride is increased greatly with an increased temperature. The refinery uses a circulating mother-liquor, which, when cold, is substantially saturated with both sodium and potassium chlorides. When this mother-liquor is heated to near the boiling-point and applied to the run-of-mine salts, it dissolves out the potassium chloride, and leaves the sodium chloride behind. As this liquor is cooled, it becomes super-saturated with potassium chloride, which separates out in fine crystals, very similar in appearance to table salt. This is filtered from the mother-liquor, which is heated and used again. The separated potassium chloride has a purity of over 98 per cent.

The refined potassium chloride is marketed for use in manufacturing high-grade fertilizer, and for various chemical and industrial purposes.

Developments to date indicate that the New Mexico fields contain enough potash to supply the entire needs of the United States for many years to come; and even more important is the fact that these beds of potash salts render this country independent of the long standing German world monopoly, so that a recurrence of the war-time shortage, with its ruinously high prices, need not be feared. This assurance, however great its political import may be, does not suffice to place the New Mexico potash on even terms with the German product in the world markets or even in all parts of this country. To date, the market for New Mexico potash has been largely special and local. In the early stages of mining, the raw material could be marketed for low-grade fertilizer; but later such markets were closed, and producers were obliged to refine their product before they could sell it. The inland location of the New Mexico fields constitutes a handicap; for instance, New Mexico potash cannot compete with the German salt in the cotton fields of the South Atlantic states since it costs more to ship potash by rail to Galveston, the nearest port, than it costs to ship from Germany to the Atlantic seaboard by boat. In the other direction, the New Mexico producers are faced with local competition provided on the Pacific Coast by potash extracted from desert lakes.

The large initial investment necessary for sinking a thousand feet to the productive beds, the workmanlike manner in which the underground operations are conducted with full regard for safety, and the present necessity for refining the salts before they can be marketed, introduce elements of expense that cannot be met except under favorable market conditions. The importance of a supply of potash salts being controlled and conserved in this country is sufficiently great that the Government might be justified in subsidizing the potash producers if necessary, if only to insure against a recurrence of a war-time shortage.

PUMICE AND PUMICITE

GENERAL FEATURES

Pumice is a highly cellular glassy rock or lava made porous by the expansion of steam or other gases escaping from a molten magma. Pumicite is a natural glass atomized by volcanic explosions. Pumicite is sometimes called volcanic ash, but this is a poor name since neither pumice nor pumicite is a product of combustion.

Pumice occurs in the vicinity of volcanoes as porous blocks of a white or light-gray color. It has the same composition as the normal rhyolites. A good pumice contains 65 to 75 per cent silica, 12 to 15 per cent alumina, 8 to 10 per cent soda and potash, and a small amount of accessory minerals. Most of the silica is combined in an amorphous glass, but some free quartz may be present.

Most of the pumicite blown from volcanic vents accumulates nearby, but some of it may ultimately settle to the earth hundreds or even thousands of miles from its source. It may be later washed away and sorted by stream action and subsequently deposited as a more or less compact bed. Pumicite consists of sharp, angular fragments of a composition very similar to that of pumice, except that more mechanically mixed impurities are likely to be present.

USES

The principal use of pumice and pumicite is as an abrasive. Lump pumice is used for rubbing down or polishing wood and metal surfaces and in leather finishing. Pumicite and finely ground pumice are used as an abrasive in cleaning and polishing compounds, in rubber erasers, for cutting down hard rubber, fibre board, stone and glass. Their cellular structure makes them well suited for use as heat insulators around pipes and in refrigerators. After fine grinding they are sometimes used to replace some of the cement in concrete, and the use of lump pumice as an aggregate in light-weight concrete is growing. They are used to a certain extent as inert extenders or fillers.

NEW MEXICO OCCURRENCES

According to R. W. Ellis[1] deposits of pumicite occur on the west side of Duck Creek Valley in northwestern Grant County. These deposits are said to extend for several miles along the highway above Cliff. Ellis estimates their thickness at 20 to 50 feet.

[1] New Mexico Mineral deposits except fuels: Univ. of N. Mex. Bull. 167, p. 49, 1930.

Ellis[2] also mentions a deposit of pumicite on both sides of Percha Canyon about halfway between Hillsboro and Kingston, Sierra County. He estimates the thickness at 15 feet. This deposit is said to contain coarse sand and volcanic debris.

A deposit of pumicite in Socorro County was described many years ago as tripoli[3] or tripolite, and earlier was called infusorial earth.[4] Both of these designations are in error; microscopic examination of this material shows it to consist predominantly of shards of volcanic glass, with a small amount of clay and a smaller amount of sand, but totally lacking in fossil diatoms. This material is a typical pumicite of fairly high grade.

This deposit lies about three-quarters of a mile east of the side road that branches north from U. S. Highway 380 at the San Pedro school house, directly across the Rio Grande from San Antonio. From a point on this side road about 1½ miles north of the highway, the pumicite can be seen about a quarter of a mile to the east in a bold westward-facing bluff about 50 feet high. The lower slopes of this bluff are of reddish unconsolidated clay, and the pumicite forms a white cliff near the top of the bluff. Above the pumicite is a layer of volcanic agglomerate containing large rounded pebbles of leached pumice stone.

The outcrop of pumicite extends for about 1,200 feet north and south, and can be followed eastward in two ravines for about 300 feet, where it is apparently cut off by a fault. North of the ravine that cuts through this deposit, the pumicite has an average thickness of about 2 feet, with a maximum thickness of 4 feet at the southeast corner of the northern block. The block south of this ravine is roughly 100 yards square, and the pumicite is exposed on two sides with a thickness of 3 to 5 feet. Probably something less than half of this southern block is of workable thickness.

Many years ago[5] this material was mined and hauled to Socorro to supply a local demand. Some of it was pulverized and sold in cans for use as scouring powder, and some was marketed in the form of sawed blocks for use in polishing and scouring.

The New Mexico Pumice Stone Co[6] operated a pumice deposit in Valencia County many years ago. The deposit is on the north side of the Atchison, Topeka & Santa Fe railway near Grant, and southwest of Mt. Taylor. Samples brought to the writer several years ago could be more accurately designated as pumicite, but lump pumice of good quality was being developed in 1935 by Mr. G. V. B. Levings, Vice President and General Manager of the Barnsdall Tripoli Corp., Seneca, Mo. Mr. Levings

[2] Op. cit., p. 108.
[3] Herrick, C. L., The so-called Socorro tripoli: Amer. Geol., vol. 18, pp. 135-140, 1896
[4] U. S. Geol. Survey Mineral Resources, 1886, pp. 587-588, 1887.
[5] Joseph A. Smith, oral communication.
[6] Jones, F. A., New Mexico mines and minerals, p. 264, 1904.

was developing the property himself, the Barnsdall Corp. having no interest in it.

Mr. Levings furnished the following analyses of his pumice and of choice Italian pumice. Both analyses were made by the Williams Laboratories, Joplin, Mo.

Analysis of Pumice

	Italian	Mt. Taylor
Ignition loss	3.17%	5.60%
SiO_2	67.50	69.47
Fe_2O_3	2.32	1.43
Al_2O_3	12.96	13.48
CaO	1.06	1.13
MgO	0.01	0.20
TiO_2	0.50	0.25
Na_2O	9.89	6.58
K_2O	2.41	1.70
SO_4	0.12	0.08
Undetermined and error	0.06	0.08

The Gold Seal Products Co., Albuquerque, N. Mex., has mined some pumicite about 5 miles west of Los Lunas. The material was mixed with bentonite and other ingredients and marketed as Gold Seal washing powder.

REFRACTORY MINERALS

GENERAL FEATURES

Under this heading only the simple aluminum silicate minerals are considered. Refractory clays, such as fire clays, are treated separately under Clays.

The three minerals, sillimanite, kyanite, and andalusite are identical in chemical composition, having the formula $Al_2O_3.SiO_2$. They differ in mode of crystallization and in some physical properties but are all highly resistant to heat. Andalusite and kyanite will invert to sillimanite between 1350° and 1400° C. Sillimanite is extremely refractory, even at temperatures above 1600°C.

All of these minerals are relatively rare, their characteristic occurrence being as accessories in metamorphic rocks, usually disseminated, but occasionally found in concentrations of commercial size.

USES

The refractory minerals are particularly useful in the manufacture of high-grade electrical porcelain of a quality desirable for spark plug cores and such porcelain insulation as must withstand high heat and pressures. The supply of high-grade mineral material for this purpose is not equal to the demand, and successful experiments in manufacturing artificial sillimanite are reported. If such manufacture is successful on an industrial scale, the use of the more expensive minerals may be diminished or discontinued.

NEW MEXICO OCCURRENCES

These minerals have been reported from New Mexico only in the pre-Cambrian areas of the Rocky Mountain extension in Rio Arriba and Taos Counties, and of the three aluminum silicates only kyanite and sillimanite have been worked commercially. The property belonging to Mr. Philip S. Hoyt, located near the Government Spring in the mountains west of Tres Piedras, has been the principal producer. The pre-Cambrian rocks here consist of schists, striking northerly and dipping gently toward the west, with numerous quartz veins essentially parallel with the planes of schistosity. These quartz veins outcrop prominently, and some of them carry abundant kyanite in pockets, single blades up to several inches long, and rosettes made up of radiating blades. The kyanite is pale blue and apparently quite pure. It breaks free from the quartz fairly readily. Some of the quartz is white and very coarsely crystalline, while some of it is finer grained and pink.

At the time of the writer's visit this property was not being worked, but it was evident that considerable kyanite had been extracted from a shaft and from open cuts. Surface exposures indicate that there are other promising areas on the property that have not yet been developed. Data on production and reason for cessation of operations at this property are not available.

Andalusite and sillimanite are reported as occurring in these pre-Cambrian schists. A large mass of sillimanite-rich schist lies on the south side of the Arroyo Hondo[1] and about 12 miles south and a little west of Taos, on the north side of Picuris Mountain. This deposit crops out as a ledge of dark-colored schist several hundred feet long, containing abundant slender crystals of pink sillimanite about half an inch long, disseminated through the rock. This ledge has not been worked and is hardly prospected. Undoubtedly it contains a large quantity of sillimanite, but its commercial value depends on whether the small sillimanite crystals can be separated cheaply and thoroughly from the surrounding rock.

No commercial deposits of andalusite are known in the state.

RICOLITE

GENERAL FEATURES

Ricolite is the name applied to an ornamental stone of banded serpentine that occurs north of Red Rock in Grant County in the west edge of the pre-Cambrian mass that forms the Burro Mountains. This is believed to be the only occurrence of ricolite, although related serpentine rocks are not particularly

[1]Another "Arroyo Hondo" is northwest of Taos.

rare. The statement in Dana's Mineralogy[1] that "ricolite is a banded variety (of serpentine) from Mexico" appears to be a misprint.

The mineral serpentine is a hydrous magnesium, silicate, $3MgO.2SiO_2.2H_2O$. The pure mineral is extremely rare, as serpentine nearly always contains some iron. It is not a primary mineral but is invariably derived from the alteration, by hydration and otherwise, of magnesium minerals or of magnesium-rich rocks. Serpentine rock is simply rock composed largely of the mineral serpentine. The best commercial asbestos is serpentine (mineral) crystallized in long fine fibres.

USES

The uses of asbestos are discussed separately. (See chapter on Asbestos.) The chief use of serpentine rock is as an ornamental stone, for which it is especially adapted on account of its general firmness and fineness of texture, its relative softness which permits ready cutting to shape, its generally rich green color and the usual mottled distribution of color which gives a pleasing pattern effect, and its capacity for taking a rich but not glaring polish. Some serpentine rocks that can be cut in large slabs, especially if mixed with carbonate rocks, are known as serpentine marbles, of which the best known variety is called Verd Antique.

NEW MEXICO OCCURRENCES

The New Mexico ricolite was first quarried about 1888, and a shipment was made to Chicago, where the material was used as interior wainscoting. As far as can be learned, there has been very little production since. According to a statement in the Mineral Resources volume of the United States Geological Survey for 1889, the name ricolite, meaning "rich stone" was proposed for this material by Mrs. L. J. Caldwell of Chicago. At this time the material was described as resembling mexican onyx but quite different in composition. No other record of the use of this material in building has been found.

Recently Mr. Ernest Bennett of Silver City has been experimenting with ricolite for ornamental lamp stands, and has produced some very fine turned pieces. These are for sale in a small way in Silver City, but apparently no attempt has been made to develop an extensive market. On account of variations in the banding, no two pieces are precisely alike.

This material seems to offer some attractive commercial possibilities. It is ideal for lamp stands, vases, and similar medium-sized stationary ornaments. It would make handsome table tops, mantel pieces or wainscot panels, but the expense of getting out large slabs and transporting them 30 miles to the

[1] Dana's Textbook of mineralogy, John Wiley & Sons, Inc., New York City, 4th ed., p. 675, 1932.

railroad might be prohibitive. It is not so suitable for smaller ornamental uses, such as ash trays, pen bases, and paper weights, as on account of its softness it is easily marred under frequent handling, particularly by chipping of the edges. It can be easily worked or carved into any desired shape and is worthy of a wider market than it has at present.

The ricolite deposit is situated in sec. 16, T. 18 S., R. 18 W. It is in the form of a steeply dipping tabular body that has been trenched deeply across by a gulch tributary to the Gila River. This exposure on steep hillsides permitted working in open cuts, and considerable excavation has been done, particularly on the west side of the gulch. The adjacent country rock is pre-Cambrian granite schist, and the ricolite in this dike-like mass is so evenly banded that it resembles in appearance a finely stratified sediment.

Across the hill to the west, less than half a mile from the green ricolite exposure and approximately in alignment with it, recent prospecting has disclosed a deposit of canary yellow serpentine, not banded but mottled in black. In general appearance this resembles a handsome moss agate, except for the color. It is probably a variety of the ricolite, as in hardness, texture and all other physical characters except color, it is similar to the typical green rock. In this yellow ricolite are seams of fine quality but short-fibered asbestos. These seams would limit the size of blocks that could be taken from some parts of the deposit, but outside of this feature the yellow ricolite would appear to offer all the possibilities mentioned for the green material, except for the fact that the brilliant yellow color fades on prolonged exposure to bright light.

SALT AND SALINES

GENERAL FEATURES

The term "salt" in ordinary usage, stated as "common salt" for precision, refers to sodium chloride, mineralogically termed *halite.* The chemist, however, classes as a salt not only the union of sodium and chlorine, but the analagous union of any base or metal with any acid radical. Chemically, therefore, gypsum or barite is as much a salt as is halite.

The term "saline" used as an adjective means "salty" in the ordinary sense. Used as a noun it refers in general to any salty substance, and in particular to the soluble salts of magnesium or the alkali metals. It is also used as a noun to designate a salt deposit, especially of the dessicating lake type.

In this discussion, the term "salt" will be used in the ordinary sense, designating halite or common salt, and the term "saline" will be applied to those soluble salts that occur associated with the halite, with the exception of gypsum and the potash salts, which are discussed separately.

Natural salt, occurring as the mineral halite, is easily recognized by its characteristic taste. It forms cubic crystals, which are soft and brittle; it is generally white but sometimes colored red, less often blue or yellow, by impurities. It is readily soluble in either hot or cold water. Its natural occurrences are mostly as individual crystals or as crystal groups, precipitated out of supersaturated brines, or else as beds of rock salt, which are simply large, massive and compact accumulations of individual but tightly interlocked halite crystals.

Salt, on account of its abundance and its solubility, is usually the principal dissolved constituent of natural brines, but, it rarely occurs without some admixture of other salines. Potash salts frequently accompany common salt deposits, but only occasionally is the potash present in large quantity or in great concentration. (See chapter on Potash Minerals). Sodium salts other than the chloride, and salts of magnesium and calcium are among the most commonly occurring salines associated with common salt.

USES

The uses of common salt are too well known to call for more than passing mention. All of the salt produced in New Mexico is fed to livestock. Salt refined outside the state is marketed for table use. Salt is extensively used also in the preservation and flavoring of prepared foods, such a salt meats and fish, and butter. Other uses of salt are in refrigeration, such as for making and shipping ice cream, and artificial ice manufacture, in tanning and dyeing, in metallurgy and ceramics, and for several other industrial purposes.

Salines other than common salt find their principal uses in the chemical industries and in the manufacture of drugs and medicinal compounds.

ASSOCIATED SALINES

Sodium sulfate is a common minor saline constituent of salt deposits. It occurs in several combinations. The mineral *glauberite* is a double sulfate of sodium and calcium, $CaSO_4$. Na_2SO_4, and has been reported from the saline lakes in Estancia Valley. This glauberite is not identical with Glauber's salt, which is a hydrous sulfate of sodium, $Na_2SO_4.10H_2O$, known mineralogically as *mirabilite.* This mineral occurs in Lake Lucero near the south end of the White Sands area in Tularosa Valley. Mirabilite is very unstable when dry, as it loses its water of crystallization and breaks down to a fine powder. In some eases this material has compacted and recrystallized as the mineral *thenardite,* Na_2SO_4, a simple sulfate of sodium without the combined water. Bodies of thenardite of considerable size are known in Verde Valley, Ariz., formed probably by the breakdown and recrystallization of mirabilite or by direct precipitation from solutions high in carbonate salts. It is reported[1] that "deposits of anhydrous sodium sulfate have been worked in Dona Ana County, New Mexico," but no particulars are given, and no other references to thenardite in New Mexico have been found.

Any one of these three saline minerals, glauberite, mirabilite or thenardite, may be used as the raw material for manufacturing the commercial Glauber's salt, which when refined is identical in composition with pure mirabilite. Glauber's salt has a widespread medicinal use in small quantities, but the demand is not great, and most of it is met by the sodium sulfate produced as a by-product in the refining of table salt. The brine in Lake Lucero, Dona Ana County, is exceptionally rich in sodium sulfate, but so far, efforts to extract it commercially have not been fruitful on anything larger than an experimental scale.

Magnesium sulfate is another accessory salt accompanying many common salt deposits and occurring in small quantity in many mineral waters. It is easily recognized by its characteristically bitter flavor of epsom salts. In its mineral occurrence it is known as *epsomite*, and forms as a finely crystalline white deposit, often as an incrustation, with the composition represented by the formula $MgSO_4.7H_2O$, which is the same as refined epsom salts. Related to epsomite is the relatively rare double sulfate of sodium and magnesium, known as *bloedite*, $Na_2SO_4.MgSO_4.4H_2O$. Both bloedite and epsomite occur at Estancia Lakes in Torrance County, and it is reported that experiments have indicated possibilities of commercial extraction of epsom salts from these minerals. To date no production on an industrial scale has been accomplished.

Refined epsom salts have a widespread medicinal use on a small scale, and most of the purest grade is marketed through the retail drug trade. Crude epsom salts are used in the dyeing, tanning, paper-making and other industries. The price is not high, ranging between $1 to $2 per hundred pounds for the crude grade and $2 to $3 per hundred pounds for the refined salts. The price is kept low by cheap importation from Germany.

NEW MEXICO OCCURRENCES AND PRODUCTION OF COMMON SALT

The greatest salt deposits in New Mexico are not now worked for their halite content. They occur in beds up to half a mile thick, underlying much of the southeastern portion of the state. (See chapter on Potash Minerals). In this series of beds are concentrations of potash salts, and the territory in which they occur has been extensively explored by Government and private agencies for its potash content. This salt series was deposited by the dessication of a broad shallow sea, connected with the ocean

[1]Ladoo, R. B., Non-metallic minerals, p. 571, McGraw-Hill Book Co., Inc., New York City, 1925.

by a narrow strait that passed through Mexico in Permian time. The origin and composition of this deposit is discussed at some length in the chapter on Potash Minerals, and in the section dealing with Permian time in the chapter on the geology of the State.

Common salt is such a low-priced product that its distribution is controlled almost entirely by local market demands. Consequently, although southeastern New Mexico contains enough salt underground to supply the needs of the entire United States for thousands of years, these deposits have not been worked for their common salt but only for their more valuable potash. The possibilities of commercially producing common salt as a byproduct of potash extraction would seem to depend entirely on market demands. Similar Permian salt deposits, without the potash content, are worked in Kansas, and the refined Kansas table salt is widely distributed in the southwestern retail market. No refining of common salt is at present done in New Mexico.

There are smaller and more recent salt deposits in this State from which crude salt is being produced commercially, largely for livestock use, and limited to markets within a few hundred miles. One of these salt plants is at Laguna Salina in Estancia Valley, and the other is at Zuni Salt Lake in western Catron County. The two occurrences are similar, in that each depends for its production on an annual harvest of salt crystallized by solar evaporation from a shallow lake containing dense brine. Genetically the two are very different, as the Zuni Lake is in the crater of an extinct volcano, and the Estancia Lakes are in hollows excavated by the wind in the bottom of a broad flat-floored basin.

Zuni Salt Lake.—The Zuni Salt Lake, in northwestern Catron County, furnishes an annual crop of salt that is marketed for use of livestock within a radius of about 60 miles. This lake occupies the bottom of a basin rimmed by cliffs of basalt and Cretaceous sediments. Within the lake are two cinder cones, one with a distinct crater that contains a smaller lake in the bottom. These cinder cones, only a few hundred feet in diameter, represent the last products of the volcanic activity that furnished the basalt which caps the cliffs and which also, by explosive activity, probably produced the larger crater in which the lake lies.

The main crater is roughly circular and a little more than a mile across. The cliffs, of yellowish and gray sandstone, surround the depression and are capped with basalt, except on the west side where the sediments extend clear to the top, and on part of the south side where the cliffs are all basalt. Darton states that the finding of blocks of sedimentary rock around this crater, some of them identifiable as of Carboniferous age, proves this to be an explosion crater that ejected volcanic material and wall rock from a considerable depth.[2]

[2]Darton, N. H., The Zuni Salt Lake; Jour. Geol., Vol. 13, pp. 185-193, 1905.

The cinder cones are located southwest of the center of the main crater. The smaller of the two cones lies to the east and is an island in the lake. Its throat is blocked solidly with cinders of red and black scoria. The western cone, which is larger and lapped by the lake on its north and east sides, is elliptical rather than circular in shape and has a crater resembling from the top a steep funnel slightly out of round. The bottom of this crater is occupied by a pool of clear salt water from 100 to 200 feet across. This pool stands slightly above the level of the lake outside.

Soundings made by the writer in the inner pool showed a maximum depth of 23 feet, although it had been previously reported as more than 500 feet deep. The outer lake is irregular in shape, variable in size with the season, and probably will average something under a mile in its greatest diameter. Its greatest depth is about 10 feet and its average depth about 4 feet.

This lake is exposed to solar evaporation, which in the dry season causes it to lose volume faster than the water is supplied from inside the cinder cone, or by seepage from the slopes to the south. During most of the year the water in this lake is a dense though unsaturated brine, but toward the end of the dry season the loss by evaporation results in supersaturation and the formation of a crust of salt in the shallower portions of the lake. The salt is gathered by laborers wading in water about a foot deep and using large flat forks. Skilful workmen can separate the salt cleanly from the underlying mud, and any silt washed in on the salt by summer showers is easily rinsed off while gathering. The salt is loaded into scows and stock-piled in the open for sale according to demand.

This property was operated for several years under state lease by the Frank A. Hubbell Co. with headquarters in Albuquerque. The only market at present is to ranches in the vicinity of the deposit. Production is stated by Mr. James Hubbell to average about 500,000 pounds per year, with a small additional amount produced and consumed by the Zuni Indians. Recently the lease passed into the hands of a Mr. Curtis.

Estancia Lakes.—In Estancia Valley are several lakes that furnish a saline residue as a result of solar evaporation. The occurrence of sulfate salts in these lakes has already been mentioned, but by far the greatest amount of the salt that occurs here is halite or common salt. Nearly seventy of these lakes and salt flats have been mapped, in parts of Tps. 4, 5, 6 and 7 N., Rs. 9 and 10 E. They range in size from, the smaller flats of only a few acres to the Laguna del Perro, which is over 12 miles long and covers an area greater than that of all the smaller lakes combined. From only one of these lakes, the Laguna Salina situated a little to the southeast of the center of the lake area, has salt been extracted on a commercial scale.

The character and origin of the lakes have been studied by Meinzer,[3] who has shown that Estancia Valley, a closed basin without outlet, was formerly the site of an extensive lake. The position of the shore lines indicates that this lake at its maximum extended for some 40 miles north and south and nearly 25 miles east and west. The present relic lakes occupy the central lowest portion of this old lake bed, which was once under water nearly 150 feet deep.

This old lake, called by Meinzer "Lake Estancia", was apparently without outlet, and so on shrinkage must have had its dissolved salts concentrated. In such a lake the finest sediments would be deposited in layers in the central part, filling and covered any original irregularities in the basin floor and leaving a level flat consisting of layers of fine silt. As the lake shrunk until no standing water was left, the salts would be concentrated in and on these sediments. Apparently the dessication of the lake proceeded so far that not only was all the standing water evaporated from the surface, but the lake sediments were thoroughly dried out to a depth of several feet. Wind, blowing over this flat of dry and light silt, would find adventitiously exposed spots, due to locally excessive drying and cracking, or a break in the cover of vegetation, or a disturbance and loosening of the surface material from any cause. The loose top material would be removed from these spots by wind-scour, thus forming shallow depressions in the originally flat floor of the old lake. Once one of these depressions was started, it would create eddies in the air currents that would tend to concentrate the scour and so deepen the depression. As the silt was removed from this zone of concentrated scour, the wind would be unable to carry it farther and would have to drop it on the leeward side of the scoured-out spot, thereby raising the level of the bank on that side, increasing the total depth of the depression and concentrating the wind-scour still further.

The results of this action are shown in the peculiarly characteristic topography of the region. It consists now of an irregularly distributed group of clay hills, looking like anything but an old lake flat. Between these hills lie the relic lakes and salt Marshes. Each of these depressions has the top of its bank composed of wind-blown clay, and the bottom of its bank composed of well-stratified lake-laid sediments. The clay hills deposited by the wind are prevailingly higher and more numerous on the eastern sides of the basins, which is what would be expected in a region of prevailing winds from the west. Wind-scour could remove the silt when it was dry but not when it was wet. The depth of the excavation would therefore be limited by the level of the ground-water, but in any exceptionally dry season the

[3] Meinzer, O. E., Geology and water resources of Estancia Valley, N. Mex.: U. S. Geol. Survey Water-Supply Paper 275, 1911.

depression might be scoured out as deep as the water level at that time, depressed below normal temporarily by the drought. A succeeding normally wet season would raise the water level to or above the surface of the deepest excavations, producing a salt marsh if the water level rose just to the surface, or a lake if it rose still higher. Evaporation from these wet or water-covered surfaces would cause an inflow of ground water from all sides of the valley. Such movement of the ground water would rinse out the salt from the sediments beyond the excavated or scoured area and result in a concentration of the soluble substances, mostly common salt, in these marshes and ephemeral lakes.

At the time of the writer's first visit, in August, 1932, the plant at Laguna Salina was in operation. This is located about 2 miles north of U. S. Highway 60, from which a road branches off at a point about 6 miles east of Willard. According to Mr. H. C. Pogue, then resident manager for the operating company, this property was first worked commercially in 1915 by Julius Meyer and later by the Sanchez Salt and Epsomite Co. It then passed into the hands of Mrs. Lucia de Aragon Schwartz of Denver, who disposed of it in January, 1930, to the New Mexico Salt Co., which went into a receivership in June, 1932. According to several residents of the vicinity, the difficulties at this property have been due to an attempt to operate on a scale incommensurate with meager financing, rather than to any lack of quality in the product. News dispatches in March, 1933, stated that the property had reverted to Mrs. Schwartz, and that the former New Mexico Salt Co. had ceased to exist.

Mr. Pogue, who had worked the property under the receivership, and later for the owner, secured a straight rental lease in June, 1933, and since that time has worked the property as a personal enterprise, under the registered name of the New Mexico Salt Co. He stated that there was produced and marketed 350 tons of salt in 1932, and 700 tons in 1933. Prices ran from 30c to 40c a hundred pounds at the lake, depending on quality. All salt was sold crude, with no attempt at refining, but three grades were separated in harvesting, averaging respectively about 85, 92 and 98 per cent pure.

Before the Meyer operations, Mr. Pogue stated that for several years individual ranchers had been accustomed to take out an occasional wagonload of salt for livestock. No figures are available on this production, but it was stated not to exceed 3 or 4 wagonloads per day during three summer months, which would give an annual average approximating 1 ton daily.

The present market includes local ranchers, supplied by truck within a radius of about 150 miles, and rail shipments east as far as Arlington, Tex., west as far as Gallup and north as far as Dolores, Colo., to which point 11,000 pounds a week was shipped during the summer of 1932, sacked for muleback transportation. All of this salt is used for sheep and cattle; some customers were said to prefer the lower grade of salt, as they claimed that its small content of epsomite was beneficial to their livestock.

In the earlier individual production, the salt, deposited in a thin cake, was simply scraped up from the bed of the lake. The recent operators have found it advisable to control the deposition by evaporation in vats. Two of these, each about 100 by 250 feet, had been made by throwing up a low dike on the floor of the lake, and a well had been sunk several feet deep near the south end of the vats. The brine, which varies in its level from just above to just below the lake bed, was pumped from this well by gasoline pump or windmills into the vats and exposed to solar heat. The vats were floored in part with cinders, from which the salt separated more cleanly than from the sticky black mud that forms the lake bed. As evaporation proceeded, the salt was deposited in a cake on the floor of the vats. The thickness of this cake was controlled by adding more brine. Evaporation was not continued to complete dryness, but the salt was extracted while still under an inch or so of brine. By this method, some of the undesirable impurities were held in solution in the remaining liquid, which also served to wash off from the salt any windblown sediment or adhering dirt. The salt was harvested by hand, the laborers using coke forks. The fork was slid under the cake of salt, which was rinsed in the brine and then thrown into a wagon. The salt was stock-piled for two weeks or more to permit complete drainage and drying, and then shipped in bulk by trucks, or in sacks containing 50, 60 or 100 pounds.

The best season for the harvesting of salt, from either Estancia or Zuni Lakes, is from April to July, near the end of the dry season. The late summer rains that characterize the New Mexico climate tend to dilute the waters of the lakes and so hinder the precipitation of the salt. Mr. Pogue stated that at the Laguna Salina a 30 minute rain would dissolve all the precipitated salt in the lake, which would recrystallize out if the rain were followed by five days of sunshine. Such freshly recrystallized salt was considered the best grade that could be harvested.

SAND AND GRAVEL

GENERAL FEATURES

Sand and gravel are unconsolidated aggregates of rock fragments ranging in size from silt to large boulders. The dividing line separating sand from gravel is placed by some authorities as low as one-tenth inch, by others at one-fourth inch. Material finer than 100 mesh (0.0058 inch or 0.147 millimeter) is ordinarily called silt or dust and material larger than three inches is called cobbles or boulders.

Sand and gravel may be derived from any rock, but common usage generally implies material containing a large percentage of quartz or highly siliceous minerals.

USES

According to the most recent figures available[1] the uses of sand, in the order of their importance, are building, paving, glass, molding, grinding and polishing, engine, railroad ballast, fire or furnace, and filter; and the uses of gravel, in corresponding order, are paving, building, and railroad ballast. There are many other uses—too many to be mentioned in detail here.[2]

NEW MEXICO OCCURRENCES

Deposits of sand and gravel are of almost universal occurrence in New Mexico. Practically every community has an ample supply easily available for local use, and there is therefore comparatively little rail movement of sand and gravel except for use as ballast. Road builders usually find suitable material for fill and aggregate within a short haul of their work. Aggregate for sidewalks, foundations, mortar, and other similar work is usually obtained by screening the material from local pits.

Practically all the sand and gravel used in the State is obtained from the dry beds of arroyos or from the extensive Quaternary and Tertiary alluvial and bolson deposits. Material from stream beds is usually excavated by hand or scraper and screened at the pit or after delivery. Producers working in more indurated deposits have power excavators and mechanical screening plants.

In Bernalillo County the Shufflebarger Transfer and Storage Co., the Springer Transfer Co., and several smaller companies and individual contractors supply the important Albuquerque market. The two larger companies have modern excavating machinery and preparation plants. Most of their product is used locally, but some aggregate for special uses has been shipped to points within a hundred-mile radius. A small amount of molding sand is obtained near Albuquerque for use in a local foundry.

The Kemp Lumber Co., and the Roswell Sand and Gravel Co. handle the sand and gravel trade near Roswell, Chaves County. Kemp also ships to Carlsbad and furnished 40 carloads for use in concreting the shaft at Carlsbad Cavern.

[1] 13. S. Bur. Mines Minerals Yearbook, 1934, pp. 30-33, 1935.

[2] Detailed information on the uses of sand and gravel is contained in the following publications:

Ladoo, Raymond B., Non-metallic minerals, pp. 499-616, McGraw-Hill Book Co., Inc., New York City, 1925.

National Sand and Gravel Association, Washington, D. C., various publications.

Tuck, Ralph, Classification and specifications of siliceous sands: Econ. Geology vol. 25, pp. 67-64, 1930. (Urbana, Ill.)

Weigel, W. M., Technology and uses of silica *and* sand: U. S. Bur. Mines Bull. 266, 204 pp., 1927.

The Atchison, Topeka & Santa Fe, the Chicago, Rock Island & Pacific, and the Southern Pacific railroad companies operate sand and gravel pits at convenient places along their roads, notably in Dona Ana, Mora, Quay, Roosevelt, Socorro, and Valencia Counties. At some pits operations are carried on by railroad employees but a large part of the work is done by separate companies on a contract basis. The material is used for ballast, fills, railroad yards and bedding cattle cars.

The State Highway Department and road contractors are important producers and users of sand and gravel. The excavation may be done by hand, slip or wheel scrapers, or by power-operated shovels and draglines. The material for highway construction and surfacing is practically always prepared in semi-portable screening plants.

Other sand and gravel operations in the State include the Eastwood pit and screening plant at Tolar, Curry County; the Boss Construction Co. pit near Ft. Sumner, De Baca County; Frank George, Gallup, McKinley County; Reinken & Reynolds, Watrous, Mora County; and Maney Brothers, Espanola, Rio Arriba County.

PRODUCTION

The first recorded production of sand and gravel in New Mexico was in 1906, when 1,210 tons valued at $1,500 was produced. During the period from 1906 to 1933, inclusive, the production was 5,814,258 tons valued at $3,683,646. There was some production in the years 1913-19 but figures are not available.

The actual production, as recorded in the Mineral Resources; and Minerals Yearbook volumes, is shown in the accompanying table:

Production of Sand and Gravel in New Mexico, 1906-1933[1]

Year	Short tons	Value
1906	1,250	$ 1,500
1907	209,478	50,724
1908	8,250	12,050
1909	4,902	3,032
1910	4,310	2,043
1911	267,615	18,774
1912	125,872	29,963
1913-1919	([2])	([2])
1920	209.193	128.815
1921	327,345	168,895
1922	244,315	146,670
1923	464,410	239,470
1924	526,787	267,110
1925	141,013	107,204
1926	128,577	86,805
1927	360,020	226,990
1928	187,239	111,296
1929	337,768	177,368
1930	314,667	282,360
1931	339,640	275,086
1932	834,521	570,555
1933	777,086	776,936
TOTALS	5,814,258	$3,683,646

[1] Mineral Resources of the United States, U. S. Geol. Survey and U. S. Bur. Mines, annual.
[2] Some production, but no record.

CRUSHED STONE

Crushed stone, used largely as a substitute for sand and gravel, is produced from any one of a number of rocks by mechanical rock breakers or by sledge hammers. In New Mexico crushed stone has been produced from granite and related rocks, basalt, limestone, and sandstone.

Several quarries have been operated in the State, mostly to obtain stone for use as railroad ballast. The following table shows the production of stone in New Mexico for the years 1905 to 1933, inclusive. Some dimension stone has been included in the totals.

Production of Stone in New Mexico 1905-1933[1]

Year	Crushed Stone Short Tons	Crushed Stone Value	Total Stone Value
1905	186,625	$ 86,575	$ 110,922
1906	362,667	145,217	168,567
1907	784,336	342,846	381,011
1908	1,070	735	15,955
1909	498,175	269,981	300,313
1910	950,437	441,473	443,650
1911	831,392	402,494	406,454
1912	725,474	333,972	335,937
1913	438,561	202,016	219,566
1914	326,025	315,000	418,305
1915	167,922	231,157	308,809
1916	101,243	75,520	77,290
1917	115,000	68,000	72,411
1918	113,322	84,874	86,343
1919	50,000	40,000	56,373
1920	329,830	280,380	297,271
1921	34,000	40,000	52,356
1922	364,620	215,850	224,525
1923	596,790	402,308	402,308
1924	650,000	420,000	432,023
1925	120,000	90,000	92,034
1926	160,000	80,000	80,000
1927	470,000	235,000	235,000
1928	375,000	190,000	190,000
1929	400,090	217,552	217,552
1930	211,000	158,440	161,944
1931	375,650	537,740	537,740
1932	308,640	253,051	253,051
1933	427,980	437,287	437,287
TOTALS	10,475,849	I6,597,468	7,014,997

[1] Mineral Resources of the United States, U. S. Geol. Survey and U. S. Bur. Mines, annual.

SPURRITE

Spurrite is a rather rare mineral, a combined silicate and carbonate of lime, with the chemical formula $2Ca_2SiO_4.CaCO_3$. A specimen of this material from the Tres Hermanas mountains about 7 miles northwest of Columbus, Luna County, was sent for identification to the State Bureau of Mines and Mineral Resources in 1930 by Mrs. Nellie Fitzpatrick of Deming, and was identified by microscopic examination by A. H. Koschman. Prior to this discovery, the only reported occurrences of spurrite were from Velardena, Mexico, and from Scawt Hill, Ireland.

The spurrite in the Tres Hermanas mountains, like that in the type locality, is limited to a narrow zone in limestone, at an intrusive contact. The deposit has not been prospected extensively, but from the surface exposures it appears to lie in a wedge-shaped mass having maximum dimensions of some tens of feet. No information is available as to its extent in depth, and the data are insufficient for an estimate of total quantity.

The New Mexico spurrite is of a bluish-gray color, and looks much like an exceptionally lustrous limestone, or marble, but is distinctly harder. It is compact and massive, can be cut and worked rather readily, and takes a fairly good polish. Experiments have indicated that it can be fashioned into attractive small ornamental pieces, such as ash trays, pen stands, or paper weights. Commercialization of this deposit has not gone beyond the experimental stage.

SULFUR

GENERAL FEATURES

Sulfur is an element that is widely distributed in chemical combinations, but of relatively rare occurrence in the free state. Many of the minerals classed as metallic ores are sulfides or sulfosalts; these are not utilized for their sulfur content, excepting pyrite, the sulfide of iron that is used to furnish sulfurous fumes in the manufacture of sulfuric acid. Non-metallic sulfates are discussed under "Associated Salines," pages 141-142; nonmetallic sulfides, excepting the gaseous hydrogen sulfide, are almost unknown in the natural state.

Elemental sulfur, also called native sulfur and brimstone, occurs most characteristically near volcanic vents or at the orifices of hot springs of volcanic origin. Pure native sulfur occurs in clear honey-yellow crystals, soft enough to be scratched by the finger nail. Sulfur melts at a temperature not far above the boiling point of water and burns in air with a blue flame, producing the characteristic pungent odor of sulfur dioxide. The best specimens of native sulfur have been obtained from deposits of volcanic origin, some of which are worked commercially.

Native sulfur, less pure but more extensive, occurs also in sedimentary beds, usually gypsiferous limestones or shales. In such deposits, the gypsum is believed to be the source material, from which the sulfur is formed through the action of organic reducing agents.[1] This type of deposit produces most of the commercial sulfur mined today in this country and in Europe. Impure native sulfur may be yellow, brown or gray, due to variations in the collodial state, or to admixture with foreign matter.

EXTRACTION

Nearly all the sulfur produced in the United States comes from Texas and Louisiana, where it occurs as a capping on salt domes, under some hundreds of feet of cover. Due to its low price (averaging under $20 per ton) sulfur in impure deposits cannot be mined economically by ordinary underground methods. The Frasch process of mining, utilizing the low melting point of sulfur, has been devised and used extensively in the Gulf fields

[1]Ladoo, R. B., Non-metallic minerals, p. 600; McGraw-Hill Book Co., Inc., New York City, 1925.

and elsewhere. In this process[2] holes about a foot in diameter are drilled into the sulfur bearing formation, and fitted with three concentric pipes, thus providing an outer tube, an inner tube, and a central pipe. Hot water under pressure and at a temperature some 60°C. above the melting point of sulfur, is forced down the outer tube, and escapes into the sulfur bearing formations through perforations in the lower part of the casing. The sulfur melts out of the rock and flows to the bottom of the well. Through the central pipe, which is the longest of the three, hot compressed air is forced into the molten sulfur, which consequently rises through the inner tube, due to the operation of the air-lift principle, and flows out at the surface, where it is allowed to cool, and solidify. Since the impurities in the sulfur-bearing formation do not melt at the temperatures used, the molten sulfur that flows out is sufficiently pure to be marketed without further refining.

The Frasch process seems peculiarly well adapted to the sulfur deposits in the Gulf region, and enormous reserves have been developed in Louisiana and in Texas. Ladoo says:[3] "At present (1925) therefore, these three companies can produce from 7500 to 9000 tons of sulfur per day, * * * about three times the normal pre-war world consumption."

Sulfur is a very important mineral in many industries and is of minor importance in many others. In the United States the most important use is in the manufacture of sulfuric acid, followed by fertilizers and insecticides and paper manufacture.

During the five-year period from 1929 to 1933, inclusive, the average annual consumption of sulfur in the United States was 1,163,000 long tons, valued at approximately $21,000,000. The average annual consumption by uses during this period was: Chemicals, 39 per cent; fertilizers and insecticides, 25.5 per cent; pulp and paper, 17.7 per cent; explosives, 3.7 per cent; dyes and coal-tar products, 3.4 per cent; rubber, 2.4 per cent; and miscellaneous uses, including paint and varnish and food products, 8.2 per cent.

NEW MEXICO OCCURRENCES

Native sulfur in New Mexico has been reported from the region near Jemez Springs as a hot-spring deposit, from near White Oaks in gypsum, and recently from near Artesia. An old sulfur mine is said to have been worked near Guadalupe, but its location has not been confirmed. The San Juan Sulfur and Chemical Co., with headquarters at Aztec, does not operate in New Mexico, but owns some properties on the Gunnison River in Colorado.

[2] See Wells, A. E., and Fogg, D. E., The manufacture of sulfuric acid in the United States: U.S. Bur. of Mines Bull. 184, 1920.

[3] Ladoo, It. B., op. cit. p. 601.

In 1885 a deposit of sulfur[4] was reported to occur north of Lone Mountain, 5 miles from the town of White Oaks, Lincoln County, which was said to contain nearly 50 per cent of sulfur mixed with gypsum. No later information on this deposit has come to the attention of the State Bureau of Mines and Mineral Resources. It is unlikely that any large quantity of high-grade sulfur occurs in this area.

The sulfur deposits near Jemez Springs were examined in a preliminary way by G. R. Mansfield, of the U. S. Geological Survey, in 1918. He reports[5] that about 1902 M. S. Otero extracted, refined and marketed about 100 tons of sulfur. According to Mansfield, the total sulfur bearing areas in this region amount to not more than 10 acres, the sulfur is irregularly distributed and the deposits are thin, and "the quantity of available sulfur is too small to be of commercial importance, especially in view of the inaccessibility of the deposits." In the fall of 1933 the New Mexico Acid Co. was erecting a plant for extraction of sulfur from the deposits. The plant was estimated to have a capacity of 150 tons a day and was to utilize carbon disulfide as a recovery agent. According to later reports this process failed, and during the summer of 1934 two retorts were being installed.

In the summer of 1931, Oliver Pearson and sons of Lake Arthur, while drilling for water in. Sec. 8, T. 16 S., R. 22 E., encountered sulfur in the well cuttings over a range reported to extend for 20 feet, from 940 to 960 feet below the surface. Specimen material from these cuttings, given by Mr. Pearson to the writer, shows the sulfur to be the clear yellow crystalline variety, apparently of a high degree of purity. If a bed 20 feet thick, carrying abundant sulfur of this quality, exists at the stated depth, it would seem to offer good possibilities for commercial extraction by the Frasch process. If, on the other hand, the drill fortuitously encountered a vertical sulfur-bearing seam, perhaps only a few inches wide, the occurrence would have no commercial prospects. Only further drilling can determine which is the case. No more information is available on this occurrence, excepting newspaper reports to the effect that the Union Sulfur Co. conducted further investigations in this area.

The large reserves already developed in Texas and Louisiana would seem to militate against the success of any new sulfur prospects, except under unusually favorable conditions of quality, ease of extraction, or location.

[4] Day, William C., Sulphur; U. S. Geol. Survey Mineral Resources, 1885, p. 496, 1886.
[5] U. S. Geol. Survey Mineral Resources, 1918, pp. 367-369, 1921.

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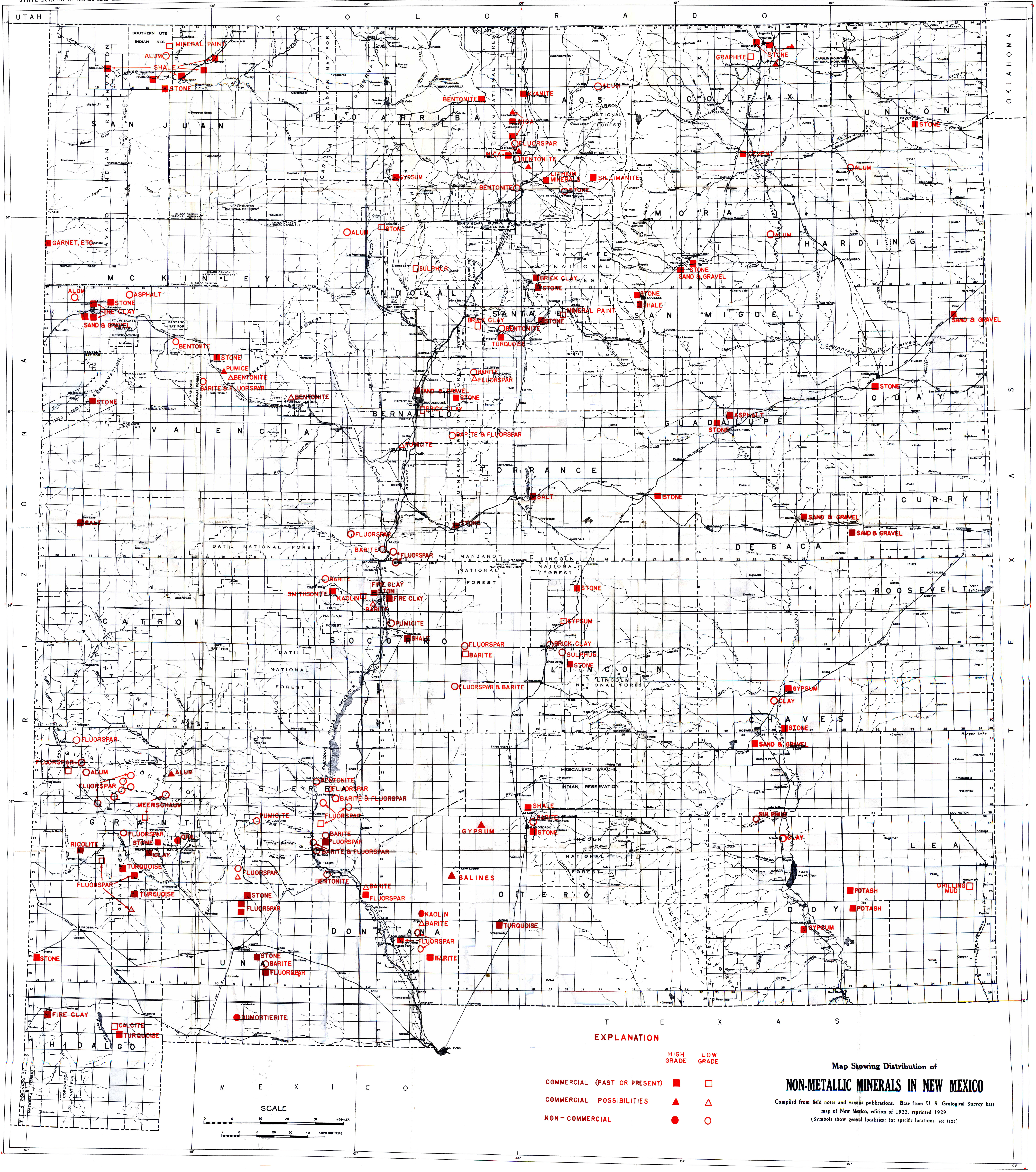
Figures in *italic* indicate chapter references.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MORA
HARDING
SANTA FE
SAN MIGUEL
VALENCIA
BERNALILLO
GUADALUPE
QUAY
TORRANCE
CURRY
DE BACA
ROOSEVELT
CATRON
SOCORRO
LINCOLN
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SIERRA
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EDDY
DONA ANA
LUNA
HIDALGO
EXPLANATION
HIGH GRADE
LOW GRADE
COMMERCIAL (PAST OR PRESENT)
COMMERCIAL POSSIBILITIES
NON-COMMERCIAL
SCALE
Map Showing Distribution of
NON-METALLIC MINERALS IN NEW MEXICO
Compiled from field notes and various publications. Base from U. S. Geological Survey base map of New Mexico, edition of 1922, reprinted 1929.
(Symbols show general localities; for specific locations, see text)