UNITED STATES DEPARTMENT OF THE INTERIOR
Ray Lyman Wilbur, Secretary

GEOLOGICAL SURVEY
W. C. Mendenhall, Director

Bulletin 838

NITRATE DEPOSITS OF THE UNITED STATES

BY

G. R. MANSFIELD
AND
LEONA BOARDMAN

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1932

For sale by the Superintendent of Documents, Washington, D. C. - - - - - Price 40 cents

CONTENTS

ILLUSTRATIONS

NITRATE DEPOSITS OF THE UNITED STATES

By G. R. Mansfield and Leona Boardman

INTRODUCTION

For many years there have been recurrent rumors and press accounts of the occurrence of deposits of saltpeter (potassium or sodium nitrate) in different parts of the United States but particularly in the Southwest. The richness and extent of some of these deposits have been described in glowing terms, and the public has been informed of the organization of companies, the purchase of machinery, and the beginnings of commercial exploitation.

During the World War, when supplies of nitrate from Chile were endangered and the amount of general shipping was greatly reduced, considerable money was spent by private companies in attempts to put some of these deposits on a producing basis. The Ordnance Department of the Army became interested in them as possible domestic sources of supply and called upon the Geological Survey to make detailed investigations of them. The results of these investigations proved uniformly disappointing and except for certain areas in California and some other States have hitherto remained unpublished.

With the signing of the armistice the efforts at production of nitrate ceased for a time, but with the passage of the potash act (Public 424, 69th Cong., approved June 25, 1926; 44 Stat. 768) another wave of revival in interest ensued. It has therefore seemed worth while to bring the available information together and publish it so that it may become an accessible part of the public record.

Much of the compilation of the material in this report is the work of the junior author, but the senior author is responsible for the general planning and for the revision of the work of the different geologists whose reports on special areas are included herein. He has also contributed some field work in California, Idaho, Oregon, and Texas.

The conditions under which nitrate deposits may occur are so widely distributed that almost any part of the United States might be expected to yield minor amounts of these substances. Actually nitrates have been reported from such well-watered States as Pennsylvania, Tennessee, and Alabama, but occurrences are much more numerous and conspicuous in the arid and semiarid parts of the country. The authors can not hope that they have recorded all known deposits of nitrate in the United States, but they have attempted to mention all those for which enough data have been provided to enable the Geological Survey to state the approximate location and conditions of occurrence of the nitrate.

The writers are very grateful for the cooperation and aid that have been received from many persons and companies interested in the nitrate deposits. Though it is not possible to mention all of these individually, some acknowledgment is made in connection with the treatment of the different occurrences.

PRINCIPAL TYPES OF NITRATE DEPOSITS

The nitrate deposits of the United States fall generally into two broad types distinguished by their mode of occurrence as cave deposits and caliche deposits. To these may be added a third type—negligible in quantity as compared with the other two but of possible interest in connection with the question of origin of nitrate deposits—called playa deposits.

Cave deposits.—The cave deposits, as the name implies, are found in caves, in recesses on canyon walls, on cliffs, and in other places protected to a greater or less extent from the weather. The cave type is the most widely distributed and is not confined to regions with arid climate, though examples of it are much more numerous in such regions. Moreover, the cave type of deposits is associated with a wide variety of rock types, including many kinds of sedimentary and igneous rocks. The cave deposits also include a wider variety of nitrate-bearing salts. Potassium nitrate is in many places the principal nitrate compound, though sodium nitrate and calcium nitrate are also common and sodium nitrate may exceed potassium nitrate in amount. More rarely magnesium nitrate and ammonium nitrate may be present. Associated salts are sodium chloride, calcium sulphate, and locally one or more varieties of alum.

Cave deposits are surface or near-surface accumulations which may locally be highly pure. They form coatings on rock walls or fragments, fillings of crevices and cracks, and by falling down on the floors of caves or at the bases of cliffs they mingle with the earthy matter at such places. They do not penetrate more than a few inches or at most a few feet into the rock mass and then only along deep cracks or fissures.

Caliche deposits.—Caliche deposits are confined to arid regions. They form blankets a few inches thick and from a few inches to a foot or more below the surface. These blankets conform with the general topography but vary rapidly in thickness and richness from place to place. Though locally and rarely found with coarser types of rock, the caliche is most commonly associated with clays and is best developed on the flatter and more gently sloping portions of hills formed of clay. Generally the caliche blanket lies on the hills without regard to the attitude of the beds beneath it, which may have any degree of inclination from horizontal to vertical. Thus the caliche is not ordinarily related to any particular bed that may be regarded as a source of the nitrate, but locally richer accumulations are associated with particular layers. The reason for this unusual association may lie in some favorable difference in texture rather than in the presence of greater supplies of nitrate, for in such places the clay beneath the caliche blanket is as barren of nitrate as in other localities.

The caliche nitrate is chiefly sodium nitrate and is commonly associated with sodium chloride, sodium sulphate, and calcium sulphate.

Playa deposits.—In some playas, for example, Leach Lake, in California, Noble [1] has found that nitrate is widely distributed in the clay just under the dry surface of the lake, but that the amount is small, averaging less than 1 per cent. The amount diminished from the surface down to the depth of 1½ feet. His tests did not go deeper than 3 feet. This type of occurrence indicates that nitrates are accumulating in certain playas at the present time and may have some bearing on the question of the origin of nitrates.

ORIGIN OF NITRATES

Many statements have been published regarding the origin of nitrates, and a considerable literature on the subject has grown up which can not be discussed in detail here. Perhaps the simplest account that has come to the attention of the writers is a brief article by Gale [2] which is so thoroughly applicable to the needs of this report that it is substantially repeated here for reference.

> Nitrates exist in small amounts in many places, and nothing is more natural than that the prospector should attempt to follow these indications to their source in the hope of discovering some large body of material containing a sufficient percentage to justify its exploitation. It appears that many well-informed people are being misled by small amounts of these salts, found in many places, so that it would be well * * * to give thought to the peculiarities of the occurrences of nitrate in nature and the way in which it is known to be formed. Consideration of this point may eliminate much unnecessary work and expenditure in prospecting. Turning to an encyclopedia we find: " Saltpeter (or nitrates) occurs but seldom in strata, being for the most part a product continually formed by the action of nitrifying bacteria upon

[1] Noble, L. F., Nitrate deposits in southeastern California: U. S. Geol. Survey Bull. 820, p. 15, 1931.

[2] Gale, H. S., Origin of nitrates in cliffs and ledges: Min. and Sci. Press, vol. 115, pp. 676–678, Nov. 10, 1917.

decomposing protein in the presence of oxygen." Protein is the name given in organic chemistry to a class of compounds found in animal and vegetable tissues made up of the elements of carbon, hydrogen, and oxygen, together with nitrogen in chemical combination, the class being distinguished from other organic compounds by the presence of the combined nitrogen. Nitrogen in this form is generally called organic or albuminoid nitrogen. Protein is regarded as one of the most essential constituents of food for man and animals. It is represented by the albumen of the egg, the gluten of the wheat, and certain parts of meat and blood, as well as various grains and seeds. Although protein is food for animals and is generated in plants, it is not directly available as food for plants that require nitrogen in the form of a nitrate; that is, a salt of nitric acid. Nitrates are essential to the growth of plants and are present in all fertile soils, in which the nitrates are formed mainly by the action of nitrifying bacteria.

These nitrifying bacteria are present almost everywhere that conditions are favorable. They are found in practically all soils, and nearly everywhere on the surface of the earth. They have been found on the surfaces of rock masses high in the mountains. They become active, as do other more familiar ferments, as, for instance, the yeast in dough, under proper conditions of warmth and moisture and with access to the oxygen of the air, and they become less active or quite inactive in the absence of any of these favoring conditions. The farmer treats his soil to exactly the conditions leading to the best results, and one of the principal results is that the nitrifying bacteria become active and supply nitrate for the growing plants. There must be organic matter or humus present to support this action, as well as other conditions. * * *

During 1916 more than 2,500 tons of saltpeter came from India to the United States, to be used mostly in munition manufacture. Nitrate is produced regularly in India, and in some other countries, by the cultivation, under exceptionally favorable conditions, of organic wastes, including manure, but chiefly the filth that accumulates about the dwellings of a none too sanitary population. This refuse is collected in small yards, is turned over from time to time so that it shall have proper aeration to promote bacterial activity, is protected from the leaching of rains during the wet season, is rendered slightly alkaline as one of the conditions favoring the nitrifying action, and is then periodically taken up and leached to extract the nitrate salts that have accumulated in it. The same earth or soil is worked over and over, but organic refuse is continually added, and care is taken to keep the compost slightly alkaline.

The same thing that is being done artificially in India is going on in many natural accumulations of compost, either manure or the general refuse of animal life where animals are herded together. Cave earths were worked as a source of saltpeter during the Civil War and at other times in the history of the United States. There is no doubt that the nitrates in the caves originated in an exactly similar way. Caves or cavernous ledges are the natural refuge of all sorts of animal life, including insects, birds, reptiles, and many of the larger animals. In these recesses they leave not only excrementa but bits of their food, hair, bones, flesh, and even grains, mixed in a soil that is often light and porous, and may be filled with twigs and dried leaves. This is probably stirred by the coming and going of the cave denizens. Parts of these recesses are often damp with ground moisture or with wind-blown storm water or mist, and when damp, and at the same time warm, they are in an ideal condition to promote the activity of the nitrate-forming bacteria. Thus, it is easy to account for the accumulation of saltpeter or nitrate salts in caves and in the cavernous recesses of rock ledges.

Nitrate salts are so extensively soluble in water that they readily dissolve in ground or surface moisture. They are continually forming in soils and as continually being washed away, so that there seldom exists any considerable accumulation of nitrates in soils. In caves, too, the nitrates are largely washed away in the same manner. In places more protected from such action the accumulations found have been formed. Even these are doubtless variable, the product found at any one time being the difference between what has been formed or brought in and what has been carried off. The ready solubility of the nitrate salts accounts for one other factor in the accumulation of such deposits, namely, the migration of the salt from the soil or place of formation and its recrystallization on the walls of the rock in crevices, and even in the cavities of a porous rock. Almost everyone is familiar with the tendency of a soluble salt to take up moisture in a moist climate and to creep up the sides of the container, often spreading considerable distances. Nitrate formed within a cavern will thus creep wherever the air or the ground moisture can take it and will crystallize where the evaporation of the dissolving moisture may leave it. Such evaporation can not go on in the depths of the earth away from access to the air, so that the accumulation of such crystalline crusts can not be looked for at a distance from the surface nor where the air can [not] circulate.

The foregoing is an adequate explanation for most of the occurrences of nitrate salts that have been reported from many parts of the United States. Very often the nitrate is found in direct association with cave earth rich in decomposing organic material, and this earth will frequently give high results on testing for nitrate. Visible organic matter is not always plainly associated with the deposits of nitrate salts, but the connection may almost invariably be traced. * * * There are many variations which will lead the prospector to think that his case is different from the type described. For instance, how is one to account for the fact that a test for nitrate may often be obtained on a barren hill slope, in a soil just below the surface layer, especially in certain peculiar clay soils? The explanation is, however, the same as in the more definite cases cited above. Even these apparently barren soils contain much organic matter, especially at the surface. Bits of animal refuse and vegetation are sufficient to show fixed nitrogen almost anywhere that a sample may be taken. In a semiarid climate the soluble salts formed in the soil are not so completely washed out as in moister climates, and not infrequently they collect in the soil in considerable quantity. If the soil be a "gumbo" clay it is quite easy to imagine that a surface may seal over very effectively almost as soon as it becomes wet, and although the soluble salts in the surface may be washed away, a part will be carried down. As the surface dries it cracks, and, letting in the air, the drying of the underlying layer is promoted as a sort of secondary process. Thus, a lower layer rich in soluble salts ordinarily characteristic of such soils is formed. This layer has, at a number of places, been found to contain nitrate in small amounts associated with sodium sulphate, chloride, and possibly carbonate. The nitrate found in such places may be explained as the accumulation of ordinary soil nitrate in the subsoil, where it happens to be under such conditions that it is not more completely washed away. * * *

The question is often asked, How were the great deposits of nitrate in northern Chile formed, and is it not possible that something of the same sort might be found in this country? The origin of the Chilean nitrate deposits has been widely discussed, and it can not be said that a positive answer has yet been given. However, the deposits in Chile are not unlike the hillside occurrences of nitrate-bearing soils referred to above, and it is not unlikely that they may have originated in the same way. The caliche, or nitrate-bearing layer in the Chilean deposits, lies just below one or two definite layers of what is essentially a surface-leached soil zone. The soil in this case happens to be largely a mixture of broken rock, as it is the wash that lies between the bedrock of the hills and the almost flat fill in the floor of the intermontane valleys. Rains in this region are so exceedingly rare that the soluble salts are not leached as they would be in almost any other country. Fogs are prevalent, which serve to dissolve the more soluble salts of the surface and to carry them down. Ground moisture is found at the shallow depth [from] which [it] is doubtless being constantly drawn toward the surface by capillarity and evaporated by the heat and dryness of the atmosphere during the day. Between these two influences the soluble salts become concentrated in a zone which is usually not far below the surface. The deposits are also localized regionally, as well as horizontally, and this may perhaps be accounted for in the same way, chiefly as a result of the movement of ground moisture. In spite of the many fanciful explanations that have been given to account for the origin of the Chilean nitrate, it seems not unlikely that scientists will in the end come to an agreement that these salts were produced in the same way that they are being formed all over the world and that the extraordinary accumulations in Chile are principally the result of the unusual climate at the place where they are found. As such a climate does not exist anywhere in the United States it seems unlikely that considerable deposits of this type will be found here.

Gale's account brings out the essentially surficial nature of the agencies that produce the nitrate salts as well as of those that control its accumulation in the places where it is found. The fact that nitrates occur in association with volcanic rocks at many localities, as in the Candelaria district in Texas, has led many to expect deep-seated sources for the nitrate. The fact should not be overlooked, however, that many excellent examples of nitrates occur in association with limestone and sandstone at localities more or less remote from volcanic rocks. The nature of the rock, whether volcanic or sedimentary, has indeed little to do with the occurrence of the nitrate. The rock in these localities serves mainly as a distributor of soil water, or moisture, and for this purpose its texture is, perhaps, the most significant feature.

Close-textured or fine-grained rocks are relatively impervious. Such rocks, where exposed in cliffs or caves, are unfavorable for the accumulation of salts, and nitrates are generally absent from their outcrops, except in places where they have been greatly fractured. On the other hand, the caliche deposits of arid regions usually overlie clays, for these hinder the downward seepage of moisture and serve to localize the salts at the contact of the dense bedrock clay with the more porous soil.

In protected situations coarse-textured rocks outcropping in cliffs or caves, especially those rocks that are fractured or that contain vesicles or cavities, are the favorite places for the occurrence of nitrates. In exposed arid regions, however, nitrate-bearing caliche is usually absent from such rocks, for they readily permit downward percolation of moisture and thus tend to dissipate rather than to localize the salts.

Noble,[3] who has discussed the origin of the clay-hill caliche deposits of southeastern California, considers some 14 possible sources of origin for this material and concludes that the evidence is not sufficient to dismiss wholly from consideration any but marine origin and perhaps a derivation from nitrate concentrated in beds or veins in strata underlying the clay-hill areas. Among the possible modes of origin discussed are saline residues of evaporated lakes, guano in caves and other places, action of nitrifying bacteria on organic matter in the soil, fixation of nitrogen from the air in soil and on surface rocks by bacteria, fixation of nitrogen on leguminous plants, nitrate particles in the air produced by oxidation of ammonia or by mechanical action of the wind, nitric acid in rainfall from electrical discharges during thunderstorms, organic matter entombed in the strata at time of deposition, nitrogen gases expelled during volcanic eruption and carried into soil and rocks by rains resulting from the condensation of erupted water vapors, nitrogen gases in igneous rocks, nitrogen in spring waters, and nitrate disseminated in strata underlying the clay-hill areas.

Three hypotheses of the accumulation of nitrate-bearing caliche also considered by Noble are upward movement of soluble salts by ground water and subsurface moisture through capillary action, downward movement from soil and surface sources, and enrichment by general erosion. This last he considers the dominant process. He concludes:

> There are many possible primary sources of the nitrate and many possible combinations. Which source or combination of sources is the true one is not known because sufficient evidence is not available. Three processes are probably involved in the accumulation of the caliche. Enrichment by general erosion is probably the dominant process, subject to at least two controls—the actual quantity of saline material available and favorable climatic conditions. Two factors must obviously enter into every hypothesis concerning the source of the nitrate and into every explanation of the mode of accumulation of the caliche. They are arid climate and time.

The idea held by many who undertake to exploit nitrate deposits, that beds rich in nitrate may occur at depth or may comprise the mass of the hills in which they occur, has been tested quite satisfactorily in the Geological Survey's studies of nitrate in the Amargosa region[4] of California. In that region the rocks associated with the deposits,

[3] Noble, L. F., op. cit., pp. 95–105.

[4] Noble, L. F., Mansfield, G. R., and others, Nitrate deposits in the Amargosa region, southeastern California: U. S. Geol. Survey Bull. 724, 1922. Noble, L. F., op. cit.

chiefly clays, are inclined at various angles, affording exposures equivalent to vertical thicknesses of more than 1,000 feet at some localities. The blanket of nitrate-bearing caliche, however, lies over the upturned edges of these beds much as a cloth cover might overlie a row of books on edge, thus attesting the essentially surficial character of the deposits.

COMMERCIAL IMPORTANCE OF NITRATE DEPOSITS

Cave nitrates have been utilized at times in our national history as sources of saltpeter essential in the manufacture of gunpowder (black powder). This was particularly true during the Civil War, when nitrates from Wyandotte Cave in Indiana, Mammoth Cave in Kentucky, and other caves were utilized in this way. It is hardly conceivable that such a condition should arise again. Black powder, for the manufacture of which saltpeter is particularly needed, was relegated to a comparatively insignificant place during the World War. More powerful explosives derived from nitrocellulose and coal-tar preparations have taken its place as principal agencies of destruction in warfare. Moreover, if a large quantity of black powder should be desired more plentiful supplies of saltpeter could be derived from by-product nitrogen from coke ovens or from synthetic nitrogen, the production of which in this country is advancing rapidly toward the goal of supplying all domestic needs and producing an exportable surplus.

Potassium nitrate is not yet used to any extent in the manufacture of fertilizers. The potassium for such purposes is supplied by potash salts, chiefly chlorides or sulphates or mixtures of these salts, derived principally from foreign sources, and the nitrogen is taken from Chile saltpeter or from one of the numerous organic, synthetic, or by-product sources. Thus even if cave deposits could supply large amounts of potassium nitrate it is not certain that suitable markets could be found.

Caliche nitrate in this country is a more recent discovery than cave nitrate, and so far as the writers are aware no commercial use has ever been made of it. During the World War the senior author with others was engaged in studying the caliche nitrate deposits of the Amargosa Valley in California. These were then and are still, so far as available records go, the richest known nitrate deposits that have any areal extent in this country. On the basis of careful sampling, estimates [5] then prepared indicated that the

[5] Noble, L. F., Mansfield, G. R., and others, Nitrate deposits in the Amargosa region, southeastern California: U. S. Geol. Survey Bull. 724, pp. 92, 93, 1922.

Upper Canyon and Lower Canyon fields, the most promising parts of the Amargosa region, contained 168 acres that could produce 1,980 short tons of refined nitrate. (See p. 24.) This, however, was without regard to price. The other caliche deposits of California described by Noble [6] have not been sampled with a view to estimating tonnage, but it is clear from the work already done that they contain no bodies of nitrate comparable in amount per acre with those in the Amargosa fields just mentioned. The caliche type of deposit in this country is therefore not a commercial source of nitrate. As the playa type of deposit is poorer than either of the others its commercial possibilities may be dismissed without further comment.

CONCLUSIONS REGARDING COMMERCIAL DEVELOPMENT

From accounts given in this report and from earlier published accounts it seems clear that of the many nitrate deposits already known in this country not one contains enough nitrate to afford promise of commercial development under any prospective conditions in the country at large either in the near or the distant future. There are probably many other nitrate deposits as yet undiscovered or at least only locally known. The types of country in which these are likely to occur and the general conditions under which they would have formed are, however, quite well known. This knowledge affords little hope that any deposits of sufficient magnitude to have commercial value will be found.

Needless to say, this adverse judgment regarding the nitrate deposits of the United States has been adopted with the greatest reluctance by all concerned, but it is well to face the facts. Anyone who is not convinced by this judgment and who is determined to devote his time or money to the further exploration of nitrate deposits should do so with a full knowledge of the evidence in hand and should not be led into such a venture by more or less misleading representations.

Fortunately, the United States does not have to depend on its own natural nitrate deposits for supplies of nitrogen for fertilizer and other uses. In addition to imported supplies of Chile nitrate there are being produced in this country increasing quantities of by-product and synthetic nitrogen which bid fair within a few years to give the country complete independence in this essential requirement.

[6] 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, 1931.

PROSPECTING FOR NITRATE

The known character of the nitrate deposits in this country affords little hope for the prospector that his deposit will prove an exception to the general rule. Nevertheless, should he wish to satisfy himself on this point it is essential that he make a fair test of the country rock immediately associated with his deposit and not content himself with samples of surface material or material from cracks and vesicles in fractured or porous rock. For example, if a sample taken from the walls or face of a cave or tunnel yields nitrate salts, enough material should be chipped off at the given place to expose fresh country rock. This will ordinarily be found within 6 inches or a foot. Care should be taken that this surface does not become "salted" by contamination from near-by cavities or cracks. Chips of this fresh rock when tested by the brown ring method described below will readily disclose the presence of even very slight amounts of nitrate.

BROWN-RING NITRATE TEST

Materials.—For those who are interested in making their own field tests for nitrate the following directions are given:

Reagents needed:
- Ferrous sulphate crystals (chemically pure).
- Concentrated sulphuric acid (chemically pure).

Equipment necessary:
- Two bottles, capacity 6 to 8 fluid ounces, for reagents.
- Two test tubes; ½ inch by 6 inches is a good size.
- One small glass funnel.
- Filter paper.
- One small metal plate, 3 or 4 inches in diameter.

A special box containing a wooden block bored with holes to fit equipment and provided with a carrying handle is a very convenient container for the outfit. A hammer and a canteen or water bottle are also necessary.

The ferrous sulphate is made into a saturated solution with distilled water made acid by adding a few drops of sulphuric acid. If the sulphuric acid is not added the solution is likely to be milky or turbid. This solution does not keep indefinitely, and a fresh solution should be made every month or so. About 3 or 4 fluid ounces of the solution is enough to make up at one time, and 2 or 3 ounces of dry crystalline ferrous sulphate is sufficient for many nitrate tests.

The sulphuric acid keeps indefinitely. It is a very strong acid and will seriously burn the skin. It will char wood or clothing and corrode metal. From 4 to 6 fluid ounces of the acid is a good supply.

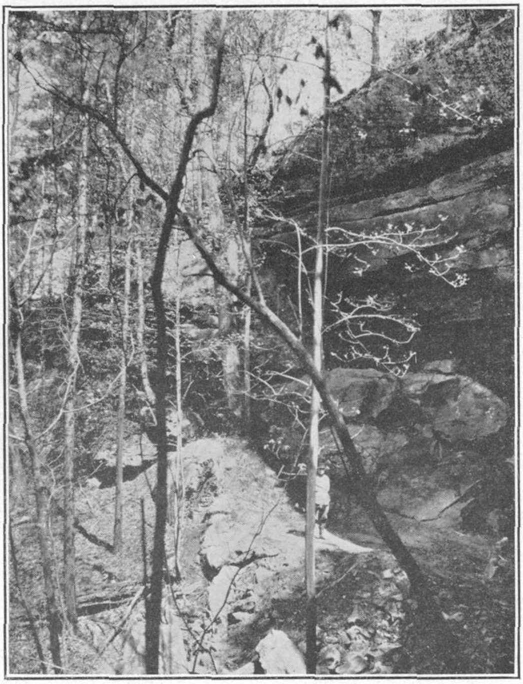
NITRATE DEPOSITS IN THE UNITED STATES

Scales

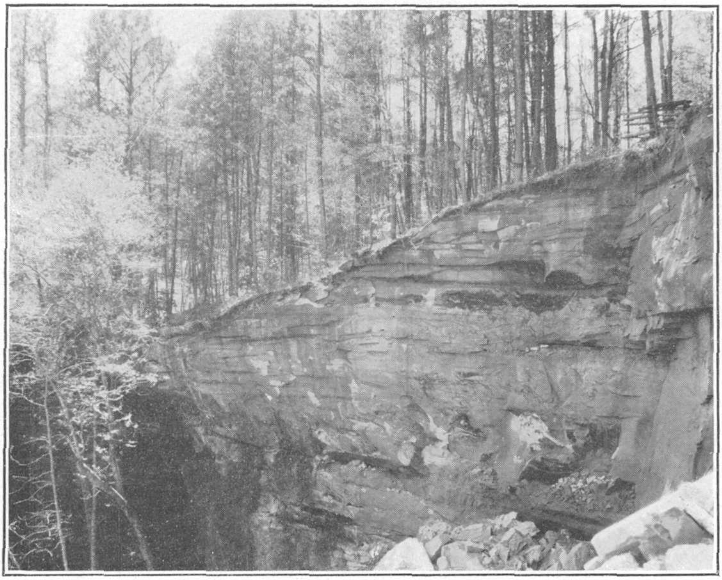
100 0 100 200 300 400 500 600 Miles

100 0 100 200 300 400 500 600 Kilometers

1932



A. SANDSTONE LEDGES THAT SHELTERED NITRATE DEPOSITS



B. SANDSTONE LEDGES PARTLY BLASTED AWAY, SHOWING PATCHES OF SALINE INCRUSTATIONS

NITRATE-BEARING SANDSTONE LEDGES NEAR GUM POND, LAWRENCE COUNTY, ALA.

Procedure.—Pulverize on the metal plate the material to be tested and place a small amount of it in a test tube. The quantity that will occupy about ¼-inch space on a pocketknife blade will be about right. Dissolve in about half or three-quarters of an inch of water and shake well to aid the solution. If the solution is not perfectly clear filter it through filter paper into another test tube. Add about an equal amount of the ferrous-sulphate solution to the filtered solution in the test tube and shake well. Hold the test tube at an angle of about 45° and slowly pour a little sulphuric acid into the tube. The acid should not mix much with the solution. It should flow along the lower wall of the tube and collect on the bottom because it is very heavy. Use sufficient acid to cover the curved bottom of the test tube. If nitrate is present a brown ring will form at the junction of the two liquids. The ring will be well defined, even with small amounts of nitrate. Experience has shown that unless the reaction is very well marked the quantity of nitrate present will not be greater than 1 per cent. If the sample contains as much as 3 per cent of nitrate a "boiling test" will probably be obtained; that is, the solution will rapidly turn dark, almost black, and begin to boil, with the evolution of brown fumes of nitric oxide.

For different tests use the same amount of material, and then the intensity of the brown color will be a rough measure of the relative amounts of nitrate in the samples tested.

Noble's experience with the brown-ring test[7] showed that

> if more than 3 per cent of nitrate was present little idea could be formed of the actual percentage, because the reaction usually became too violent to preserve the brown ring. In general, a reaction strong enough to turn the solution black caused the liquid to boil violently, throw off brown fumes, and immediately thereafter become transparent, thereby indicating the presence of 5 per cent or more. It was never possible to get a black boiling reaction from material containing less than 3 per cent of nitrate.

Any person attempting to make use of the brown-ring test would better practice it a few times on material definitely known to contain nitrate in order to familiarize himself with the procedure and the results before starting to test unknown materials.

---

[7] Noble, L. F., op. cit., pp. 3, 4.

NITRATE DEPOSITS BY STATES

In the record that follows 23 States are included. (See pl. 1.) The information available differs with each State, the deposits in some having been studied more intensively than those in others. Doubtless the record is far from complete, but there seems little likelihood that new discoveries will offset the general tenor of the conclusions stated above. The States and their respective counties are discussed in alphabetic order.

ALABAMA

Niter was obtained in limestone caves, principally in the Tennessee River Valley, for making powder during the Civil War.

LAWRENCE COUNTY

Occurrences of nitrate in sandstone ledges near Gum Pond, in the southern part of Lawrence County, were examined in 1917 by H. S. Gale, whose report on the deposits is given below:

GUM POND LOCALITY

By H. S. Gale

Nitrate of potash has been reported from various sources as occurring in the lower sandstones of the coal-measure series in northern Alabama. One occurrence in particular has been carefully exploited, and so much work has been done in exploring for the source of this salt that it furnishes an especially good example of this type of deposit for discussion.

The deposit referred to lies near the former post office of Gum Pond, in the extreme southern edge of Lawrence County, about midway in the county from east to west. (See fig. 1.) The principal prospecting has been done on private lands in secs. 26 and 36, T. 8 S., R. 8 W. Huntsville meridian, Alabama.

The surface of southern Lawrence County and northern Winston County is made up of an upland level or plateau, having an altitude of about 2,500 feet. This plateau is intrenched by the stream courses to a depth of 200 feet or more. It is apparently determined by the occurrence of several massive and resistant sandstones, which are essentially flat lying throughout an extensive area. The upland surface is in places covered with a mask of unconsolidated gravel and clay and in part is covered with a sandy soil probably derived from the underlying sandy rocks; but the rocks, including sandstone ledges and shale, are exposed on the slopes of the ridges and in the stream valleys. These rocks lie at the margin of the productive coal field, and from their relation to the lowest coal bed worked about

6 miles south of Haleyville, said to be the Black Creek seam, they are supposed to represent the section of the Pennsylvanian rocks that normally underlies the coal. The one particularly massive stratum of sandstone in the section forms conspicuous ledges about midway between the ridge tops and the deeper valley bottoms. This is the ledge in which the saltpeter or nitrate of potassium is found.

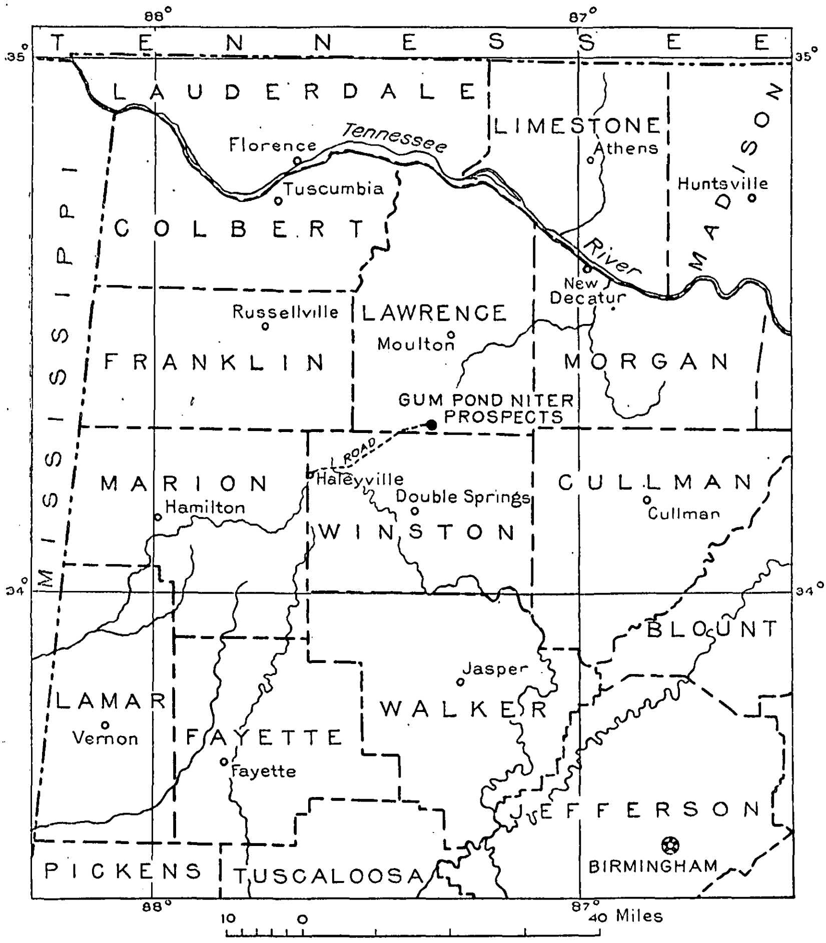


FIGURE 1.—Map showing location of Gum Pond niter prospects, Lawrence County, Ala.

The outcrops of the most massive sandstone stratum are commonly undercut by weathering and erosion, so that the upper part overhangs, forming shallow caves, which are sometimes referred to as "rock houses." This undercutting is probably due chiefly to the dampness that hangs along the soil line and under shelter, causing the rock to crumble. It may be in part due to the occurrence of naturally softer strata at the lower portion of the ledge than near its top, but in either case the result is the same. (See pl. 2.)

At several points along the outcrop of this sandstone ledge seams and incrustations of almost pure potassium nitrate in white crystalline granular form have been found. These materials naturally occur under the overhanging portions of the ledges, usually in the deeper portions of the recesses where they are farthest removed from the liability of being washed away by storm or ground waters. The total amount of salts thus found probably has not exceeded a few pounds, although a few of the original prospects now destroyed may have contained somewhat larger showings than those still preserved. The best showing seen was in a protected block of the talus pile lying under the cliffs. The nitrate was formed as seams on the surface and in bedding cracks that had opened up with the disintegration of the rock, showing that it was then in a purely secondary form of deposit. The block was surrounded and more or less covered with a loose light-brown soil, which is of the kind ordinarily accumulated in caves or under recesses where animals find shelter. It is full of organic refuse of all kinds, in fact is a sort of natural compost pile, with a base of ground-up leaf fragments, twigs, and nutshells, bits of hair, bones, and dried manure. In its ordinary dry condition decomposition of this soil is probably very slow, but if dampened by rain, mist, or ground moisture, particularly in warm weather, there is no reason why this should not be an almost ideal compost for nitrification, in just the way nitrification is known to proceed in properly managed manure piles or in soils containing the necessary organic matter under favorable cultivation. The comparatively rapid generation of nitrates in small amounts in such situations is thus readily explainable.

The specimens of potassium nitrate obtained from these ledges, however, have attracted or excited a great deal of interest. Analysis of many such specimens gave returns showing a large percentage of pure nitrate salt, and the hope was incited that these specimens represented deposits of large and workable quantity. At first the idea was advanced that as the nitrate incrustations were found always on the faces of this sandstone ledge, there might be a parent source of the same sort within the sandstone strata underground, or the nitrate might be disseminated in this rock in such a way that these surface incrustations were but leachings derived by ground solutions brought out by capillarity and deposited with the evaporation of the water on the surface. Prospecting conclusively dispelled the idea of any interbedded deposits in the sandstone, at least at any point near the outcrop. The question was next raised whether nitrate deposits from which these traces were derived might not exist at depth and be found by deeper workings. It is difficult to say that such a thing is impossible, but no such deposit of nitrate salts has ever been known.

The work done on these deposits consisted principally of two large quarries blasted out on the outcrop of the sandstone ledges at points where the showings of nitrate were most prominent. As the sandstone is essentially flat-lying, and as the outcrop is an almost vertical-faced ledge overlooking the creek valley below, the plan was conceived of boring a series of holes at some distance back from the face, which were loaded with a heavy charge of dynamite and exploded, blowing off an immense quantity of rock and exposing a clean face of fresh unaltered or unweathered sandstone. The holes were 4 or 5 inches in diameter and 50 feet deep and ranged about 35 feet back from the face of the original cliff. It is scarcely necessary to say that no bed of nitrate was revealed in the sandstone. Samples of the drillings and cuttings from the freshly exposed face of the cliff were reported to have been tested, and it was said that in some of these from a trace to 0.2 per cent of nitrate was found, although the evidence rests only on the oral statement of one of the interested persons. Such tests would need the confirmation of carefully corrected methods of analysis, extreme care in the collection and preparation of the samples, and other similar precautions if they were to be used as the basis of any theory of origin of the nitrate incrustations described, because there is great likelihood of error in such tests of minor traces. At best such small amounts could scarcely have any practical value.

No samples of the richer nitrate crusts from the undisturbed exposures were collected, for the salt was very evidently potassium nitrate, as reported by previous tests and as indicated by granular crystalline texture and cooling saline taste. There is no need to doubt the quality of these indications, but there is no evidence that such salts exist in any appreciable quantity.

WINSTON COUNTY

A sample consisting of sandstone, quite fresh, with no evidence of surface-weather staining, coated with a substantial crust of nitrate salts, evidently essentially pure potassium, was received in the Geological Survey in 1916 from a locality in the southeastern part of Winston County, in the valley of one of the northern forks of the Black Warrior River.

ARIZONA

COCHISE COUNTY

Deposits near San Simon.—From 1915 to 1918 the Geological Survey received many letters from different correspondents regarding nitrate deposits in the Peloncillo Mountains about 9 miles northeast of San Simon, a town on the Southern Pacific Railroad in Cochise County, Ariz. (See pl. 4, No. 27.) These deposits were examined by L. F. Noble, of the Geological Survey, in November, 1918. As his report[8] has been published, only brief mention of them need be made here. He described them as the Eberenz-Beach nitrate claims. The nitrate occurs as incrustations in alcoves and as shallow impregnations in volcanic tuffs where overhung by cliff-making beds of tuff.

Mr. Eberenz, an experienced sampler, had previously obtained a 200-pound sample representing an average of the tuff cut from the east wall from the portal to the face of a 25-foot tunnel. This large sample had been pounded up, quartered, and averaged down to a 1-pound sample. An analysis of this sample yielded 1.77 per cent of sodium and potassium nitrates taken together. Later Mr. Noble, in company with Mr. Eberenz, took three samples in the tunnel. One of these, cut by Mr. Eberenz himself upon request, represented the average nitrate content of the tuff for the entire length of the tunnel. It represented, though in much smaller quantity, the material constituting the earlier 200-pound sample. Upon analysis in the Survey laboratory, none of these samples yielded any nitrate.

Mr. Noble's results were therefore adverse to the view that the tuff was impregnated to any considerable depth with nitrate. Even if the results obtained from the 200-pound sample should be substantiated by further work, there seems little likelihood that under present conditions the deposit could be exploited commercially.

COCONINO COUNTY

Cosnino caves.—The Cosnino caves, of which there are about 14, are about 20 miles east of San Francisco Peak, the highest point of the San Francisco Mountains. (See pl. 4, No. 24.) The walls of the caves are composed of flows of basaltic lava. The caves were formerly used as dwellings by the Cosnino Indians. Here and there the walls show white incrustations, which consist principally of nitrate of potassium (81.4 per cent). The remaining constituents are nitrate of ammonia, nitrate of lime, nitrate of magnesia, and nitrate of soda. The nitric acid thus represented is thought to have been derived from the oxidation of the ammonia evolved by sheep dung, and the fixed bases were furnished by the wall rock.

Walnut Canyon.—Nitrate incrustations on cliff dwellings in Walnut Canyon had been reported to the Geological Survey, and these were examined in November, 1912, by J. H. Hance, from whose report the following account is taken. (See pl. 4, No. 23.)

Walnut Canyon is located about 12 miles east-southeast of Flagstaff, Ariz., and according to Darton[9] exposes a section through the lower half of the

[8] 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, pp. 71–80, 1931.

[9] Darton, N. H., A reconnaissance of parts of northwestern New Mexico and northern Arizona: U. S. Geol. Survey Bull. 435, pp. 28, 29, 1910.

Kaibab limestone and 200 feet into the Coconino sandstone, both of which are of Pennsylvanian age.

The dwellings stand at two horizons only. The lower is at the base of a massive limestone about 70 feet above the Coconino sandstone. At this horizon there is a cherty stratum about 15 inches thick which has weathered in reentrant angles. The upper dwellings are located on a shelf formed by the weathering of a less resistant arenaceous limestone.

The deposits are irregularly located, some walls showing considerable coatings, whereas others seem devoid of any. All, however, have a common origin. The roof of the dwellings is an impure massive limestone, about 15 feet thick. Near the middle the limestone appears less uniform in composition, and small pits, resembling potholes partly inverted, have formed by subaerial erosion. Bats and possibly swallows have used these small pockets for roosts, and the excrement of these animals has been nitrified and leached to lower portions of the wall and in some places has formed a thin coating on the roof inside the dwellings. In some places either a fire has been kindled inside of these ruins by campers or tourists, or else the incrustation antedates the passing of the prehistoric inhabitants, as some coatings are browned and smoked with soot. The coatings are thin, ranging from less than a millimeter to nearly a centimeter in thickness in more favored spots.

The deposits offer no possibilities for commercial development, especially as they are on a Government preserve, and any attempted collection would probably tend to further level the interesting dwellings. The quantity, however, is small and not sufficient to tempt exploitation. The chief feature is the simple genesis so clearly illustrated.

Three samples of this material were taken and sent to the Geological Survey laboratory at Washington for examination. R. K. Bailey reported that two contained small amounts of aluminum, one contained a small amount of potassium, two showed good tests for nitrate, two showed small amounts of sulphate, and all contained some chlorine.

GILA AND PINAL COUNTIES

Gila River.—An exposure of nitrate in a railroad cut facing the Gila River about 2 miles above Winkelman has been reported as follows: [10]

> The face at this spot is sheer wall about 100 feet high, and the vents filled with nitrate are visible from top to bottom. None of them are more than 6 to 8 inches wide, and the nitrocalcite seems to be mixed with red iron.

The reported deposits of nitrate in the Gila River Canyon above Winkelman were visited in November, 1912, by J. H. Hance, of the Geological Survey. (See pl. 4, No. 22.) According to his account the country rock at that locality is composed of thin-bedded marine limestone with intercalated shale, sandstone, and volcanic rocks. Dislocation and faulting are abundant, and the rocks are thoroughly fissured. In some of the sections exposed leaching has progressed for a considerable distance from the surface. Pockets and small pits are abundant, and these have evidently been used as a shelter by bats, birds, and small animals. Excrement from these animals has been

[10] Gale, H. S., Nitrate deposits: U. S. Geol. Survey Bull. 523, p. 28, 1912.

leached into and over the limestone, forming nitrocalcite (hydrous calcium nitrate). Such deposits have scientific interest but are of no commercial value.

GREENLEE COUNTY

Lindgren [11] notes the occurrence of gerhardtite, a nitrate of copper, in the Clifton-Morenci district, Ariz., where this mineral is found in cliffs of granite porphyry in the deeply-eroded Chase Creek Canyon at Metcalf. He describes the mineral as formed by the trickling of atmospheric waters over and through rocks containing a small percentage of copper.

PINAL COUNTY

[See also Gila and Pinal Counties]

Aravaipa Canyon.—Early in 1926 newspapers in both the West and the East carried accounts of the discovery of a "mountain of nitrate" in Aravaipa Canyon, Pinal County, about 15 miles southeast of Winkelman, Ariz. (See pl. 4, No. 21.) The Arizona Bureau of Mines took cognizance of these reports and dispatched two members of its staff to make a preliminary investigation of the locality. Their report was embodied in a statement issued in February, 1926, by Director G. M. Butler, of the Arizona Bureau of Mines, from which the following excerpts are taken.

> The supposed deposits of nitrate consist of a flow of rhyolite overlain by beds of rhyolite tuff. This material outcrops along the sides of Aravaipa Canyon, north of Mammoth and southeast of Winkelman, for a distance of 3 or 4 miles, and has a total thickness of some 600 feet. * * *
>
> Apparently most of the exploration work in this locality has been done by means of one open cut in the massive rhyolite rock. This cut exposes a fissure or crack which has been filled with relatively soft white material. The joints of the rock on both sides of the crack are also filled with a similar substance for a distance of several inches from the fissure. Samples taken from the material filling the fissure do contain nitrate and apparently calcium sulphate, but the percentage of nitrate appears to be very small in the samples collected. Tests were made on the fresh rock close to the fissure on one side, and no nitrate was found therein, although the filling of minute joints does contain this substance.
>
> The source of the nitrate in this narrow fissure is at present a mystery, although it is significant that the fissure runs up the face of the cliff to a rather inaccessible cave, which may well contain bat guano, and rain water seeping down through the tuff may have carried the nitrate down into the fissure either from this guano or from minute quantities of nitrate contained in the tuff. At any rate, the geologists of the Arizona Bureau of Mines can not conceive of the possibility of extracting nitrate profitably from such material as has been described.

---

[11] Lindgren, Waldemar, Copper deposits of the Clifton-Morenci district, Ariz.: U. S. Geol. Survey Prof. Paper 43, p. 121, 1905. Cited in Bull. 523, p. 27, 1912.

The Director of the Bureau communicated with the manager of the company that is exploiting these deposits, who replied as follows:

"Large private interests are spending considerable money in research work and at present are using the rock from Aravaipa Canyon as a basis for this work. They are using the services of the best experts that they can get and do the work in their own private laboratories. * * * They have assured me that the facts will be given out to the public as fast as anything can be determined of public interest. I would consider it out of place to call on a public institution to assist private interests in an enterprise in which the public is not permitted to invest. As to the findings of your geologists, they are the same as our experts found months ago, and all these things have been thoroughly considered by our men.

"We do not consider that there is any public laboratory equipped to do the work that we are doing, and we would not be interested in any geological reports by any man on this particular property. I know a lot of people who have no interest in the property will write you, and you can answer as you see fit."

This letter was written in response to a suggestion that the writer lay before the bureau all the facts in his possession and that a joint investigation of the deposit be made. In view of the fact that this offer was declined, it does not seem possible for the bureau to do anything in this matter other than to lay the facts collected by its geologists before the public.

Fortunately Director Butler's experience with the manager of the Aravaipa deposit was unusual. Prospectors and operators have frequently shown a very active desire to cooperate with public agencies in the examination of nitrate and other mineral deposits. This was particularly true during the World War.

In November, 1927, the Aravaipa nitrate occurrence was visited by B. W. Dyer, of the Geological Survey, in the course of an inspection of operations under a potash prospecting permit covering parts of secs. 9, 10, 14, 15, 16, 21, 22, and 23, T. 6 S., R. 18 E. Gila and Salt River meridian, Arizona. An abstract of Dyer's report follows:

The permit was taken with the expectation of developing nitrates. A small amount of nitrates was found by the permittee on the ground near the base of a sheer cliff, also in small cavities in the rhyolite which formed the cliff.

Aravaipa Creek runs the full length of this permit, entering on the east near the center of section 14 and leaving on the west in the NW. ¼ sec. 16. For several miles the creek forms a box canyon; the walls on either side rise practically vertical and are several hundred feet high. The cap rock in this area is the Gila conglomerate;[12] below this is several hundred feet of rhyolite.

Small amounts of nitrates and soft, friable crystals of calcium carbonate are found in the small cavities in the rhyolite, especially near the foot of the cliff. No nitrates were found over 100 feet above the foot of the cliff. Also on the ground at the base of the cliff, where there was a small overhang, the soil contained at least one-fourth nitrates.

In section 15, on the south side of the creek, a tunnel 35 feet long has been driven in the rhyolite, and no nitrates were found beyond 3 to 5 feet from the portal.

---

[12] Ross, C. P., Geology and ore deposits of the Aravaipa and Stanley mining districts, Graham County, Ariz.: U. S. Geol. Survey Bull. 763, 1925.

A tunnel 50 feet long has been driven into the rhyolite cliff in the north side of the creek in section 16, and here the nitrate did not extend beyond the portal.

From the accounts just given it is clear that the Aravaipa nitrate occurrence is of the typical cave variety, which locally furnishes surface material of high quality but which disappears just below the surface or within relatively few feet of it. As the great mass of the rock with which such deposits are associated is barren, they afford no hope of commercial development.

SANTA CRUZ COUNTY

Lee's specimens.—In February, 1917, the Geological Survey received from Robert E. Lee, of Nogales, Ariz., a sample of nitrate-bearing material from Santa Cruz County. The locality was not stated. The sample consisted of volcanic tuff or conglomerate with only a small amount of soluble matter. This was essentially potassium nitrate.

Border area.—In a letter dated May 6, 1917, J. Perren Kent, of Phoenix, Ariz., forwarded the following description of a nitrate deposit which he thought might be useful to the Government as a source of supply in war time. His accompanying sketch map is not reproduced, but the general location is shown in Plate 4. (No. 25.)

> The deposit is located in Santa Cruz County about 30 miles west of Nogales. Nothing is surveyed here with reference to sections, to the best of my knowledge, but all is within the forest reserve. You will note that I have marked the international boundary, and monument 129 is directly south of Pena Blanca. I am positive of this number (129). At Casa Piedras [northwest] I think is monument 132, and 130 or 131 is on top of the hill just due south of the place where I found the deposit. By reference to the map inclosed you will see a point marked "spring" in the deep canyon that adjoins and lies parallel with the boundary line. That is where I found the nitrate, and it extends in a northerly direction through the rough mountains nearly to the point "upper or little Bear Valley." There is an old and well-marked trail from an old adobe house south directly to the monument referred to and a group of very noticeable Indian markings close to the spring.

Two samples were submitted with the letter. Upon examination in the Geological Survey laboratory they proved to be sandstone impregnated with a very small amount of potassium nitrate. On Mr. Kent's map the names of several small settlements appear, together with locations of mines and of old adobe houses. Obviously the region has for a long time been sparsely inhabited, and these people may have kept horses or other stock. Thus at least some possible organic sources of nitrate are present. It is particularly significant that Mr. Kent should have found the nitrate near a spring, close to which were markings (and possible refuse) left by Indians. The occurrence is thus similar in all probability to that at Agua Fria Spring in Texas, described on page 55. It is obvious that the quantity of nitrate available must be very small.

Mustang Hills.—E. B. Foster, of Burke, Idaho, in a letter dated October 10, 1918, gave the location of a nitrate deposit in Santa Cruz County, Ariz., which he had previously worked. The deposit is on the trail from the Dan Mathes ranch southwestward to Elgin, a station on the Southern Pacific Railroad. It is in the Mustang Hills about 2 miles from the ranch and 3½ miles from Elgin. These localities are shown on the Benson topographic map. As marked by Mr. Foster on a copy of this map, the deposit lies on the south side of a little canyon that heads against a gap in the hills and opens northeastward. It is in the NW. ¼ sec. 14, T. 20 S., R. 18 E. Gila and Salt River meridian. (See pl. 4, No. 26.) Mr. Foster writes:

> As to this nitrate, the whole mountain is a red limestone and on the side of the bluff there is what I call a bug hole, and in this hole, where the nitrate is, there is a large deposit of wash gravel and loose red dirt. With a little powder and some picking I could move 15 tons of dirt and rocks in a day, and mixed in with this dirt is plenty of nitrate. You can get some pieces as large as your head. * * * A cattleman told me there was something in the hills killing his cattle, so I looked it up and found the cattle were licking the nitrate for salt.

No samples appear to have been forwarded from this deposit, but a sketch submitted with the letter shows this to be a cave deposit similar to some of those previously described and equally hopeless as a commercial source of nitrate.

YAVAPAI COUNTY

Dana notes that gerhardtite has been found in the copper mines at Jerome, Ariz.[13]

Cameron[14] quotes reports of nitrate deposits at Briggs, Yavapai County, Ariz.

ARKANSAS

BAXTER, MARION, NEWTON, AND STONE COUNTIES

The Confederate Army operated numerous mines and refining plants for nitrate used in the manufacture of powder in the Arkansas Ozarks on Cave Creek, in Newton County; on White River 16 miles above Cotter, in Marion County; on Sylamore Creek, in Stone County; and at the old Patsy Guinn Cave, on Spring Creek, in Baxter County.[15]

---

[13] Cited by Gale in U. S. Geol. Survey Bull. 523, p. 27, 1912.

[14] Cameron, F. K., A preliminary report on the fertilizer resources of the United States: 62d Cong., 2d sess., S. Doc. 190, 1912.

[15] Shiras, Tom, Nitrate mines in Arkansas: Manufacturers Rec., August 17, 1916.

BENTON, CARROLL, AND MADISON COUNTIES

Deposits in the Eureka Springs district were reported to the Geological Survey in 1915 by Mr. Dan Coleman, of Clifty, Ark., and further information concerning them was received from him at Mundell, Ark., in 1916, 1917, and 1918. The map which he furnished shows the deposits to be located southwest of Eureka Springs, near Mundell, in Benton and Carroll Counties, and on Big Clifty Creek, in southwestern Carroll and northwestern Madison Counties. Samples from the deposits forwarded by Mr. Coleman and inspected in the Geological Survey contained crystalline salts consisting largely of potassium nitrate. The deposits were not examined by the Geological Survey, but information was received from the Armour Fertilizer Works to the effect that that company had expended considerable money in an investigation of them or similar deposits in that general region. As the result of these investigations it was concluded that the deposits are merely surface exudations on cliffs and ledges or in cavernous openings and that they do not extend to any considerable depth. Information about nitrate in this district, with samples, was also forwarded to the Geological Survey by Mr. E. A. Blunt, of Carthage, Mo., and Summit, Ark., in 1916 and 1918, and by Mr. J. L. Brooks, of Wichita, Kans., in 1917. At the request of the Geological Survey for information concerning the location of deposits in this district, the Granger-Kelley Lumber Co., of Eureka Springs, Ark., stated that the strongest indications of saltpeter in the district are in secs. 35 and 36, T. 19 N., R. 26 W., Madison County.

CARROLL COUNTY

[See Benton, Carroll, and Madison Counties]

JOHNSON COUNTY (?)

A sample of an incrustation, the soluble part of which is mainly potassium nitrate with some calcium nitrate, was received in the Geological Survey in 1918 from Mr. G. P. Cole, of Lamar, Ark. No information was furnished as to the locality from which the sample was obtained.

MADISON COUNTY

[See Benton, Carroll, and Madison Counties]

MARION COUNTY

[See also Baxter, Marion, Newton, and Stone Counties]

Niter or saltpeter is found in Marion and Newton Counties in caves of the limestone region.[16]

---

[13] Gale, H. S., Nitrate deposits: U. S. Geol. Survey Bull. 523, p. 11, 1912.

A sample consisting of a siliceous earth with probably 1 or 2 per cent of potassium was forwarded to the Geological Survey by P. W. Frost, of Flippin, Ark., in 1918 from the bluff along the White River.

NEWTON COUNTY

[See Baxter, Marion, Newton, and Stone Counties]

POPE COUNTY

An occurrence of nitrate near Ben Hur was reported to the Geological Survey in 1916 by E. H. Johnson, of Ben Hur, Ark.

SEARCY COUNTY

The occurrence of nitrate in a cave in Searcy County was reported to the Geological Survey in 1915 by G. W. Tones, of Des Moines, Iowa.

STONE COUNTY

[See Baxter, Marion, Newton, and Stone Counties]

CALIFORNIA

The Geological Survey has published two detailed reports relating to different nitrate deposits in California.[17] The individual deposits therein described are briefly reviewed in the following discussion by counties. (See pl. 3.)

IMPERIAL COUNTY

Bailey[18] records the occurrence of niter at Volcano, locations covering 4,800 acres having been made along the old beach lines of Lake Le Conte (the former high level of the Salton Sea), east of the Mud Volcanoes, in T. 10 S., R. 14 E., in Imperial County, formerly part of San Diego County. The few specimens brought in gave from 3 to 5 per cent of niter.

INYO COUNTY

The nitrate deposits in Inyo County are among those described in the two Geological Survey reports just cited. They include the Zabriskie area, extending 8 miles or more along the Amargosa Valley from the vicinity of Shoshone to Tecopa; the Resting Springs area, extending 1 mile west and 2 or 3 miles northeast of Resting Springs; the Tule Springs area, extending about 3 miles northeast from the vicinity of Tule Springs (Tule Holes on the map of the

[17] Noble, L. F., Mansfield, G. R., and others, Nitrate deposits in the Amargosa region of southeastern California: U. S. Geol. Survey Bull. 724, 1922. 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, 1931.

[18] Bailey, G. E., The saline deposits of California: California State Min. Bur. Bull. 24, pp. 178, 180, 1902. Cited by Gale, H. S., U. S. Geol. Survey Bull. 523, p. 27, 1912.

Avawatz Mountains quadrangle); the Upper Canyon field, extending about 2 miles northwest, north, and northeast of Acme (Morrison) siding, 5 miles south of Tecopa; the Confidence field, extending 10 miles northwestward along the west side of South Death Valley, beginning at a point near the old Confidence mill, about 20 miles by road northwest of Saratoga Springs; and the Furnace Creek area, between Ryan and the floor of Death Valley. All these localities are shown on the map of the Avawatz Mountains quadrangle except the Furnace Creek area, which is shown on that of the Furnace Creek quadrangle.

Zabriskie field.—The Zabriskie field,[19] with which should be included the Ratliff claims,[20] near Shoshone, lies in nearly horizontal lake beds of Quaternary age. The so-called deposits are chiefly of the caliche type, but some cave niter is present. The caliche, however, is very thin and spotty in its occurrence, being virtually absent over much of the area, and where present is with few exceptions of low grade. The lake beds are largely covered with wash, which is unfavorable for the accumulation of nitrate, and where exposed by dissection they generally form steep slopes, which are also unfavorable for nitrate. The cave deposits are negligible, and the field as a whole is one of the poorest examined.

Resting Springs and Tule Springs areas.—The Resting Springs and Tule Springs areas are underlain by upturned Tertiary strata similar to those of the Upper Canyon field, next described, but the areas of exposure are smaller and the nitrate showings poorer.

Upper Canyon field.—The Upper Canyon field, which lies partly also in San Bernardino County, contains the richest nitrate deposits thus far found in the United States. The nitrate occurs in the form of caliche, which lies as a blanket over upturned clay strata of Tertiary age and of nonmarine origin. These clays are in fact comparable to the playa clays that now occupy many desert valleys in California, but they have been deformed by crustal disturbances. The Upper Canyon field has been more intensively explored by the Geological Survey than any other nitrate field. Nevertheless, as noted in the Amargosa report,[21] the average nitrate content for the entire field was less than 3 per cent, and the available caliche covered only 98 acres. The neighboring Lower Canyon field, in San Bernardino County, could furnish an additional 70 acres underlain by caliche with comparable nitrate content. An estimate of the available tonnage that could be produced without regard to price from both fields taken together was 1,980 short tons. This amount is negligible in comparison with the usual needs of the country.

[19] Noble, L. F., Mansfield, G. R., and others, op. cit., pp. 61–67.
[20] Noble, L. F., op. cit., pp. 62–71.
[21] Noble, L. F., Mansfield, G. R., and others, op. cit., pp. 91, 92.

Confidence field.—The Confidence field[22] was explored sufficiently to give a fair idea of the variations in amount and character of caliche associated with many kinds of bedrock and of topography. The average nitrate content of the samples of caliche analyzed was less than 1.03 per cent. The richest sample taken in the Confidence Hills, which was also the richest sample taken in the entire Amargosa region, contained 15.63 per cent of sodium nitrate. This material was of the "blister" type, which is rare and very spotty in its distribution. Another sample of this type of caliche yielded only 1.99 per cent of nitrate. It was estimated that the largest quantity of this caliche that could be gathered from the entire field, even by careful hand work, would be less than 100 tons.

Furnace Creek area.—The Furnace Creek area[23] is one of the largest and most spectacular areas of Tertiary strata in the desert region. Enormous tracts of it are intricately carved into badlands, and at some places the beds form rounded hills which resemble the typical niter hills of the Amargosa region. The few field tests made in this area indicate that nitrate-bearing caliche is present at least here and there, but that, according to Noble's rating, its nitrate content is less than 2 per cent.

KERN COUNTY

A sample containing potassium nitrate, together with some other soluble salts, said to have been obtained from sec. 16, T. 32 S., R. 34 E., was forwarded to the Geological Survey in 1918 by Mr. P. H. Baker, of Tehachapi, Calif.

MERCED COUNTY

Hilgard[24] describes some places in California where nitrates occur in the soil in exceptional abundance. Such, for instance, is an alkali tract lying in the bottom of the Merced River in a local basin of impervious limestone surrounded by a low ridge which is only exceptionally overflowed by the river; so that even the salts that have bloomed out on the surface are not usually washed away. An analysis of this soil follows:

Analysis of alkaline soil from Merced Valley, Calif.

Soluble salts in 100 parts of soil crust	1.00
Sodium sulphate (Glauber's salt)	3.88
Sodium nitrate	10.72
Sodium carbonate (sal soda)	63.00
Sodium chloride (common salt)	1.21
Sodium phosphate	4.10

[22] Noble, L. F., Mansfield, G. R., and others, op. cit., pp. 51–59.
[23] Noble, L. F., op. cit., pp. 86–88.
[24] Hilgard, E. W., Alkali lands, irrigation, and drainage in their mutual relations: California Univ. Coll. Agr. Rept. for 1890, appendix, pp. 25–26, 1892. Cited by Gale, H. S., op. cit., p. 26.

MODOC COUNTY

Persistent reports of deposits of nitrate in Modoc County have come to the Geological Survey. The deposit most frequently mentioned is on Davis Creek near the south end of Goose Lake. Some reports state that when examinations were made in 1916 excellent samples were obtained from an old tunnel that had been driven about 65 feet underground. The tunnel has been cited as evidence that the nitrate occurs at depth and away from surface exposures, the age of the working and the cavelike conditions having evidently been overlooked. Specimens of the rock from the tunnel were a flow-banded lava, probably rhyolite. Available information regarding the occurrence indicates that it is of the type described as ledge or cave deposits and not of sufficient extent to be of commercial importance.

Incrustations of potassium nitrate have been found near Cedarville.[25]

RIVERSIDE COUNTY

Vivet Eye tract.—The Vivet Eye tract, in the Riverside Mountains 6 miles south of Vidal, has been described by Noble.[26] The nitrate here is associated with loose, powdery saline material occurring in small cavities in gypsite. The gypsite itself is practically barren of nitrate. The individual deposits of the saline material are small but from the tests made average about 7 per cent in nitrate content. If, however, all the loose material that could be gathered from the cavities were taken out and treated it would probably yield only a few tons of sodium nitrate.

Desert northeast of Salton.—The desert northeast of Salton is reported by Gilbert Bailey[27] to furnish occurrences of potash niter.

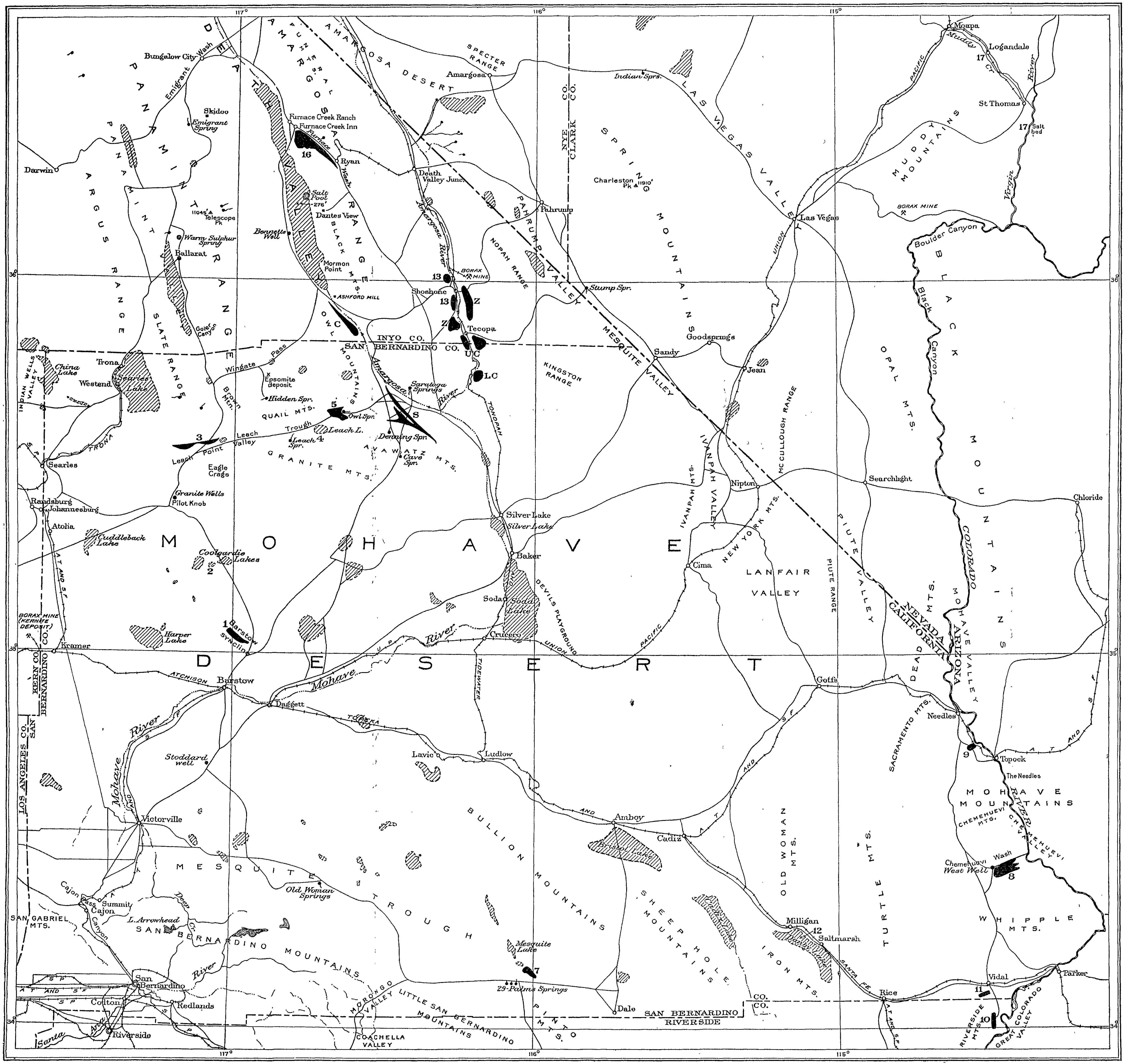
SAN BERNARDINO COUNTY

In the report on the Amargosa region[28] the following nitrate-bearing areas in San Bernardino County are described: Lower Canyon, Round Mountain, Salt Spring, Saratoga, Upper Canyon (southern part), and Valley. These areas are all included in the Avawatz Mountains quadrangle. (See also pl. 3.)

Lower Canyon field.—The Lower Canyon field[29] lies at Sperry, about 5 miles south of the Upper Canyon field. The caliche is unevenly distributed and on the basis of analyses made assayed 2.36 per cent in nitrate content. The more promising part of the field

---

[25] Eakle, A. S., Minerals of California: California State Min. Bur. Bull. 91, p. 245, 1923.
[26] Noble, L. F., op. cit., pp. 49–55.
[27] Bailey, G. E., op. cit., p. 169.
[28] Noble, L. F., Mansfield, G. R., and others, Nitrate deposits of the Amargosa region, southeastern California: U. S. Geol. Survey Bull. 724, 1922.
[29] Noble, L. F., and others, op. cit., pp. 85–88.



MAP OF NITRATE FIELDS IN CALIFORNIA

includes only 70 acres. A tonnage estimate of the Upper and Lower Canyon fields taken together has been given on page 24.

Southern part of Upper Canyon field.—The county line crosses the summit of Bully Hill, the richest portion of the Upper Canyon field. (For description of this field see Inyo County.)

Round Mountain field.—Round Mountain is a small hill in the middle of Owl Spring Wash about 2 miles northwest of the Saratoga field, of which it may be considered an extension. Although not specifically tested, no reason exists for supposing it superior in any way to the neighboring Saratoga field.

Salt Spring area.—The Salt Spring area extends a mile or more east of Salt Spring near the south end of South Death Valley. It is similar to the neighboring Saratoga field but less promising.

Saratoga field.—The Saratoga field [30] occupies a strip about 9 miles long on the northeast side of the Avawatz Mountains about 3 miles across Amargosa Valley from Saratoga Spring. It is divided into two nearly equal parts by the fan from Cave Spring Wash. This was the first of the Amargosa fields to receive intensive study, and, though only a small part of it was thus examined, the tests probably furnish a fair idea of its general character. The caliche proved to be discontinuous and patchy, and its nitrate content averaged less than 2 per cent.

Valley field.—About 10 miles northwest of Saratoga Spring Tertiary strata are exposed for a mile along the Amargosa River, whose saline waters are forced to the surface at this point apparently by the bedrock dam formed by the strata.[31] This area, which seemed less promising than the Saratoga field, was not tested.

Additional occurrences of nitrate in San Bernardino County are described by Noble [32] as follows: Barstow syncline, Beale, Coolgardie Lakes, Danby Lake, Leach Lake, Owl Spring, Pilot, Twentynine Palms, Vidal, and West Well. The locations of these areas are shown on Plate 3.

Barstow syncline.—The Barstow syncline [33] is about 9 miles south of Barstow in the Strontium Hills. The nitrate deposits are of the clay-hill caliche type but from tests made contain less than 2 per cent of nitrate and have no commercial value.

Beale area.—The Beale area,[34] 6 miles southeast of Needles along the Colorado River, includes some clay hills of relatively small extent that here and there contain caliche. None of this material when tested yielded as much as 3 per cent of sodium nitrate.

[30] Noble, L. F., and others, op. cit., pp. 31–51.
[31] Idem, pp. 21, 23.
[32] 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, 1931.
[33] Idem, pp. 5–8.
[34] Idem, p. 57.

Coolgardie Lakes.—The Coolgardie Lakes, in Superior Valley north of Barstow, comprise three playas surrounded by pre-Tertiary granite and Tertiary volcanic rocks. The middle one was tested to see if modern playas contain any significant amounts of nitrate. The surface material gave no reaction for nitrate; that a foot beneath the surface gave a weak reaction, and that 2 to 3 feet below the surface gave a very weak reaction. None of the material contained as much as 1 per cent of sodium nitrate.

Danby Lake.—The Danby Lake area,[35] which occupies part of Danby Basin, lies just west of Saltmarsh and Milligan, stations on the Atchison, Topeka & Santa Fe Railway. The surface of the lake is sufficiently saline to present a puffy appearance, and a bed of salt lies within about 8 feet of the surface. The surface material, the brines in the pits and test holes, and the underlying salt bed were all tested for nitrate but with negative results.

Leach Lake.—Leach Lake,[36] shown on the map of the Avawatz Mountains quadrangle about 15 miles southwest of Saratoga Spring, is a playa whose surface is saline enough to present in places a rough and puffy appearance. The tests made indicate that nitrate is widely distributed in the clay just under the surface of the lake but that the amount is small, averaging less than 1 per cent. The amount diminishes below a depth of 1 to 1½ feet, but the tests did not go below 3 feet.

Owl Spring nitrate field.—At the head of Owl Spring Wash, about 10 miles southwest of Saratoga Spring, there are discontinuous areas of upturned Tertiary beds exposed by the erosion of overlying later gravel. These areas harbor here and there small amounts of nitrate-bearing caliche which serve as the basis for designating the area as the Owl Spring nitrate field.[37] The tests, however, show that the caliche is in most places less than 5 inches thick and averages less than 1.5 per cent in nitrate content.

Pilot nitrate field.—A group of Tertiary beds exposed along the south side of the Slate Range about 15 miles southeast of Trona constitute the so-called Pilot nitrate field.[38] Only a small part of the Pilot field was explored, but the ground examined is believed to be fairly representative of the whole. None of the material tested contained as much as 2 per cent of sodium nitrate.

Twenty-nine Palms area.—About 50 miles east of San Bernardino, in the southern part of San Bernardino County, is a group of springs known as Twenty-nine Palms Springs,[39] near which are clay hills underlain by Tertiary strata that in some places carry nitrate caliche. The most promising of these hills as a source of nitrate caliche is

---

[35] Noble, L. F., op. cit., pp. 57–62.
[36] Idem, pp. 13–16.
[37] Idem, pp. 16–25.
[38] Idem, pp. 10–13.
[39] Idem, pp. 25–32.

Mud Hill, which is 2 miles N. 15° E. of Twenty-nine Palms Springs. This hill has been explored rather carefully, but the total area of outcrop in which the caliche occurs does not exceed 12 acres. The caliche is less than 8 inches thick, and the richest material available does not exceed 3 per cent in nitrate content.

Vidal tract.—The Vidal tract [40] is a clay-hill area about 2½ miles southwest of Vidal in which some clay has been mined. Some nitrate-bearing caliche is present, but upon testing none was found richer than about 1 per cent in nitrate content.

West Well tract.—The niter-bearing ground that constitutes the West Well tract [41] lies along the south side of Chemehuevi Wash between West Well and the Colorado River, chiefly in T. 4 N., R. 24 E. The area includes both the clay-hill caliche type of nitrate and the cave type, the latter in some Tertiary volcanic rocks that project above the clay hills and alluvium. Particular attention was paid to the "400-acre area," which contained the most promising nitrate deposits. The best of the reactions obtained in field tests of the caliche did not indicate the presence of as much as 3 per cent of sodium nitrate. In the volcanic rocks no reactions strong enough to justify systematic sampling were obtained.

Calico district.—Bailey [42] reports the occurrence of soda niter as crystals lining a cave in the Calico district.

TULARE COUNTY

The following analysis, quoted from Hilgard,[43] represents the soluble salts in an alkali crust at the San Joaquin Valley Agricultural Experiment Station, near Tulare City, Calif.:

Analysis of salts from locality near Tulare City, Calif.

Potassium sulphate	3.25
Sodium nitrate	16.40
Sodium sulphate	20.91
Sodium chloride	12.21
Sodium carbonate	27.02
Sodium phosphate	1.87
Organic matter	17.07
Ammonium carbonate	1.27
	100.00

SUMMARY FOR CALIFORNIA

In all the districts mentioned in the account just given for California, the more promising of which have been rather intensively

[40] Noble, L. F., op. cit., pp. 55–57.

[41] Idem, pp. 38–49.

[42] Bailey, G. E., op. cit., p. 169.

[43] Hilgard, E. W., Alkali lands, irrigation, and drainage in their mutual relations: California Univ. College Agr. Rept. for 1890, appendix, pp. 25–26, 1892.

explored for nitrate by the Geological Survey, no deposits that could be considered as having even remote possibilities of commercial use were found. Clearly Bailey's optimism with regard to many of the nitrate deposits that he reported [44] has not been justified by later examinations.

COLORADO

GENERAL FEATURES

The occurrence of nitrate salts in unusual amounts in Colorado soils, forming a type distinct from that of the "cave deposits," has been discussed by Headden.[45] These are assigned to the fixation and nitrification of atmospheric nitrogen by bacteria. The amounts available in the soils, as estimated by Headden, seem large and at first sight may be misleading, as possibly suggestive of the presence of commercial nitrates in the soils. It should be remembered, however, that the occurrence of these soil nitrates is spotty and, as far as recognized, very shallow, their depths being only a few inches at most. Gathering any such deposits and preparing them for the market on any considerable scale would involve the handling of large amounts of inert soil and would doubtless result in greater unit costs than those of nitrogen from by-product, synthetic, or other available sources. The soil nitrates are therefore not to be considered as commercial sources of nitrogen under any probable market conditions.

Nitric nitrogen has been reported by Stewart and Peterson [46] as widely distributed in the country rock in certain parts of Colorado and Utah. They state, for example, that

> Fifty-eight samples of Cretaceous shale were collected and analyzed for nitric nitrogen. These samples are representative of the Book Cliff section of Colorado and Utah from Grand Junction, Colo., to Emery, Utah, and include sections examined at Thompsons, Green River, Price, and Castledale, Utah, covering an area of country 250 miles long with an average width of 10 miles. * * * The shales are more highly impregnated with nitric nitrogen than even the Cretaceous sandstones. The highest—obtained near Grand Junction, Colo.—contained 1,700 parts per million of nitric nitrogen, which is equivalent to a little over 10 tons of sodium nitrate per acre to a depth of 6⅔ inches.

The authors cited recognize that though the total quantities of nitrate present in some areas are large, according to certain postulates, the concentrations are so low that the deposits themselves are unworkable. These authors consider the original rock as the source of the nitrogen.

---

[44] Bailey, G. E., op. cit.

[45] Headden, W. P., The occurrence and origin of nitrates in Colorado soils, some of their effects, and what they suggest: Colorado Sci. Soc. Proc., vol. 10, pp. 99–122, 1911. Cited by Gale, H. S., U. S. Geol. Survey Bull. 523, pp. 14, 15, 1912.

[46] Stewart, Robert, and Peterson, William, The nitric nitrogen content in the country rock: Utah Agr. Coll. Exper. Sta. Bull. 134, pp. 433, 458, 465, June, 1914.

The experience of the Geological Survey in its study of nitrate in different parts of the country throws doubt on this interpretation. It can not yet be stated positively that nitrates are not present in disseminated form throughout some layers or bodies of rock, but accumulating evidence points to surficial sources for and surficial accumulations of nitrates and in general to the operation of some organic agency. (See pp. 3–8.)

TELLER COUNTY (?)

A sample forwarded to the Geological Survey in 1916 by R. K. Thomas, of Cripple Creek, Colo., was found to consist chiefly of sodium nitrate mixed with a small amount of sodium chloride. Information was not given in regard to the locality from which the sample was obtained.

IDAHO

BANNOCK COUNTY

Pebble area.—In July, 1916, T. K. Gibson, of Pocatello, Idaho, reported the occurrence of a nitrate deposit in the Portneuf Mountains, about 6 miles southwest of Pebble station on the Oregon Short Line Railroad and about 45 miles southeast of Pocatello. Specimens sent to the Geological Survey laboratory proved to be crystals of practically pure potassium nitrate. In September of the same year the deposit was examined by H. S. Gale, from whose unpublished report the following account is largely taken.

The prospect is situated at the very summit of one of the higher ridges in the Cache National Forest, in a ledge of limestone that contains interbedded layers of sandy or cherty material. The ledge crops out with steep dip and northeasterly trend on the very top of the ridge. A massive outcrop of the ledge standing among thick timber has been naturally undermined by weathering into shallow cavelike depressions with overhanging ledges. In these depressions of a dense but locally much fractured rock was found an abundant coating of the white crystalline salt that had been proved to be nitrate. All about the ledge abundant refuse shows animal habitation of the caves as well as of crevices in the ledge, and a small amount of cave soil at the base of the ledge is undoubtedly rich in organic nitrogenous material of many different kinds. The total quantity of the clear white nitrate salt amounted to not more than a few pounds, although some excellent specimens of almost pure material were broken off the ledge.

The ledge containing the nitrate salts is composed of limestone with some siliceous layers but is not associated in any way with igneous rocks. It stands as a projection at the summit of a high slope, slightly above the soil line but so placed that nitrates could not be derived by gradual accumulation by leaching from overlying country rock and in such position that the tendency of ground moisture would be to carry all soluble substances down and away instead of up to form such deposits. There is no reason to suspect that this is a blossom or surface cropping of bedrock deposits below. The region is one of fairly abundant rainfall, for the records at Pocatello show an annual average of about 14 inches, and precipitation along these higher mountain slopes would be somewhat greater. The undersides of the ledges where the niter is found are in a shaded situation, with favorable conditions for moisture and aeration for the bacterial decomposition of the organic forms of nitrogen distributed, and there can be little doubt that most, if not all, of the nitrate salt found here has been produced in this manner. (See p. 5.) Doubtless the residue of the soluble nitrate salt still adhering to the ledge is but a small part of all the natural saltpeter that has been produced about the place, the rest having been carried off from time to time by the washing of the ledges by storm waters.

Downey.—A discovery of nitrate in secs. 22, 23, and 26, T. 12 S., R. 36 E., near Downey, was reported to the Geological Survey in 1917. A sample from that locality examined in the Geological Survey was found to consist of nearly pure potassium nitrate.

Niter post office.—The post office Niter owes its name to the discovery some years ago of a nitrate deposit near that place. According to Albert Duke, who in 1916 was postmaster at Niter, the deposit occurs in an ice cave on property that then belonged to John Dalton, of Grace, Idaho. Another deposit in the same general region was on the property of A. D. Bradfield, of Niter, whose place was in sec. 11, T. 11 S., R 40 E., about 2 miles southwest of Niter post office. Neither of these deposits has been examined by a Geological Survey representative, but from the available data they are undoubtedly of the cave type and are of no commercial significance.

BINGHAM COUNTY

Jones Creek.—A nitrate prospect in Jones Canyon in the NE. ¼ NW. ¼ sec. 13, T. 2 S., R. 38 E., in the Ammon quadrangle, was visited by the senior author in 1925. The canyon at this place is cut in massive beds of carboniferous limestone. The deposit occurs in a small cave near the bottom of the canyon that contains possibly 6 to 8 cubic feet of guano. Nitrate-bearing breccia, 2 or 3 square feet in area and about 6 inches thick, adheres to the side of the cave near the mouth. This is practically all the nitrate in sight, though originally 6 to 8 square feet of the wall appears to have been covered by the deposit. Much of it has been removed in the course of prospecting.

BLAINE COUNTY

Soldier deposit.—A number of samples of nitrate salts with accompanying pieces of country rock from a locality described as 9 miles east of Soldier, Idaho,[47] and 9 miles north of the railroad have been sent to the Geological Survey by Mr. John Finch. No examination of this locality has been made by the Geological Survey, but a study of the samples suggests that the nitrate is of the cave type. The Soldier deposits, so far as represented by the samples examined, appear to be largely free from chlorides and sulphates and to consist mainly of potassium nitrate, with less amounts of sodium and calcium nitrates.

BONNEVILLE COUNTY

Deposits east of Idaho Falls.—Robert N. Bell, former State inspector, mining department, Idaho, reported to the Geological Survey in 1916 the discovery of nitrate in the Caribou Mountains in Bonneville County. Some beautiful specimens of nitrate salts had been received from a new locality 28 miles east of Idaho Falls. The location is approximately in sec. 1, T. 2 N., R. 40 E. Boise meridian. A sample brought in weighed about 4 pounds and consisted of practically pure sodium nitrate, but it proved to occur in the form common in the West. The best specimen came from a place where the junction of vertical breaks in the lava bluffs had resulted in a shallow cave in which pack-rat guano had accumulated. The specimen of salts was pure white and granular. Other small caves showed thinner crusts of similar material at several places where open fractures penetrated the lava bluffs. Underlying this sheet of lava is a succession of very soft ash beds in different colors from rich brown to snow white, composed of fine unconsolidated ash and scoria. Specimens of these materials, however, on analysis yielded no appreciable amounts of the soluble salts of either potash or sodium.

CARIBOU COUNTY

Blue Jay Gulch.—In the SW. ¼ sec. 1, T. 7 S., R. 44 E., in the Lanes Creek quadrangle, there are some prospects for potassium nitrate that have been the subject of considerable local interest. They are located in Blue Jay Gulch, a short steep-sided ravine, which is cut mostly in Nugget sandstone, though Twin Creek limestone occupies the higher slopes on the east side. The prospects themselves are in the Nugget. A description of the occurrence has been published by the Geological Survey,[48] prepared in part from an unpublished

[47] Mansfield, G. R., Nitrate deposits in southern Idaho and eastern Oregon: U. S. Geol. Survey Bull. 620, pp. 28, 29, 1916.

[48] Mansfield, G. R., Geology, geography, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey Prof. Paper 152, pp. 349–351, 1927.

manuscript by H. S. Gale. An earlier account of this occurrence has been given by Stewart.[49] The deposits are of the cave type and of no commercial significance.

CLARK COUNTY

Deposits northeast of Dubois.—Specimens of white crystalline granular niter have been collected by H. T. Stearns, of the United States Geological Survey, from cracks and crevices in basalt at the backs of lava tunnels near the United States Sheep Experiment Station 6 miles northeast of Dubois.[50] When the niter is removed the cracks fill up again in the course of a year or two. The niter does not alter on exposure to air. Under the microscope it is homogeneous, with the usual optical properties. Upon analysis the specimens yielded 98.74 per cent of potassium nitrate and 1.74 per cent of sodium nitrate. These results indicate an unusually pure salt.

CUSTER COUNTY

A specimen containing potassium nitrate with a small amount of sodium sulphate, said to have been obtained from a locality near Challis, on Garden Creek, was forwarded to the Geological Survey in 1925 by Alex. Klug, of Challis, Idaho.

ELMORE COUNTY

Area north of King Hill.—Niter has been found in cavities and cellular material in volcanic tuff at a locality 30 miles north of King Hill, near Camas Prairie.[51] This locality may be in Camas County.

Area southeast of King Hill.—In October, 1925, the senior author, in company with W. B. Lang, of the Geological Survey, visited a reported occurrence of nitrate about 4 miles southeast of King Hill. The deposit occupied a recess or small cave at the base of a lava cliff on the Swiss Valley ranch (prune orchard), near the top of the valley wall, which here slopes rather gently southward and southwestward to the Snake River. The cave, which is only about 20 feet long, 4½ feet high, and 3 to 4 feet deep, formed part of the back of an old haystack yard which had been frequented by stock. Nitrate had accumulated in thin incrustations and seams in the roof of the cave. The total quantity available was small, probably only a bucketful or two. There was sufficient organic matter in cracks in the cliff alone to suggest a ready source for the nitrate. The lava cliffs continue for some miles along the edge of the valley wall in each direction, and it was reported that similar conditions exist at a number of other places along these cliffs.

---

[49] Stewart, Robert, The occurrence of potassium nitrate in western America: Am. Chem. Soc. Jour., vol. 33, pp. 1952–1954, 1911.

[50] Shannon, E. V., The minerals of Idaho: U. S. Nat. Mus. Bull. 131, pp. 439–440, 1926.

[51] Bell, R. N., Fifteenth annual report of the mining industry of Idaho, for 1913, p. 211, 1914.

FREMONT COUNTY

A sample said to have been obtained from the North Fork of the Snake River 2½ miles from Warm River station was forwarded to the Geological Survey in 1916 by Dan Jondahl, of Ashton, Idaho. It was found to consist essentially of calcium and potassium nitrates, with small amounts of sodium salts.

Specimens found to consist principally of potassium salts present as sulphates and nitrates with almost no chloride were forwarded to the Geological Survey in 1923 by Jesse R. Williams, of Chester, Idaho. According to Mr. Williams the samples were obtained from sec. 28, T. 8 N., R. 42 E., 6 miles east of St. Anthony, at Chester, Idaho.

OWYHEE COUNTY, IDAHO, AND MALHEUR COUNTY, OREG.

Homedale district.—Nitrate deposits in and near the canyon of Sucker Creek, Oreg., southwest of Homedale, Idaho, on both sides of the Oregon-Idaho State line, have been described in some detail, with analyses and a discussion of the origin of the nitrates, in an earlier report of the Geological Survey.[52] It is concluded in this report that the Homedale nitrate deposits, which occur in association with rhyolitic rocks, belong to the general group classed as cave deposits. With reference to the volume of nitrates present in the area the report states:

> The little veinlets that contain the nitrate form only a small part of the whole mass in the zones where the nitrates occur—probably not more than 1 per cent—and the same veinlets carry other substances than nitrates, as is shown by the analyses. When the rock fragments are picked down from the cliff face at any of the prospects described, fresh veinlets are exposed, similar in character, number, and thickness to those previously found. How far into the rock this condition continues it is impossible to say from present data, as none of the prospects have penetrated more than 3 or 4 feet from the cliff face. The present evidence does not preclude the possibility of finding an increase in the size and number of the nitrate-bearing veinlets, or perhaps even large veins, when the rock is opened further. There seems, however, little likelihood of any marked increase in richness within the interior of the rock mass. On the contrary, it appears more probable that the richest parts of the deposit are those already exposed in the faces and along the bases of the cliffs and that the material will be found to grow gradually leaner and perhaps to disappear altogether as the rock is penetrated. Whatever may have been the mode of origin of the material, it probably owes its present position to the action of percolating waters, on the one hand, and to evaporation, on the other. On that supposition the concentration of the deposit would naturally be greatest at or near the surface, where evaporation takes place. However, no positive statement can be made until more work has been done in opening the veinlet-bearing zones, both laterally and vertically.

In 1916–17, subsequent to the publication of the report cited, the American Nitrate Co. spent considerable time and money prospecting

[52] Mansfield, G. R., Nitrate deposits in southern Idaho and eastern Oregon: U. S. Geol. Survey Bull. 620, pp. 19–44, 1916.

this area. The results amply demonstrated the surficial character of the deposits and their commercial unworkability. (See p. 100.)

JACKSON COUNTY

Niter is reported [53] as occurring in caves in Jackson County and on Cave Creek.

INDIANA

CRAWFORD AND MONROE COUNTIES

Reference to the occurrence of niter earth in Wyandotte Cave, Crawford County, "similar to that used for the manufacture of saltpeter during the War of 1812," is made in an early report of the Geological Survey of Indiana.[54] An analysis of the material is quoted which shows an equivalent of 6.55 per cent of niter, and another analysis, of bat guano from this cave, is given as follows:

Aanalysis of bat guano from Wyandotte Cave, Indiana

Loss at read heat	44.10
Organic matter	4.90
Ammonia	4.25
Silica	6.13
Alumina	14.30
Ferric oxide	1.20
Lime	7.95
Magnesia	1.11
Sulphuric acid	5.21
Carbonic acid	3.77
Phosphoric acid	1.21
Chloride of alkalies and loss	5.87
	100.00

Potash and soda, though not separately determined, are probably included in the last item. The recovery of niter from the caves of Indiana is mentioned in a later report of the State geological survey [55] in the descriptions given of Saltpeter Cave, in Monroe County; Wyandotte Cave, in Crawford County; and Saltpeter Cave, in Crawford County.

HARRISON COUNTY

Niter occurs in caves in Harrison County.[56]

MONROE COUNTY

[See Crawford and Monroe Counties]

[53] Gale, H. S., Nitrate deposits: U. S. Geol. Survey Bull. 523, p. 11, 1912.
[54] Cox, E. T., Indiana Geol. Survey Eighth, Ninth, and Tenth Ann. Repts., p. 163, 1879.
[55] Blatchley, W. S., Indiana caves and their fauna: Indiana Geol. Survey Twenty-first Ann. Rept., pp. 136, 149–151, 173, 1896.
[56] Gale, H. S., op. cit., p. 11.

KENTUCKY

CARTER COUNTY

Information concerning deposits of saltpeter in the Saltpeter Cave and other caves in Carter County was received in 1917 from J. B. Eifort, of Olive Hill, Ky., and in 1918 from Paul Esselborn, of Portsmouth, Ohio.

EDMONSON COUNTY

Niter occurs in Mammoth Cave,[57] in Edmonson County, and in small quantities in hundreds of caves in limestone in the southern and central parts of the State.

MISSOURI

BARRY COUNTY

The occurrence of potassium nitrate in Barry County was reported in 1916 by E. A. Blunt, of Carthage, Mo.

CALLAWAY, MARIES, OZARK, AND PULASKI COUNTIES

Saltpeter has been found in caves in magnesian limestone in Callaway, Maries, Ozark, and Pulaski Counties.[58]

MONTANA

DEERLODGE AND RAVALLI COUNTIES

The occurrence of unusually large amounts of nitrates in soils near Anaconda, Deerlodge County, and near Victor, Ravalli County, was reported to the Geological Survey in 1917 by Edmund Burke, of Bozeman, Mont.

FERGUS COUNTY

A report of deposits of potassium nitrate "extending from the seams in a limestone escarpment in the Judith Mountains" was made to the Geological Survey in 1917 by R. W. Petre, of Baltimore, Md.

GALLATIN COUNTY

Nitrate deposits have been reported from a number of localities in the Gallatin Valley, especially in Tps. 8 and 9 S., R. 4 E. The deposits occur both in the main valley and in some of its tributaries—for example, Canyon, Elkhorn, and Sage Creeks. The best claim was said to be on the east side of the Gallatin opposite the mouth of Cinnamon Creek. The deposits in the Gallatin Valley were examined by D. D. Condit and E. H. Finch, of the Geological Survey, in 1916. The location of the principal deposits is shown in

[57] Gale, H. S., op. cit., p. 11.

[58] Idem, p. 11.

Figure 2. Most of the occurrences are in cliffs of Madison limestone, which are more or less common. A sample taken on Sage Creek came from the shaly horizon at about the position of the phosphate beds formerly included in the Quadrant formation but now assigned to the Phosphoria. The nitrate is of the cave type

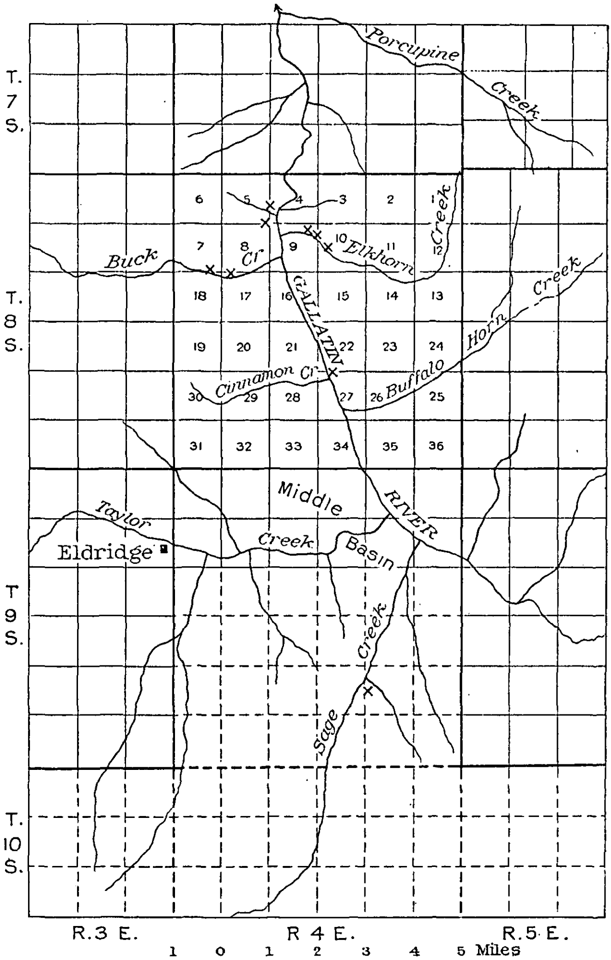


FIGURE 2.—Sketch map showing location of nitrate prospects in Tps. 8 and 9 S., R. 4 E., Gallatin Valley, Mont.

and contains impurities, including, among others, common salt and glauber salt (hydrous sodium sulphate).

RAVALLI COUNTY

[See Deerlodge and Ravalli Counties]

SILVER BOW COUNTY

A brief examination of a niter deposit about 3½ miles northeast of Melrose, occurring along the face of cliffs of black limestone on

Camp Creek, was made by R. W. Richards, of the Geological Survey, and a short report about it has been published.[59] The occurrence is essentially of the cave type.

NEVADA

CHURCHILL AND PERSHING COUNTIES

Deposits of nitrate salts in ledges and caves on the west slope of the Humboldt Range on Humboldt Lake, southwest of Lovelock, in Churchill and Pershing Counties, have been described by Gale.[60] The country rock is a much fractured rhyolite, and the deposits occur both in the fractures and as incrustations on the surfaces of ledges at places where they are overhung by higher masses. In a suite of 10 samples collected from more favorable ground only two contained significant amounts of nitrate, and these were both taken from rock crevices on a single claim of 160 acres. The nitrate occurs as sodium nitrate. Gale's suggested explanation of the occurrence is as follows:

> In explanation of the origin of the niter it is suggested, although admittedly far from conclusively proved, that the prominent headland that these ledges must have formed in Lake Lahonton [predecessor of Humboldt Lake] at or succeeding the period in which the rock bench was cut by wave action along the lake shore was probably inhabited by ducks, sea gulls, or other birds, possibly in large numbers, even as similar rocks are thus inhabited in Great Salt Lake to-day. Decomposition of organic matter in contact with alkaline material might account for the production and dissemination of nitrate salts, which may have penetrated widely the fissures and crevices of the much fractured rhyolite.

A sample of nitrate-bearing salt said to have come from a locality 2 miles south of Ocala, in Humboldt Valley, was forwarded to the Geological Survey in 1912 by C. T. Washeim, of Wadsworth, Nev.

CLARK COUNTY

Valleys of Muddy Creek and Virgin River.—The lower valley of Muddy Creek and the valley of the Virgin River [61] below St. Thomas contain exposures of Tertiary beds, some of which are eroded and weathered, with typical clay-hill nitrate areas. The few tests thus far made, however, have yielded only weak reactions for nitrate.

J. B. Jensen, of Goodsprings, Nev., reported the occurrence of nitrates west of Goodsprings in 1916.

CLARK COUNTY OR NYE COUNTY

A sample said to have been obtained from a locality near Tecopa, in Clark County or Nye County, was received in the Geological

---

[59] Richards, R. W., Niter near Melrose, Mont.: U. S. Geol. Survey Bull. 540, pp. 470–473, 1914.

[60] Gale, H. S., Nitrate deposits: U. S. Geol. Survey Bull. 523, pp. 19–23, 1912.

[61] Noble, L. F., Nitrate deposits in southeastern California, with notes on southeastern Arizona and southwestern New Mexico: U. S. Geol. Survey Bull. 820, p. 86, 1931.

Survey in 1917 from Telfair Creighton, Los Angeles, Calif. It was found to consist essentially of a mixture of potassium nitrate, calcium and magnesium sulphates, and dolomite, the soluble portion representing probably more than half of the sample.

ESMERALDA COUNTY

Fish Lake Valley.—On the east side of Fish Lake Valley[62] at the mouth of the canyon, through which a road descends from Emigrant Pass, are outcrops of tilted Tertiary clay beds on which small amounts of caliche have accumulated. A field test of this caliche yielded only a "fair" reaction for nitrate.

HUMBOLDT COUNTY

Soldier Meadows.—Nitrate claims near the Soldier Meadows ranch, in western Humboldt County, were examined by M. I. Goldman, of the Geological Survey, in November, 1914. The area examined is in Tps. 39 and 40 N., Rs. 24 and 25 E. The salts occur along the steep sides of the valley of the stream that flows by the ranch. They have accumulated in very much fractured and broken volcanic rock occupying an interval of 2 or 3 feet at the top of the talus beneath a cliff of rhyolitic lava. Nitrate salts, though undoubtedly present, are subordinate to sodium chloride and other salts, which include carbonates and perhaps some magnesium salts. The salts were purely superficial. Organic matter was scarce here, and in view of the general nature of the accumulated salts Mr. Goldman was inclined to consider the formation of the nitrates as possibly due to other causes, though he thought the accumulation of vegetation on the slope above the lava cliff might be a large factor. The deposit was obviously not of commercial value.

LINCOLN COUNTY

Nitrate deposits in Rose Valley, 15 miles from Pioche, were reported to the Geological Survey in 1921 by E. C. D. Marriage, of Pioche, Nev.

MINERAL COUNTY

An occurrence of nitrate 5 miles south of Rawhide was reported to the Geological Survey in 1918 by Frank Daniels, of Pasadena, Calif.

NYE COUNTY

Mention of prospecting activities for niter salts in some of the canyons bordering the west side of Railroad Valley, near the center of the State, is made by Gale.[63]

A sample consisting of nearly pure potassium nitrate was received in the Geological Survey in 1918 from R. A. Willick, of Ely, Nev.

---

[62] Noble, L. F., op. cit., p. 88.

[63] Gale, H. S., op. cit., p. 25.

The material was reported to have come from a locality 25 miles south of Kern Creek, on the west slope of the Kern Creek Range.

Some prospecting for nitrate was done in 1915 at a locality 3½ miles west of Amargosa.

PERSHING COUNTY

[See Churchill and Pershing Counties]

WASHOE COUNTY

An occurrence of potassium nitrate in the northern part of the Granite Range, in T. 37 N., R. 22 E., about 12 miles north of Gerlach, has been briefly described by Gale.[64] The niter salts occur under ledges and in cavelike cliff formations in a canyon on the upper waters of Grass Valley Creek, an upper tributary of Little Highrock Canyon. The niter is found as a white crystalline salt in crevices and concentrated in veins in the slide rock at the base of the cliffs, partly or wholly in positions protected from leaching by rain, snow, or surface waters. The country rock in the vicinity of the Gerlach niter prospects consists almost entirely of acidic volcanic lavas showing vesicular, ropy, and flow structure, exposed in many places in cliffs and ledges.

NEW MEXICO

DONA ANA COUNTY

Several successive correspondents in 1917–1919 called the attention of the Geological Survey to some nitrate deposits southeast of Las Cruces, N. Mex. Distances as given differ in the different communications, but so far as can be ascertained the inquiries relate chiefly to an occurrence in the S. ½ sec. 13, T. 24 S., R. 3 E., said to be in a spur of the Organ Mountains not far from the Atchison, Topeka & Santa Fe Railway. (See pl. 4, No. 14.) A good idea of the general nature of the occurrence is given in a letter from F. M. Hayner, of Las Cruces, N. Mex., dated February 1, 1919. He wrote as follows:

> East and south of Las Cruces about 15 miles is a tilted bed of tuff. The face of the bed is exposed as a cliff 200 to 300 feet high, and on the face of this cliff are found incrustations of a shell-like nature containing sodium nitrate. These shells have fallen off and formed deep beds all along the base of the cliff. I took a sample of the incrustation, and it analyzed 1.52 per cent. I then took a sample from some of the face of the cliff where the crust had been knocked off, and it showed 1.46 per cent sodium nitrate. I then put a shot in and got back 2 or 3 feet in the rock, and a sample of this analyzed sodium nitrate 1.88 per cent. I then went about 15 or 20 feet from the face of the cliff and just scooped up some of the material that formed the groundmass, and this analyzed 4.12 per cent sodium nitrate. I had these samples analyzed for potassium, and they showed 0.45, 0.65, and 0.30 per cent soluble K_2O.

[64] Gale, H. S., op. cit., pp. 23–25.

In places where the water has run near the cliff you can find the pure-white sodium crystals sometimes as thick as an inch. I have never made any exploration of the surrounding ground to see if there has been any general concentration further than mentioned above. * * * In some places where the cliff overhangs there are round pockets as big as a man's body with a part of a core left in the hole; looks a good deal like an enormous honeycomb.

These deposits had previously been brought to the attention of the Geological Survey by others, and N. H. Darton had visited them, though he had not had opportunity to examine them in detail. He estimated roughly that perhaps 200 tons of salts could be obtained by leaching out the material, but this operation would not pay under ordinary circumstances. Water is scarce, and the material is all sodium nitrate with little or no potash.

EDDY COUNTY

The so-called Lyon nitrate prospect, in Dark Canyon about 6 miles due east of Queen post office, Eddy County, N. Mex. (pl. 4, No. 15), has been described by Free.[65] The deposits occur in protected places on canyon walls on the eastern slope of the Guadalupe Mountains in a series of limestone and sandstone beds of marine origin. The nitrate occurs principally as a thin efflorescence on the surface of some of the strata. The average of the analyses of 28 samples taken to be representative of the rock rather than of the efflorescence was 1.16 per cent of potassium nitrate. Free concluded that the nitrate was probably of animal origin, that it was concentrated chiefly at and near the surface of the rocks, and that there was not enough of it to have commercial value.

HIDALGO COUNTY

Occurrences of nitrate salts seem to be numerous in western and southwestern Hidalgo County. At least three groups of claims have been brought to the attention of the Geological Survey. The first of these, near Rodeo, was examined in September, 1915, by H. S. Gale, whose hitherto unpublished account of them is given below.

CLAIMS NEAR RODEO, N. MEX., AND SAN SIMON, ARIZ.

The discovery of nitrate in the hills bordering the San Simon Valley near Rodeo, in the southwestern part of Hidalgo County, N. Mex., and San Simon, Cochise County, Ariz., is credited to Othello James and Cono Young, who, in December, 1912, are said to have first recognized the niter in ledges back of the Alexander James ranch, identifying it through accidentally throwing some of the substance into a fire. Mining claims were first located in this vicinity by Alexander James, Frank Jones, and Roy James, March 23, 1914. The approximate location of this group of claims is in sec. 9, T. 27 S., R. 20 W.

[65] Free, E. E., Report of a reconnaissance of the Lyon nitrate prospect near Queen, N. Mex.: U. S. Bur. Soils Circ. 62, 1912.

The report of the discovery reached Sacramento prospectors through the older Mr. James. The first assays of samples from the deposits were made by S. A. Gardanier, of the Douglas Assay Co., Douglas, Ariz. This group of claims lies north of the El Paso & Southwestern Railroad, northwest of Pratt station, and is distinct from the group of claims located near the town of Rodeo.

Later similar showings were found in the foothills of the mountains 3 to 5 miles east of Rodeo station, and a considerable group of claims has been located in that vicinity. This property is known as the Carothers group, although it was first located by C. B. Hayde, a prospector from Sacramento. These claims covered almost entirely the rugged mountain front that faces the San Simon Valley at this place. The Rodeo claims extend through secs. 13, 14, 22, 23, 26, 27, 28, 33, and 34 in T. 28 S., R. 21 W. [See pl. 4, No. 16.]

The San Simon Valley, in which Rodeo is situated, extends across the southern part of the boundary between New Mexico and Arizona, 20 or 25 miles north of the Mexican line. It is a broad, comparatively level plain bordered on either side by steeply rising mountains. These mountains are full of rocky escarpments, exposing ledges of volcanic flow rocks and interbedded tuffs.

Incrustations of nitrate salts have been found at several places in the cliffs that border the valley area. The principal showings occur in layers of porous tuff or ash where the outcrops are undercut and form cavelike recesses. Nitrate salts coat the surface of the rock in protected places and have also been deposited in seams and fractures within the rock, being distributed, no doubt, to a lesser extent throughout the somewhat porous portions of the deposits near the surface. Most of the samples derived from these deposits have been fragments of the ledges coated with a more or less heavy incrustation of the white crystalline material, which consists chiefly of the nitrates of sodium and potassium. Naturally such specimens show a high percentage of nitrate when analyzed.

Prospecting along the face of the ledges has, however, failed to show any continuous seam or deposit of nitrate salt, and although it is possible that a few hundred pounds of fairly rich nitrate-bearing material might be collected from the exposures, there is no satisfactory evidence to indicate that a larger deposit exists within the body of the rock. Practically no development to any considerable depth had been made at the time the deposits were visited, in September, 1915—in fact, there was little to indicate that such development would be warranted.

The occurrence is characteristically similar to many in other parts of the United States. There is little doubt that soluble nitrate salts in such occurrences are derived principally from the decomposition of organic matter at the surface, contained in the crevices of the rock or in cave soil that collects underneath the overhanging ledges at their base. The nitrate salt having been spread by capillarity in ground or surface water solutions is deposited as a crust of salt upon the evaporation of the water and happens to be preserved in certain places more protected than others. There appears to be no question whatever that if an attempt were made to quarry large quantities of this rock and leach them of the nitrate which they are supposed to contain, the amount of nitrate that would be found would be insignificantly small. No justification has been found for the idea that the showings at the surface of these ledges indicate larger deposits within the mass of the rock. Four samples, each containing from 2 to 3 pounds of material, were carefully quartered and representative portions ground for analysis. However, when 50 grams from each of these samples was extracted with water and the extract concentrated and tested for nitrates, only two of them gave a fair qualitative test and the other two were entirely negative. Of those showing the test the content of nitrate in either was estimated to be less than 0.1 per cent. It is obviously impracticable to consider any commercial operations upon such material as this.

This deposit was examined by Courtenay De Kalb, who has written an account of it entitled "Origin of nitrate."[66] His conclusions as to the value of the deposit were entirely negative. He reports the finding of concentrations in seams, samples of which did not, however, even in the richer specimens, exceed 6 per cent of sodium and potassium nitrate. For the most part the surface samples of the so-called deposits of nitrate yielded not over 1½ per cent of nitrates. Certain cemented zones within the detritus bordering gulches tributary to the San Simon Valley, containing evident soluble salts, carried from 1 to 2½ per cent of nitrate.

Mr. De Kalb's theory of the origin of these salts is that ammonia has been formed from the gases occluded with the volcanic materials in the deposits by combination with nitrogen of the air or that nitrogen and hydrogen in the volcanic emanations might have formed ammonia in the tuff itself, and that this may have oxidized to nitric acid within the volcanic tuff. From this acid the nitrate salts are supposed to have formed and, being taken into solution, to have come to the surface, where they have been deposited by evaporation of the water that held them in solution. However, this difference in opinion as to the origin of the deposit does not affect the conclusions as to its workability.

HUNGERFORD-MOORE CLAIMS

The second group of claims to which special attention has been given was the Hungerford-Moore group, about 20 miles up the Animas Valley, south of the station Animas on the El Paso & Southwestern Railroad. (See pl. 4, No. 17.) These were examined in November, 1918, by L. F. Noble,[67] of the Geological Survey. His findings, which have been published, show that the nitrate occurs in a volcanic breccia, which it impregnates to a considerable extent locally. The nitrate is of the "cave niter" type and entirely superficial. It is therefore of no commercial value.

FITCH CLAIMS

A third group of claims in the same general region was brought to the attention of the Geological Survey by Albert J. Fitch, of Hachita, N. Mex., who had located a deposit in secs. 12 and 13, T. 31 S., R. 19 W., and secs. 7 and 18, T. 31 S., R. 18 W., as nearly as he could judge. The locality is about 20 miles south of Animas station, in a small side canyon of Adobe Creek about halfway between the Double Adobe and O K ranches. (See pl. 4, No. 18.) According to his letter, dated November 12, 1918, the deposit is an agglomerate

outcropping in the center of the draw about a mile * * * from Adobe Creek and continuing for about a mile up the draw to the top of these low hills. The

[66] Min. and Sci. Press, vol. 112, pp. 663–664, 1916.

[67] 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, pp. 80–85, 1931.

lower end of the outcropping mass shows the most leaching, being very full of bugholes, which are lined to a considerable extent with the nitrate, appearing as though the boulders themselves had originally contained it and in their destruction left their value concentrated. * * * The boulders themselves have a very salty taste. At this point the outcrop is exposed some 15 feet high. In digging with a prospecting pick I dug up some broken pieces of pottery, giving evidence that it had been found before. Also the cattle have been using it for a lick for many years. The balance of the outcrop * * * shows, as far as I could determine, very little of the leaching and concentrating.

Samples sent in by Mr. Fitch were tested in the laboratory of the Geological Survey. Their content of soluble salts was low. The salts themselves were essentially mixtures of potassium and calcium nitrate with very little sodium or magnesium and a little of the chloride and sulphate radicles.

From the account given and the nature of the material there is little doubt that it is of similar type to the Rodeo or Hungerford-Moore deposits, though perhaps poorer, and is of no commercial value.

HIDALGO COUNTY (?)

Williams[68] states that nitrate of soda had been reported as occurring in the extreme southeastern [southwestern?] portion of New Mexico in considerable quantity. "It is deposited here by a few springs, the greater number being in the State of Chihuahua, Mexico, just across the boundary line." It is evident from the statement about the State of Chihuahua that Williams could not have meant the southeast corner of New Mexico, which there adjoins Texas.

SOCORRO COUNTY

DEPOSITS EAST OF LAVA STATION

J. R. De Mier, of Las Cruces, N. Mex., under date of July 3, 1918, wrote to the Director of the Geological Survey that between 1899 and 1902 he had shipped 800 tons of guano and 3,333 tons of phosphate of lime from

a series of tunnel caves 10 miles east of Lava station on the Santa Fe Railway. The caves originated from an old crater and extend for about a mile and a half south. They are covered with lava overflow, the roof being 20 to 30 feet thick. Here and there the roof has fallen, leaving long and short tunnels. The surface is practically level, accessible by teams everywhere. * * * I mined in one place about 125 tons of potassium nitrate that I blasted out. It looked like rock salt; was so pure it melted in the rocks and looked like thick sirup. * * * No work has been done there since 1902.

This locality is in the south-central part of Socorro County about 80 miles north of Las Cruces. (See pl. 4, No. 19.)

---

[68] Williams, Albert, U. S. Geol. Survey Mineral Resources for 1882, p. 599, 1883, cited by Gale, H. S., op. cit., p. 28.

DEPOSITS NEAR SOCORRO

In January, 1927, the Geological Survey received from E. E. Miller, of Kansas City, Mo., in behalf of his client Henry Fox, of Kansas City, a letter, together with samples and other data relative to nitrate claims in Socorro County, N. Mex., which were the subject of an application for lease by Mr. Fox. The claims centered on the joint corner of Tps. 3 and 4 S., Rs. 1 and 2 W., comprising secs. 36, 31, 1, and 6 of the townships named, and were about 8 miles southwest of the city of Socorro. (See pl. 4, No. 20.)

The rocks with which the nitrate was associated proved to be chiefly volcanic and to have the approximate composition of quartz latite or trachyte, some of their decomposition products being also present. The quantity of soluble and suspended matter in the water extracts of the 16 samples submitted was small, ranging from 0.70 to 3.20 per cent. The potassium nitrate content of the soluble salts was very low, barely exceeding traces of that substance. These results were at considerable variance with commercial analyses that were among the data submitted by Mr. Miller. These analyses, however, so far as indicated, did not represent identical samples and did not distinguish the potash in the soluble salts from the potash that was present in insoluble form as a constituent of the rock mass. Three of them which listed seven or eight constituents gave a K_2O content ranging from 8.01 to 9.56 per cent, but in the same analyses the N_2O_5 content ranged only from 0.02 to 1.29 per cent. Evidently most of the potash present was in insoluble form, probably in the mineral feldspar.

Although many processes have been evolved for the extraction of potash from feldspar and other silicates, none of these has yet been successful in producing potash cheaply enough to be marketed in competition with foreign potash. Moreover, even if such a process were to be devised there are many other occurrences of potash-bearing feldspar more favorably located than this one with respect to existing markets, and these would undoubtedly receive earlier attention. This deposit can therefore be said to have no present or early prospective value as a commercial source of either nitrate or potash.

In December, 1927, an inquiry was received at the Geological Survey from Julian Kent, of Albuquerque, N. Mex., relative to nitrate-bearing rocks in "what is designated by the United States Geological Survey as the 'sedimentary belt' adjoining the Magdalena area, Socorro County, N. Mex." The letter was accompanied by two samples of gray "sedimentary rock * * * which water-soluble tests show contain potassium as KNO_3 and K_2O." Mr. Kent further described his material as follows:

At the point where these samples were taken crystals of KNO_3, such as sample No. 1, are found incrusted on the outside in protected places. Sample

No. 2 was taken from the face of a drift 13 feet inside, the drift being cut at a point near the crystallization. Sample No. 1 was taken from a pocket 3 feet in the drift and was connected with the crystallization on the outside by a vein of soft chalky substance. After the pocket containing this sample No. 1 was carefully outlined and the rock containing crystal removed, a test was made of the substance near the pocket and yielded only a trace of potassium. The chalky vein to the outside yielded none. Sample No. 2 showed only a trace. Obviously the rock containing the threading of KNO_3 is of important value if located in quantity. It has not been found in quantity, and I am interested in having your opinion as to whether after finding such crystallization near the surface and then drifting 13 feet and finding it diminished to a bare trace, I would be justified in further exploration with a view to locating a bed or deposit.

When tested the samples submitted checked very well with Mr. Kent's findings. No. 1 contained small quantities of potassium nitrate attached to rock fragments, but No. 2 showed no appreciable amounts of either potash or nitrate. Mr. Kent had undoubtedly arrived at the solution of his own problem, for he had recognized that the nitrate supply diminished to about nothing within the distance covered by his drift. Needless to say further exploration of that deposit was not recommended.

NORTH CAROLINA

CHEROKEE COUNTY (?)

The occurrence of niter as crystalline crusts on mica slate "at Nantehaleh River, in Cherokee County," is noted in a list of minerals from North Carolina.[69] The Nantahala River is east of Cherokee County.

OHIO

TRUMBULL COUNTY

In July, 1916, a remarkable discovery of nitrate was reported to have been made on the Honsel homestead, in Farmington Township, Trumbull County, about 40 miles by road south of Ashtabula and 2 or 3 miles southwest of Bristolville Center. Nitrate crystals were reported to have been found embedded in clay at a depth of 20 feet in two dry holes bored with an auger for water. An occurrence of such an unusual type seemed to merit an investigation, and in October of the same year H. S. Gale, of the Geological Survey, visited the locality, and thereupon a new boring was made close to the other two. Although careful watch was kept of the materials brought up by the auger and these were tested from time to time by the brown-ring reaction method, Mr. Gale did not find any evidence of nitrate up to the time that he gave up the test. Nevertheless, at the end of the operation one of the workmen produced a

[69] Genth, F. A., and Kerr, W. C., The minerals and mineral localities of North Carolina: Geology of North Carolina, vol. 2, p. 81, 1885.

single small crystal of nitrate, which he claimed to have taken from the clay. Mr. Gale was not convinced by his manner and left the field with unresolved doubts regarding the authenticity of the crystal.

OREGON

CROOK AND DESCHUTES COUNTIES

The nitrate deposits described below lie in Crook and Deschutes Counties in secs. 32 and 33, T. 19 S., R. 19 E., and in secs. 4 and 5, T. 20 S., R. 19 E. Willamette meridian, about 53 miles southeast of Bend, Oreg. According to a report to the General Land Office made by Mineral Inspector H. R. Burrett, August 14, 1917, the nitrate in this district occurs in connection with ridges of "tufa" on which the rock is of varying degrees of hardness, the nitrate being associated with the softer portions of the rock. Although he examined only one deposit, Mr. Burrett was of the opinion that other deposits possibly even larger existed in the general region. He writes:

> This deposit is over a mile in length, with an average width of half a mile. It is tilted gently from the horizontal and rises as you go north from the south end, so that while the exposures on the south end appear to be poor and thin, on the north end they are good and comparatively thick * * * On the south end only about 20 inches of the nitrate-bearing material is seen, but on the north end there is about 6 feet. I had no way of estimating the total thickness of the deposit because even on the north end the bottom of it is not exposed. However, it appears certain that it would not be found in the valleys adjoining this deposit, because in Danielson's well, in the SE. ¼ sec. 32, T. 19 S., R. 19 E., which is sunk in the soil, the water is good, and if there were nitrates in quantity in this soil it is obvious that the water would be unfit to drink, and such is not the case. The nitrate-bearing area is probably at its highest 50 to 75 feet above the floor of the valley, so that underneath the indurated cap rock there is room for a larger deposit of nitrate-bearing material.

Mr. Burrett collected three samples, which were analyzed by the Bureau of Mines. One of these came from the NW. ¼ sec. 4, T. 20 S., R. 19 E., just beneath the "rim rock," and consisted of (surface?) material taken from 20 inches of pinkish-gray "tufa." Upon analysis it contained 1.7 per cent of NO_3. Another sample was taken about a quarter of a mile west of the center of sec. 5, T. 20 S., R. 19 E., at the end of a small tunnel 11 feet long and 2½ feet in cross section run in the soft rock just beneath the capping, all being volcanic material. This sample yielded only 0.9 of NO_3. The third sample was a composite of material taken from three vertical cuts 3 to 6 feet deep along the western border of the deposit and beneath the cap rock in the SW. ¼ sec. 32, T. 19 S., R. 19 E. This sample contained 5.7 per cent of NO_3.

At the time of transmitting his report Mr. Burrett had not received the analyses of his samples. When these were received, and especially after the occurrence had been viewed in the field by H. S. Gale, it became apparent that the nitrate was of the cave type and was of no commercial importance.

DESCHUTES COUNTY

[See Crook and Deschutes Counties]

HARNEY AND LAKE COUNTIES

Burns area.—Specimens of a siliceous rock incrusted and impregnated with potassium nitrate and a small amount of sodium nitrate were forwarded to the Geological Survey in 1917 by C. C. Lundy, of Burns, Oreg. The specimens were said to have been obtained from T. 23 S., R. 29 E. A description of nitrate prospects in Harney Basin furnished in 1918 by the Charles A. Newhall Co., of Seattle, Wash., contains information relative to nitrate claims at Warm Springs, about 4 miles southwest of Burns.

Wagontire Mountain.—Nitrates have been found in many places on and near Wagontire Mountain, in northeastern Lake County and contiguous portions of Harney County.[70] Streams have cut deep radiating gorges into the east, south, and west slopes, and in the sides of these gorges are almost continuous exposures of the rocks of which the mountain mass is composed. More resistant lavas form rim rocks extending for many miles. Where protection is afforded along the faces of these cliffs, in innumerable recesses at their bases, where they have been undercut, or where they rest upon the tuffs or less resistant lavas, nitrates and associated salts appear on the walls of the rocks, as a lining of caverns, in crevices, in the talus, and in the organic matter and dirt accumulated on the floors of caves, and in many places to an unanticipated extent they permeate the pores and vesicles of the rock itself.

The American Nitrate Co. did a considerable amount of prospecting for nitrates on Wagontire Mountain in 1916, and preliminary investigations of the possibility of extracting the nitrate salts on a commercial basis were carried on in 1917. (See p. 100.) The operations of this company included prospect tunneling and quarrying at many points along Lost Creek and successive radiating gulches about the southwest slope of the mountain, many chemical tests, and finally the construction of an experimental plant for the extraction and recovery of the nitrate. The company abandoned the Wagontire enterprise late in the summer of 1917 and dismantled the plant.

---

[70] Williams, I. A., manuscript report published in part under title Nitrate deposits of southeastern Oregon: Min. and Sci. Press, vol. 117, pp. 285–289, Aug. 31, 1918.

It is understood that the nitrates did not extend to any considerable depth and that the reason for indefinite suspension of the work was the failure of the investigations to prove the presence of a sufficient body of workable nitrate-bearing rock on which to found commercial nitrate production.

Sage Hen Creek.—The Charles A. Newhall Co. about 1916 reported nitrate prospects 5 miles up Sage Hen Creek from the Burns-Riley road, in which the nitrate is found as streaks and pockets in a gray-white volcanic rock. The rock seems to be made up of grains of volcanic ash and fragments of lava that have been partly melted and stuck together, giving a porous mass that takes up and holds water like a sponge. Nitrate occurs only in the spongy portions of the rock. According to the report of this company nitrate occurs in similar manner along the walls of Buzzard Canyon, a deep winding cleft in the lava rock southwest of Harney Lake. The American Nitrate Co. in 1916–17 did considerable prospecting in this canyon in T. 28 S., R. 28 E., Willamette meridian, and also on the so-called Rawhide claims in T. 29 S., R. 26 E. (See p. 100.)

LAKE COUNTY

[See also Harney and Lake Counties]

Warner Lake region.—In the Warner Lake region the front of the great fault scarp that borders the Warner Valley on the east rises precipitously for the most part to a height of 1,600 to 1,800 feet above the level of the lakes.[71] Nitrate claims have been filed upon ground extending along the base of these cliffs on the east side of the Warner Valley for a distance of 12 miles. The principal traces of nitrates are said to have been found in the reddish scoriaceous rocks that crop out from 500 to 700 feet above the level of the lakes. Samples obtained from this area by Mr. Williams, however, showed scarcely a trace of nitrates.

LANE COUNTY

Stafford [72] reports on the presence of niter in Oregon substantially as follows: Saltpeter is reported in marsh deposits of southeastern Oregon and, it has been claimed, in quantities sufficient to justify extraction. A very interesting occurrence is noted near Mount June, southern Lane County, where a ledge of earthy material carrying large quantities of niter is exposed.

---

[71] Williams, I. A., op. cit., p. 287.

[72] Stafford, O. F., Mineral resources and mineral industry of Oregon for 1903: Univ. Oregon Bull., new ser., vol. 1, No. 4, p. 105, 1904.

MALHEUR COUNTY

[See also Owyhee County, Idaho, and Malheur County, Oreg.]

Owyhee River.—In northern Malheur County deposits of nitrate salts have been found at several places in the canyon of the Owyhee River both above and below the Watson post office.[73] The salts appear at the base of a northward-facing vertical cliff of rhyolite and rhyolitic tuff probably 100 feet high. For a distance of 100 to 150 feet along the face and for several feet above the upper border of the talus every protected reentrant and particularly the walls of a series of undercut caverns are heavily coated with a whitish efflorescence of what proved to be chiefly sodium nitrate.

Samples containing potassium nitrate have been obtained from the vicinity of Duncan Bridge, on the Owyhee River.[74]

A sample found to consist principally of sodium nitrate, with some sodium sulphate, was forwarded to the Geological Survey in 1925 by W. C. Frazier, of Nampa, Idaho, who stated that it was obtained from a locality "about 40 miles up the Owyhee River, just over the Idaho line."

Vale area.—Reported occurrences of nitrates in Tps. 18 and 19 S., R. 45 E., near Vale, Oreg., were briefly examined by H. S. Gale in 1917. They lie at the base of a sandstone cliff estimated to be about 40 to 50 feet high, almost a vertical bluff capped by a cross-bedded conglomerate at the top. The soil at the base of this cliff gave a good brown-ring test for nitrate, even where dug to a depth of several feet, but samples taken from the fresh sandstone failed to give any test for nitrate. It was the opinion of Mr. Gale that material from this locality could not be mined or quarried in any quantity that would yield on an average more than a very small fraction of 1 per cent of nitrate salts.

McDermitt deposit.—The so-called McDermitt deposit is in T. 40 S., R. 41 E., in southwestern Malheur County, only a few miles north of McDermitt, Nev. The salts occur in a band along Cottonwood Creek from the SE. ¼ sec. 20 through the south quarters of secs. 21 and 22. They were examined by M. I. Goldman, of the Geological Survey, in November, 1914. They have accumulated at the surface of a porous layer forming the base of the canyon wall. The salts vary in composition from place to place with local conditions, but sulphates are commonly associated with the nitrates. Sufficient organic matter was in sight to account easily for the presence of the nitrates.

---

[73] Williams, I. A., op. cit., p. 286.
[74] Idem, p. 286.

UMATILLA COUNTY (?)

Samples of earthy material containing nitrates were received in the Geological Survey in 1918 from Perry Houser, of Pilot Rock, Oreg. The locality from which the samples were obtained was not given.

PENNSYLVANIA

TIOGA COUNTY

The results of an examination of what was reported to be a mountain of potash near Davis station have been described by the Bureau of Topographic and Geologic Survey of Pennsylvania.[75] Efforts of the Pennsylvania Geological Survey to obtain evidence of the occurrence of potash in more than the most meager quantity have proved fruitless.

WESTMORELAND COUNTY

An occurrence of nitrate on Chestnut Ridge, about 12 miles southeast of Greensburg and about 2 miles from Whitney, was reported to the Geological Survey in 1919 by William Best, of Pittsburg, Pa. Specimens from this locality, which were inspected in the Geological Survey, were found to consist of sandstone with thin incrustations of potassium nitrate.

TENNESSEE

The occurrence of niter in caves in the limestone region of Tennessee has been noted in publications of the Geological Survey.[76] A special investigation of 109 caves and rock shelters in the eastern part of middle Tennessee to determine their value as possible sources of nitrate was made by Thomas L. Bailey, of the Tennessee Geological Survey, in 1917, with negative results. A report of these investigations was published by the State.[77]

TEXAS

The field work on the deposits in Texas described in this report was done chiefly in 1916 to 1918 under the direction of H. S. Gale, who himself examined those in the vicinity of San Saba. In that period other deposits were studied by H. M. Robinson, from whose reports, together with that of Mr. Gale and the report by W. B.

[75] Stone, R. W., Potash fiasco in Tioga County, Pa.: Pennsylvania Bur. Top. and Geol. Survey Bull. 58, 1922.

[76] Williams, Albert, List of useful minerals of the United States: U. S. Geol. Survey Mineral Resources, 1887, pp. 688–810, 1888. Gale, H. S., op. cit., p. 11. Schrader, F. C., and others, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 286, 1916.

[77] Bailey, T. L., Report on the caves of the eastern Highland Rim and Cumberland Mountains: Resources of Tennessee, vol. 8, pp. 85–142, Tennessee Geol. Survey, 1918.

Lang on deposits in Hudspeth County in the vicinity of Van Horn, visited by him in 1929, the present account is mainly compiled. In June, 1928, G. R. Mansfield and J. W. Vanderwilt visited the San Saba occurrences and some others in Presidio County. Inquiry at Alpine and Marfa developed the fact that little activity had taken place during the 10-year interval at the other localities previously studied in the general region. It was therefore considered unnecessary to visit them.

BREWSTER COUNTY

Green Gulch area.—According to Mr. Robinson, the Green Gulch locality, which is in section 32, block 10, Houston & Texas Central Railroad survey (No. 1, pl. 4), is about 78 miles almost due south of Marathon, the nearest town on the Southern Pacific Railroad. It is possible to travel by automobile to Government Spring (pl. 5), but thence to the locality of the prospects, a distance of about 7 miles, the trip can best be made on horseback.

There is one spring in Green Gulch (pl. 5) that supplies enough water for the cattle and horses that graze here. This spring is within a mile of station 3 (fig. 3), but it is doubtful if there is enough water there for other uses than drinking.

According to Udden,[78] the rock above Oak Canyon, which is part of the rock mass that is near the prospects at station 1 (pl. 5), "may be called a quartz porphyry." This rock mass is thought by Udden to be intrusive, but other rock masses of the Chisos Mountains near this same general area are classed by him as lava flows.[79]

Station 3a (fig. 3) is a prospect pit about 20 feet deep, the bottom of which is in gray clay containing numerous siliceous concretions. Station 4 is a prospect pit about 20 feet deep, the walls of which appeared to be made up of loose blocks of a quartz porphyry or rhyolite. Station 5 is a prospect pit approximately 70 feet deep, which has been opened up by the side of a cliff of quartz porphyry. The dump from this prospect contained fragments of quartz porphyry and clay. No nitrate was found in any of these prospects.

In addition to the prospects described above, several other prospect pits are said to have been dug in Green Gulch. Nitrate has been reported from one or two of these pits, but other, probably more reliable reports deny this statement. When Mr. Robinson was in this region he visited all the prospects whose exact location was known to guides that had lived in that country for many years. No nitrate was found in the prospects examined in Green Gulch, and it is improbable that any nitrate has been found in this locality.

---

[78] Udden, J. A., A sketch of the geology of the Chisos country, Brewster County, Tex.: Texas Univ. Bull. 93, p. 71, 1907.

[79] Idem, p. 75.

Alum Cave, Chisos Mountains.—Alum Cave is about 18 miles southwest of Government Spring by horseback trail and 3 miles southwest of the Green Gulch locality, just described. (See pl. 4, No. 2, and pl. 5.) There is a wagon road from Terlingua to a point just below Alum Cave in Blue Creek, and there is a well-traveled road

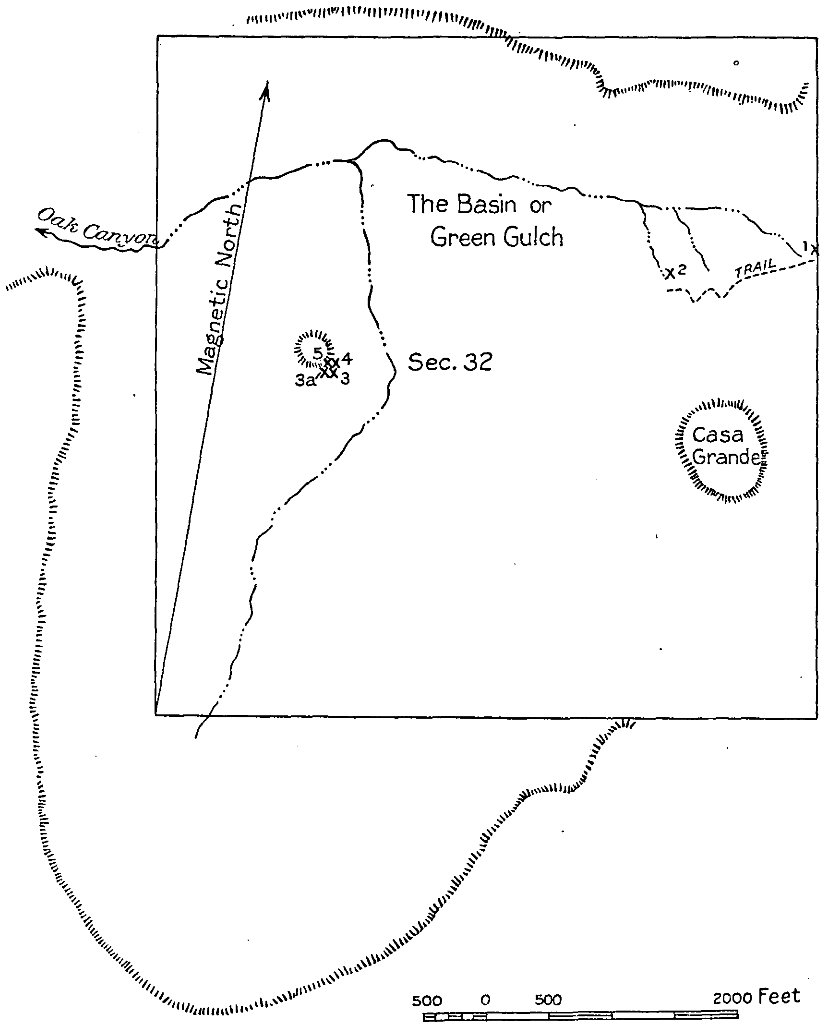


FIGURE 3.—Map showing location of nitrate occurrences in section 32, block 10, Houston & Texas Central Railroad survey, Brewster County, Tex.

from Terlingua to either Alpine or Marathon. The distance by road from Alum Cave to Marathon or Alpine by way of Terlingua, is about 100 miles. Cedar Spring (pl. 5) is about 1½ miles from Alum Cave and can be reached by a trail easily traveled on horseback. When the locality was visited, August 30, 1918, there was enough water in the spring for the animals grazing in that vicinity and enough for camp uses.

Alum Cave (station 2, pl. 5) measures about 75 feet across its base, 40 feet from floor to roof at the mouth, and about 40 feet from mouth to face. This cave lies at the base of a cliff of igneous rock over 800 feet high and is in a brecciated phase of the rock. The igneous rock appears to be rhyolite, and the cave may be in a contact zone between igneous and sedimentary rock. In this same neighborhood there are several other caves, some of which were visited. They seemed to be all more or less alike. On the walls of one of the largest caves a white incrustation was noted that had a biting taste and would not burn or sputter when heated in the flame. There was only a small amount of this material, and its behavior was unlike that of nitrate. There is evidently no commercial nitrate in these caves.

Prospect in section 6, block G–1, "D. & W." Railroad survey.—The nitrate prospect here described lies about 57 miles by road southeast of Marathon. (See pl. 4, No. 3, and pl. 6.) When it was visited by H. M. Robinson there was no surface water in the immediate vicinity suitable for drinking. The prospect is in sandy white limestone that occurs in massive beds 10 to 20 feet thick and is overlain by thin-bedded limestone and shale. Some of the shaly beds are lenticular and more or less brecciated. Igneous rocks in sheetlike masses, dark gray to black, cap many of the near-by hills. The prospect is an opening cut about 50 feet along a small bluff that faces east and about 5 to 10 feet back from the face. It is said to have been made about three years prior to the time of Mr. Robinson's examination. He searched particularly for nitrate but found none.

Agua Fria Spring, section 2, block 15, Galveston, Harrisburg & San Antonio Railroad survey.—The Agua Fria Spring locality is among those that have figured in press reports from time to time. It received considerable publicity as late as March, 1925, when efforts were being made to advertise and to finance it as a great deposit of nitrate. These efforts failed. In fact, little actual work has been done there since Mr. Robinson's visit in 1918.

By air line the Agua Fria nitrate deposit is about 58 miles almost due south from Alpine, the county seat of Brewster County. (See pl. 4, No. 4.) The distance by automobile road is about 70 miles. The detailed location with respect to topographic features and land lines is shown in Plate 7 and Figure 4. Agua Fria Spring, as the name implies, has a strong flow of cold water which, according to local reports, never goes dry. The locality is thus very fortunately situated with respect to running water, for the surrounding country is very dry, and running water in a stream bed is the exception, not the rule.

The rocks exposed at the surface on the top of Agua Fria Mountain above the spring were not examined but appear to be igneous. A short distance west of the spring sedimentary clays crop out, and except for dikes in scattered localities the rocks for several miles northeast of the deposit along the Alpine Road are sedimentary and are tentatively considered of Upper Cretaceous age.

Incrustations of nitrate one-eighth to one-half inch thick are found on the walls and in small pockets or beds in the rock near the

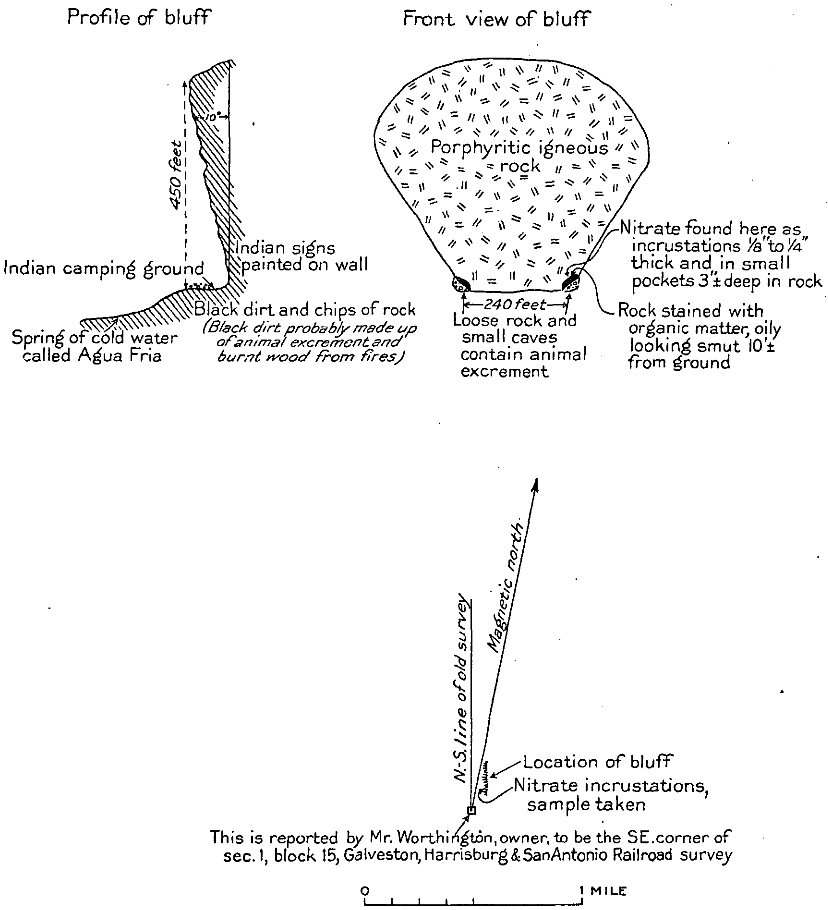


FIGURE 4.—Map and diagrams of Agua Fria nitrate deposit, near the southeast corner of section 1, block 15, Galveston, Harrisburg & San Antonio Railroad survey, Brewster County, Tex.

base of the bluff, just east of Agua Fria Spring. The rocks on which they occur are igneous and have been determined by E. S. Larsen, of the Geological Survey, as soda rhyolite. The bluff is approximately 450 feet high and hangs over enough to protect its lower part from rain and running water. Large blocks have broken down from the sides and have formed recesses or half caves at the sides of the bluff near the base. These recesses have apparently made very desirable dens for animals and may also have been used by Indians. The ground at the foot of the bluff here is black with organic matter made up largely of camp refuse and animal excreta, and the rock wall is ornamented with figures made with red paint, commonly supposed to be the work of Indians. The excellent spring of water and the overhanging bluff no doubt made an attractive camp site for the Indians, and the amount of organic matter now in sight at the foot of the bluff implies that the locality was very popular. The oxidation of organic matter, aided by the action of bacteria, is commonly thought to be the process that has formed the nitrate in many localities in the United States. With the abundance of organic matter in sight at this locality it does not seem necessary to look elsewhere for a source for the nitrate. This means that the nitrate found here is restricted to the surface, and except in small cracks near the surface the rock itself will be found barren of nitrates.

Samples of the incrustation and of the associated rock apparently free from incrustation were analyzed in the laboratory of the Geological Survey by E. T. Erickson with the following results:

Sample 1 (incrustation): Powder purified by filtration from water solution, evaporated, and dried at 180°–200° C. —K, 34.45 per cent; NO_3, 53.30 per cent.

Sample 2 (rock apparently free from incrustation):

	Per cent
K (water-soluble) in whole sample	0.666
NO_3 in whole sample	1.333
Total soluble salts at 180°–200° C	3.135
K in total soluble salts	21.24
NO_3 in total soluble salts	36.14

The analyses of the incrusted material show that it is largely potassium nitrate, whereas the rock on which the incrustation lies contains less than 2 per cent of this material. It is believed that this 2 per cent represents nitrate that has found its way into small cracks in the rock by contamination from the principal incrustation and that the rock itself is essentially barren. Mr. Robinson estimated the amount of incrusted material in sight at this locality at less than 100 pounds. As the rock on which the incrustation lies contains little or no nitrate, it is evident that the deposit as a whole is without commercial possibilities.

Section 38, block 332, Texas Central Railroad survey.—In May, 1918, Bert Anderson, of Granger, Tex., wrote to the Secretary of War that he had "some samples of an explosive taken from a mine" in Texas. This mine proved to be a cave, for in another letter he wrote: "In the mountains of Brewster County, Tex., about 60 miles south of Alpine, this material was found in a cave; it was also found in some other places in the same vicinity." Upon request, he supplied a sample, which was submitted for analysis to the Picatinny Arsenal, Dover, N. J. It must have been a "selected" sample rather than "a fair average sample of the deposit," for upon analysis by several methods it yielded 95.26 per cent of potassium nitrate (KNO_3). The Geological Survey was asked by the War Department to investigate the occurrence, and in July, 1918, H. M. Robin-

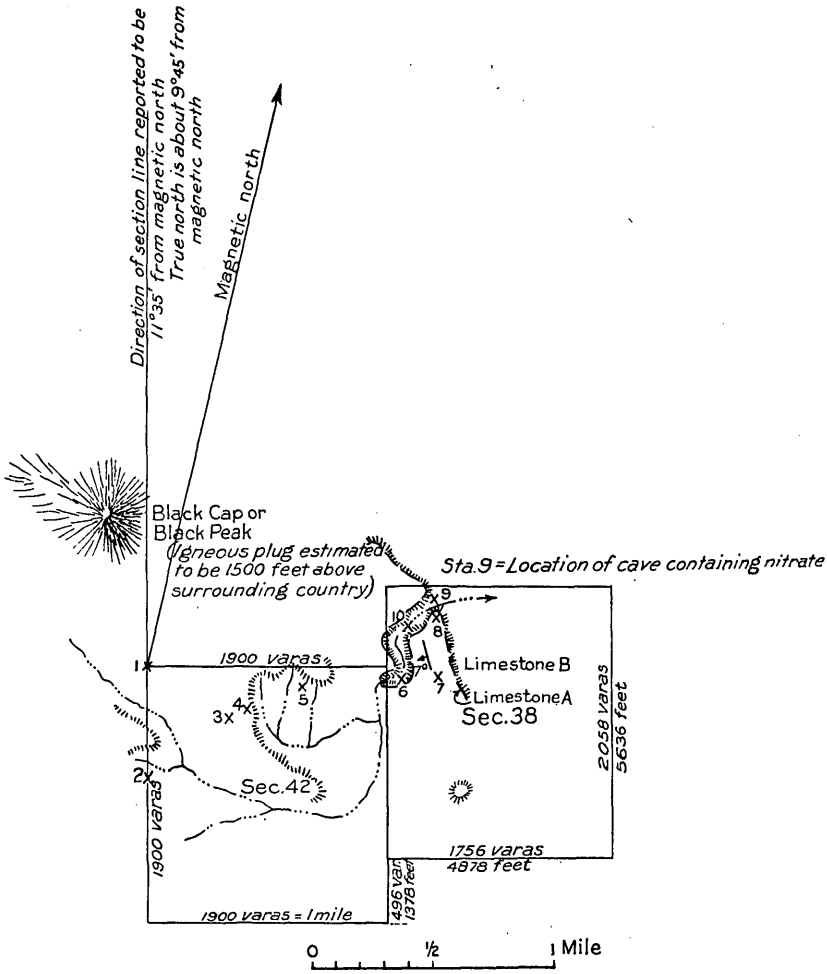


FIGURE 5.—Map of nitrate deposit in section 38, block 332, Texas Central Railroad survey, Brewster County, Tex.

son, in company with C. H. Parsons, of Granger, Tex., an associate of Anderson, visited the locality.

The nitrate deposit lies about 50 miles in an air line southeast of Alpine, Tex., but by fair automobile road it is 60 to 70 miles from Alpine and about the same distance from Marathon, Tex. Both towns are on the Southern Pacific Railroad. (See pl. 4, No. 5.) The region in the vicinity of the deposit is shown in greater detail

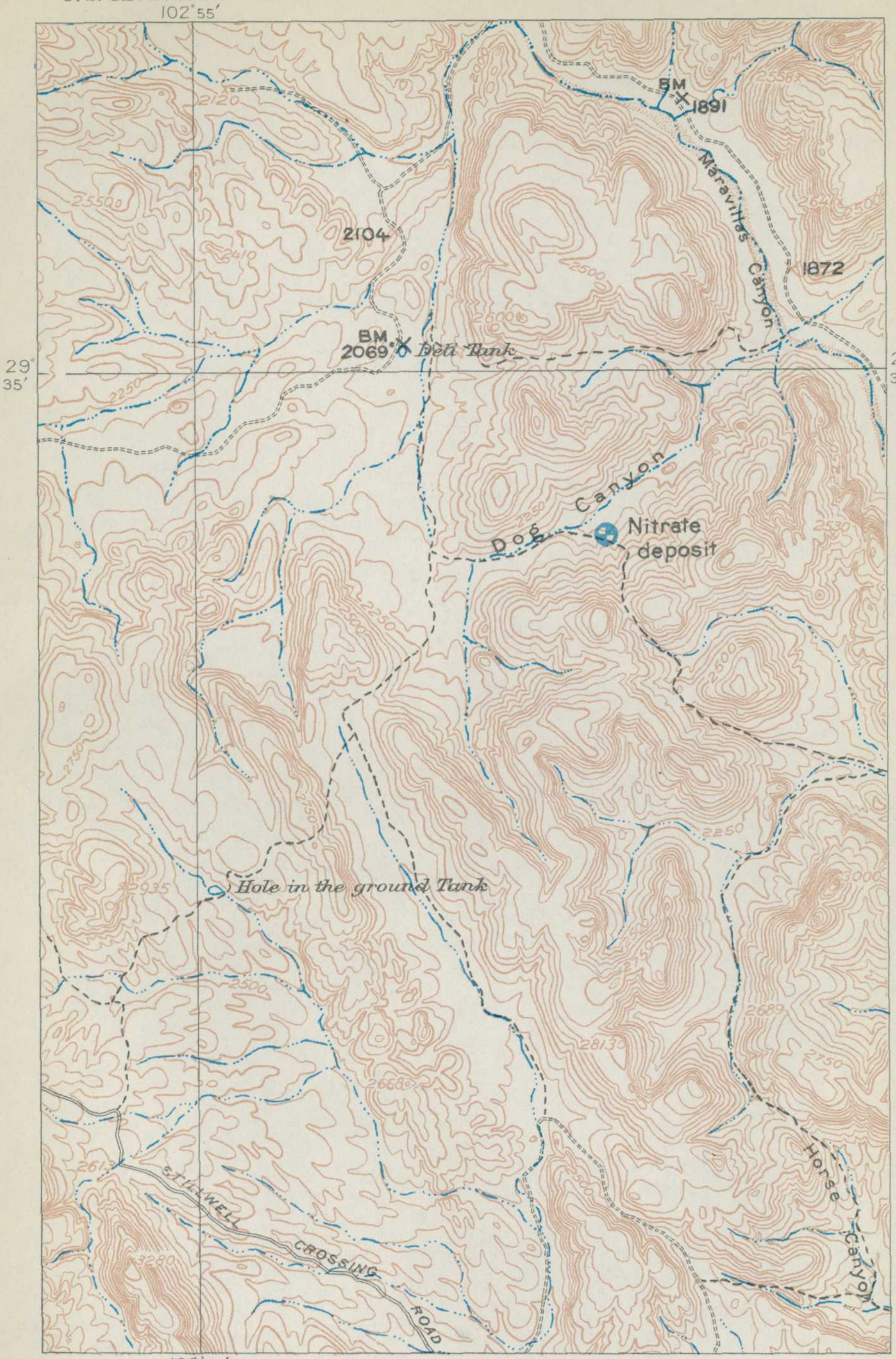
MAP OF PART OF CHISOS MOUNTAINS QUADRANGLE, BREWSTER COUNTY, TEXAS

1 0 1 5 Miles

Contour interval 100 feet
Datum is mean sea level

Nitrate deposit described in text

1932



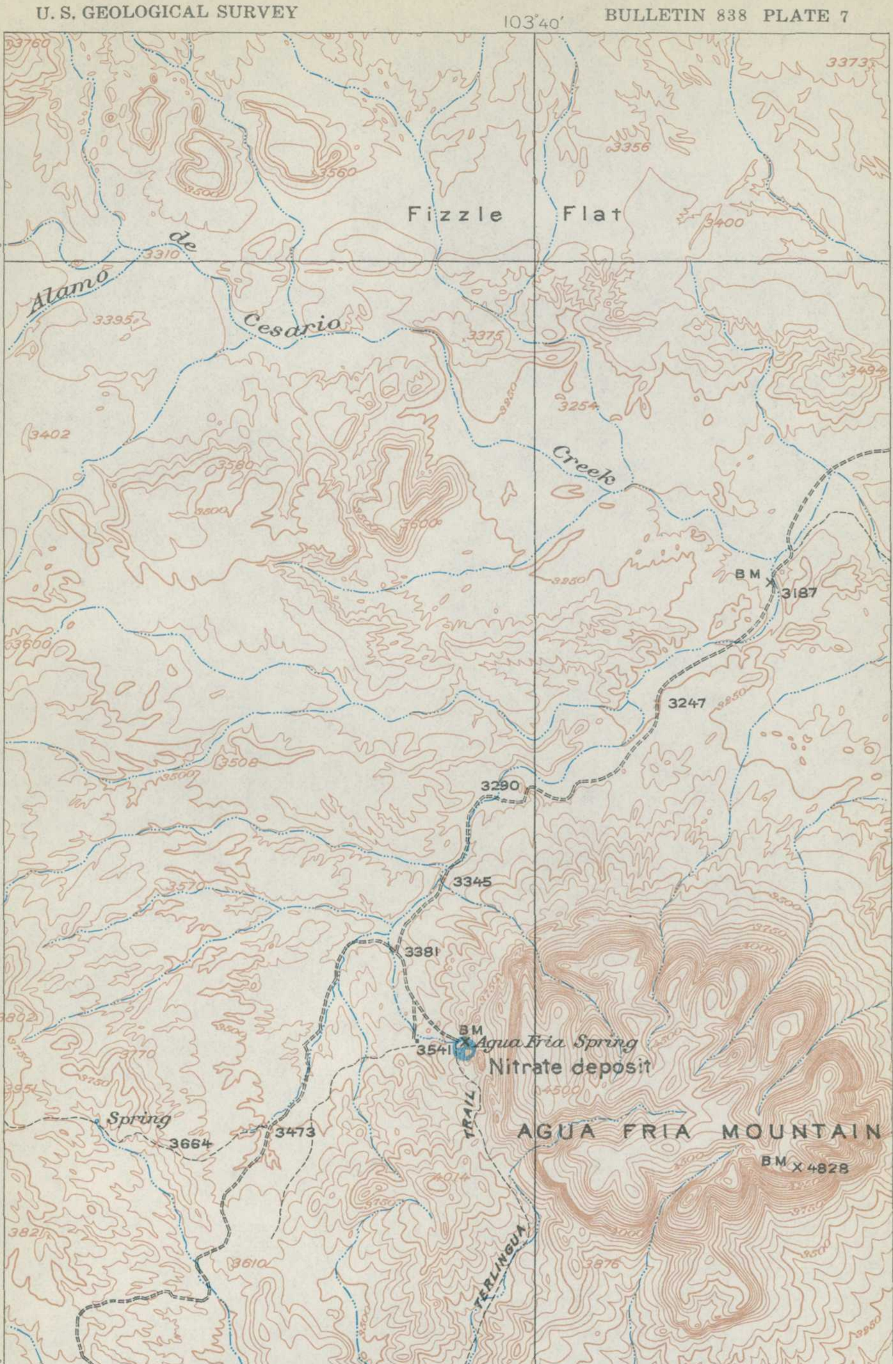
MAP OF PART OF MARAVILLAS CANYON QUADRANGLE, BREWSTER COUNTY, TEXAS

1 0 1 Mile

Contour interval 50 feet

Datum is mean sea level

1932

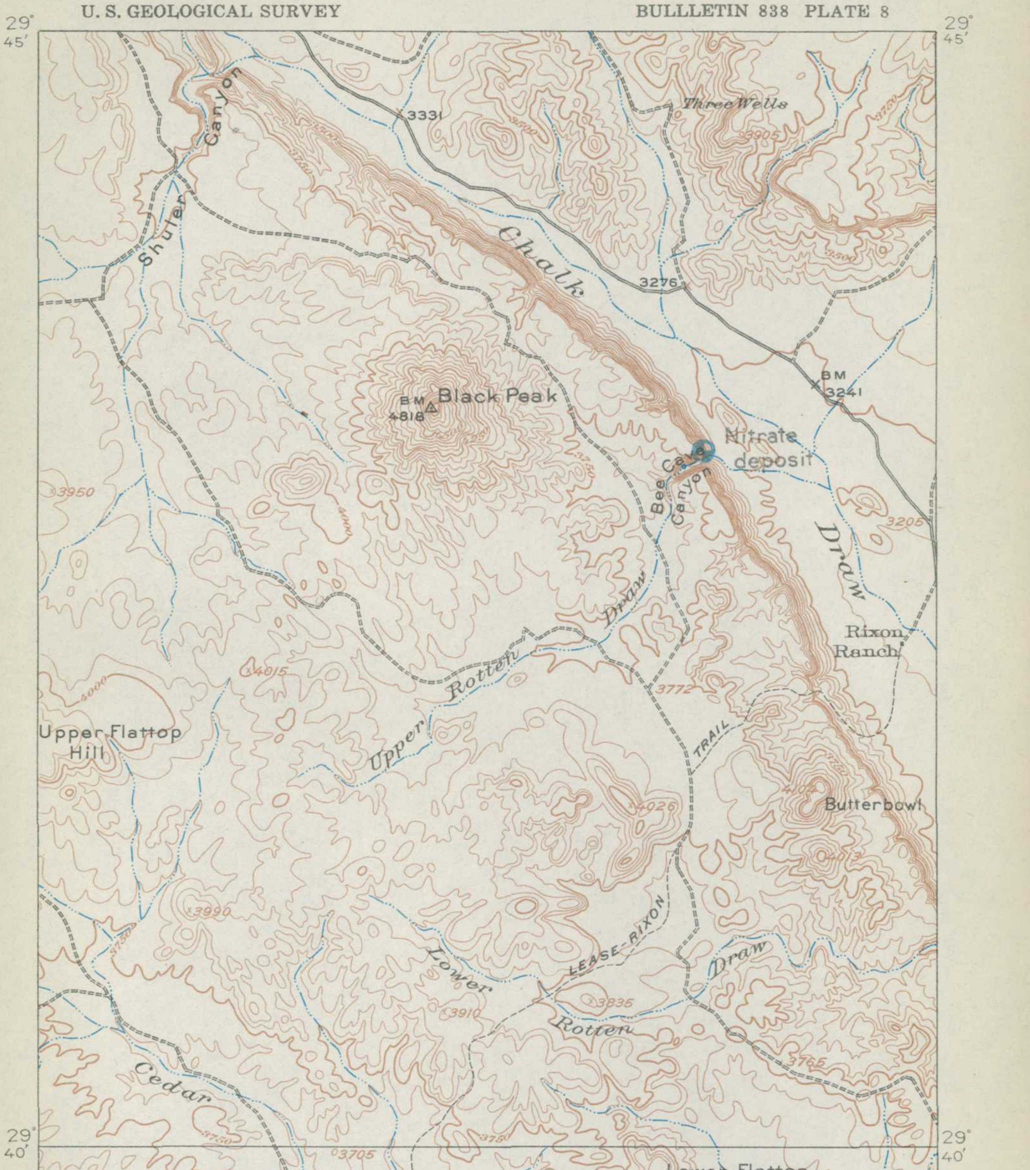


MAP OF PART OF AGUA FRIA QUADRANGLE
BREWSTER COUNTY, TEXAS

1 0 1 Mile

Contour interval 50 feet
Datum is mean sea level

1932



MAP OF PART OF NINE POINT MESA QUADRANGLE BREWSTER COUNTY, TEXAS

1 0 1 Mile

Contour interval 50 feet
Datum is mean sea level

1932

in Plate 8. A stadia traverse from the northwest corner of section 42, block 332, Texas Central Railroad survey, to the deposit indicated its position to be in the NW. ¼ sec. 38. (See station 9, fig. 5.)

The topographic map shows no perennial streams within several miles of the locality. About 800 feet southwest of the cave containing nitrate there is a water hole, or " tinaja " (station 10, fig. 5). It is in a very narrow canyon that has precipitous walls over 300 feet high and lies at the foot of a precipice that is a waterfall when the stream bed contains running water. It is more or less circular in outline and has a diameter of approximately 30 feet. Mr. Parsons reports that he has dived from the side of the water hole to a depth estimated to be about 15 feet from the surface of the water without reaching the bottom. This water hole is not a spring but is simply

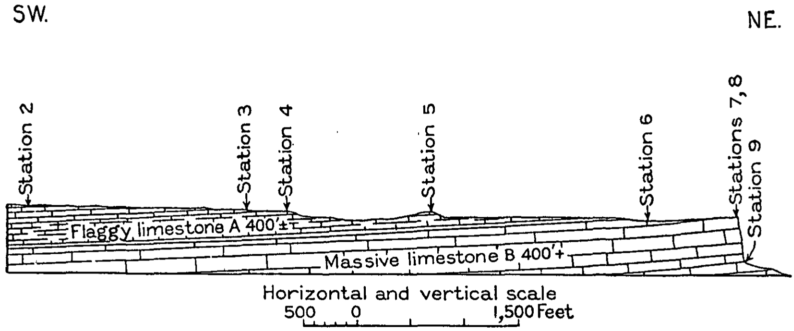


FIGURE 6.—Profile and geologic cross section of nitrate deposit in section 38, block 332, Texas Central Railroad survey, Brewster County, Tex.

a reservoir that fills up during the wet season and evaporates very slowly because of the protection from the sun's rays afforded by the steep walls of the canyon.

In the area examined about 800 feet of sediments were exposed, the major part of which were limestones. The thickness and general structure of these rocks are shown graphically in Figure 6. In the region bordering the area mapped igneous rocks are found as dikes, plugs, and sheets.

The sedimentary section can be conveniently divided into two members—a lower limestone (B) and an upper limestone (A). Limestone B is very massive, light gray, and over 400 feet thick in this locality. This limestone is like the Edwards limestone described by Udden,[80] and it is here tentatively classed as the Edwards limestone. Limestone A overlies limestone B, and approximately 400 feet of these beds are exposed in the area mapped. These rocks are thin-bedded and weather into flaglike blocks, light gray to white on their weathered surfaces. Limestone A agrees very well with Udden's

[80] Udden, J. A., op. cit., p. 27.

description of his Boquillas flags.[81] It is, therefore, tentatively classed as equivalent in age to those flags, which are Upper Cretaceous. The prevailing dip of the rocks in the area mapped is toward the southwest, and 4° is probably an average dip for the region. A dip of 7° was noted near the locality of station 7 (fig. 5).

The nitrate is found as incrustations on the side of a small cave, the location of which is represented by station 9 (fig. 5). The incrusted material is from one-eighth to 1 inch thick and is composed largely of potassium nitrate. The cave is easily accessible for 15 feet, more or less, from its mouth, and its mouth is approximately 15 feet in diameter. Two small caves, with openings about 2 feet in diameter, lead out from the main cave. The floor of the large cave and the walls of the small caves are covered with animal excreta. About 200 feet southwest from this cave there is evidence of an old Indian camping ground. The overhanging cliff at this locality formed a shelter, and the tinaja furnished the water for the campers. The sides of the cliff contain figures made with red paint. The ground near this old camping ground is black and probably is rich in organic matter from old camp refuse. There is an abundance of organic matter in and near the cave containing nitrate.

Samples were collected of the incrustations on the walls of the cave and of chips from the wall rock after the incrusted material had been scraped away. These were analyzed in the laboratory of the Geological Survey, with the following results:

	Per cent
Sample 1 (incrustation):	
Total soluble salts (180°–190° C.)	61.83
K_2O in entire sample	16.67
NO_3 in entire sample	35.48
KNO_3 in soluble salts	84.34
Sample 2 (chips from wall rock):	
Total soluble salts (180°–190° C.)	1.07
Soluble K_2O in entire sample	.13
Soluble NO_3 in entire sample	.42
KNO_3 in soluble salts	.51

The analyses show that the principal accumulations of nitrate are in the incrustations and that the wall rock upon which the incrustations have formed is practically barren. The small amount of nitrate in the rock chips probably occurs in tiny cracks or interstices closely related to the incrustations. Country rock farther removed from the incrustations may therefore be expected to contain correspondingly less nitrate.

Mr. Robinson estimates at less than 100 pounds the amount of incrusted material in sight at this locality. As the country rock con-

[81] Udden, J. A., op. cit., p. 30.

tains little or no nitrate it is obvious that the deposit has no commercial possibilities.

Section 120, block G–4, Houston East & West Texas Railway survey.—The nitrate deposit in section 120, block G–4, lies about 72 miles southeast of Alpine, Tex., and about 12 miles east of Terlingua post office, which is connected with both Alpine and Marathon by

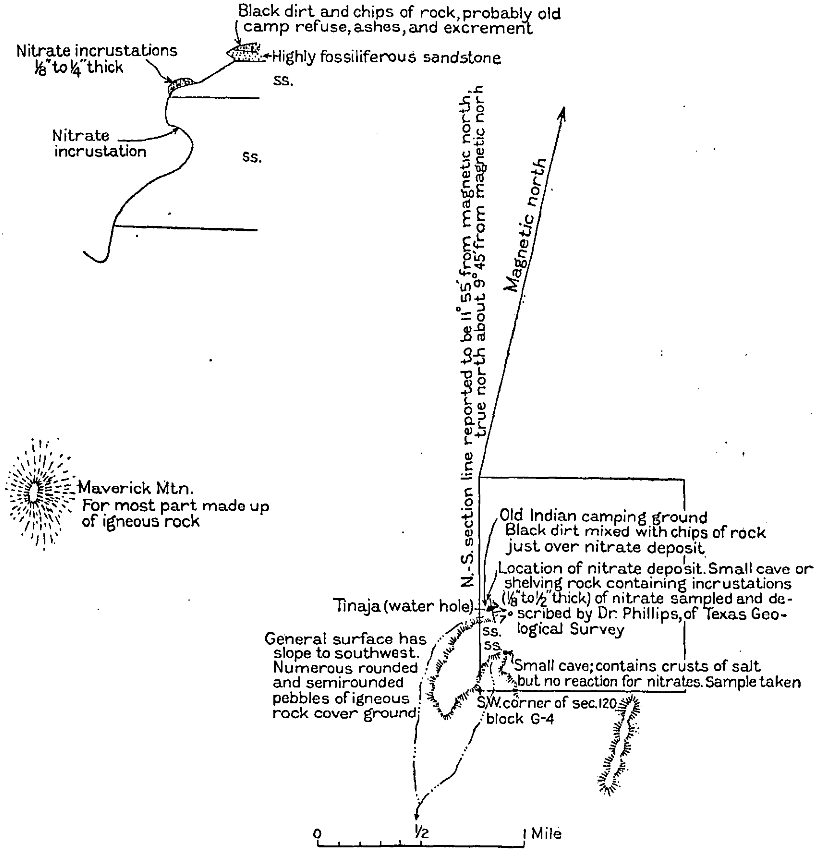


FIGURE 7.—Map and profile of nitrate deposit in section 120, block G–4, Houston East & West Texas Railway survey, Brewster County, Tex.

automobile roads that are traveled by large motor trucks. Between Terlingua and the Study Butte mine, about 6 miles east of Terlingua, the road in 1918 was very good and well traveled. East of the mine the road was rough and rocky and lay for the most part in the dry bed of Rough Run. It was possible to drive with a car within 1½ miles of the deposit, but the remainder of the road was too rough for a car, although it was passable for a light wagon with horses. The distance by road to stations on the Southern Pacific Railroad is about 100 miles. (See pl. 4, No. 6, and pl. 5.) The exact location of the deposit was determined by stadia traverse from the southwest corner of sec. 120. (See fig. 7.)

The nitrate deposit is within less than 100 feet from a water hole or tinaja, but at the time of Mr. Robinson's examination this contained no water. These tinajas are natural reservoirs, whose protected locations prevent rapid evaporation of the water. Unless they are very large they afford only a temporary supply of water. As the tinaja at this locality is small and shallow, it could not be considered an important source of water, even during a wet season. There are several springs within 2 or 3 miles of the nitrate deposits, but no readily accessible perennial streams.

The rocks in the immediate vicinity of the nitrate deposits are sedimentary and probably Upper Cretaceous. A stratigraphic section about 35 feet thick, exposed at this locality, is composed of sandstone, the upper 5 feet of which is highly fossiliferous. The sandstone here dips about 7° NE. Igneous rocks in various forms are abundant in the neighboring hills and mountains within a few miles of the nitrate deposit. Much of the surface in the vicinity is made up of partly rounded pebbles and wash from the adjoining hills.

The nitrate is found as incrustations on the surface of the sandstone and in thin seams associated with that surface where it is protected from water in small caves. The profile (fig. 7) shows the nature of these caves and the relation between the nitrate incrustations and some black dirt, which probably represents the refuse from old Indian camps. This occurrence of the nitrate has been described by Phillips.[82] His description is so full and lucid and agrees so well with Mr. Robinson's findings that it is given below for reference.

In June, 1914, I received from a friend in Alpine, Brewster County, a sample of mineral which was identified as a mixture of nitrate of soda and nitrate of potash. I sent a part of the mineral to Ledoux & Co., New York, and received from them, under date of July 6, 1914, the following analysis:

	Per cent
"Moisture	0.77
In the undried sample:	
Potash (K_2O) soluble in water	30.46
Soda (Na_2O) soluble in water	4.16
Nitrogen (as nitrate)	7.63
Equivalent to nitric anhydride (N_2O_5)	29.42

"The sample also contains small amounts of water-soluble lime, chlorine, and sulphate radicle; it is therefore impossible to state the exact contents of potassium nitrate and sodium nitrate without making a more complete analysis than the character of the sample warrants. But the data given above are sufficient, assuming sodium to be combined as nitrate, to say that sodium nitrate

[82] Phillips, W. B., Investigations of sources of potash in Texas: Am. Inst. Min. Eng. Bull. 98, pp. 115–127, 1915.

amounts to 11.4 per cent and potassium nitrate to 41.50 per cent, leaving a remainder of about 11 per cent of potash (K_2O) combined as other salts. On the other hand, if all of the nitric anhydride is assumed to be combined with potash, the amount of potassium nitrate would be 55.10 per cent, requiring 25.65 per cent of potash and leaving a remainder of 4.8 per cent of potash, together with all of the soda, combined as salts other than nitrate."

Upon receipt of this analysis and after securing further information, I visited the locality in August and obtained many samples. An average of the better grade of material was sent to Ledoux & Co., and under date of August 28, 1914, they reported as follows:

"The sample of earth containing nitrates of potash and soda marked 'Tinaja on section 120,' referred to in your favor of the 15th instant, has been examined as follows:

	Per cent
Water-soluble salts (by solution and evaporation)	29.24
Insoluble sandy matter (by difference)	70.76

"On the basis of the original sample, the water-soluble salts contain:

	Per cent
Silica	0.10
Calcium	.46
Sodium	1.00
Potassium	9.71
Chlorine	1.44
Sulphate radicle	1.07
Nitrate radicle	15.52
	29.30

"These elements and radicles are probably combined as follows:

	Per cent
Calcium sulphate	1.52
Sodium chloride	2.37
Sodium nitrate	.28
Potassium nitrate	24.96
	29.13

"The aqueous solution of the salts contains a trifling amount of organic matter, but it is free from iron, aluminum, or magnesium salts. The composition of the dry salts would therefore be practically:

	Per cent
Calcium sulphate	5.2
Sodium chloride	8.1
Sodium nitrate	1.0
Potassium nitrate	85.7
	100.0"

The question of commercial quantities arises at once. I regret to say that from a close examination of the locality and the results of chemical tests of many samples of the rock in place, I am unable to express a favorable opinion.

The potassium nitrate was found as incrustations on and thin seams in a porous sandstone of Cretaceous age. The exact locality is on section 120, block G-4, Brewster County, Tex. Thin seams of nitrate of potash occur also in a red porphyry in this vicinity. This section is east of Maverick Mountain about 5 miles and is between this mountain and the more immediate western foothills of the Chisos Mountains. The nearest railroad point is Marathon or Alpine, stations of the Southern Pacific Railway, in Brewster County, from 230 to 260 miles southeast of El Paso. The Terlingua quicksilver district is from 6 to 12 miles west.

The sandstone involved dips to the north and east from 7° to 10° but is exposed only at points where the surface drift, etc., has been worn away by water. Around Chisos Pen, about 2½ miles to the northeast, this sandstone carries beds of a subbituminous coal which has been used under steam boilers at some of the quicksilver mines.

At the particular place where the nitrate was first found, by a Mexican named Miguel de la O., on section 120, block G–4, the flood waters of Alamo Creek have cut down into the sandstone and made a fine exposure of 25 to 30 feet. I say the flood waters, for this creek is ordinarily entirely devoid of water except where it has been possible for it to excavate a tinaja (water hole) in the rock. Such a tinaja, when well sheltered, may hold water for several months, or from one rainy season to the next. There is a large tinaja of this kind at this place, and fairly good drinking water may be obtained through the greater part of the year. That this circumstance has an important bearing on the accumulation of nitrate of potash is, I think, evident from the local conditions.

The sandstone beds are of unequal hardness, and some of the upper ledges now project over the lower ledges by several feet and afford sufficient shelter to be used by Indians. Under one of the more prominent of these overhanging ledges there is now a considerable pile of ashes, half-consumed pieces of charcoal, remains of crude pottery, arrowheads, etc. This débris carries a good deal of nitrate, but only in the upper part, upon which the nitrate from the roof has fallen. The roof of this half cave is incrusted with nitrate, some of it hanging loosely to the sandstone and falling at a slight jar. Running through the roof are seams of almost pure nitrate of potash varying in width from one-eighth to 1 inch, and these appear also at the back of the cave. But behind the incrustations and alongside of the seams there is a mere trace of potash in the sandstone itself. Two inches behind a heavy incrustation of nitrate the sandstone barely reacts for potash; at 6 inches there is no reaction at all.

After removing the incrustration of nitrate with a chisel the sandstone shows no impregnation with nitrate. The seams of nitrate do not enter the rock but are confined to the surface or to a plane but slightly below the surface.

I think that the nitrate of potash here has not been derived by capillary action from deeper-lying deposits. From what we know of the sources of this material elsewhere, we shall have to look to animal excreta, especially human excreta, for its origin here.

It is, I think, beyond question that this tinaja was a camping ground for a great many years. The water is well sheltered and abundant for the greater part of the year. The adjacent country is even to this day a favorite range for deer, quail, etc., and the dry bed of the creek affords a comparatively easy and safe route to the Rio Grande for hunting or war parties.

I made a diligent search for other like places in the vicinity but found none. Many samples of sandstone, shale, etc., were examined for potash, but not one revealed its presence. It is only at this particular tinaja that any potash has been discovered, and the conditions here seem to me to preclude commercial possibilities, however interesting from a scientific standpoint. Aside from such circumstances as have been mentioned, there is one that militates most effectively against the probability of the existence of workable deposits of potash anywhere near the surface, and that is the mean annual rainfall in the district. While this can not be stated accurately, it is not likely to be less than 15 inches. This means that upon every square mile there falls every year not less than 285,000,000 gallons of water. During a residence of nearly 18 months in the adjacent quicksilver district, I observed the most awful storms, the eroding, dissolving, and transporting effects of which were most remarkable. The erosion that has taken place at the tinaja and that is now in progress is abundant evidence of the destructive nature of these torrential storms. It is possible that some isolated deposit of nitrates might have been buried under one of the great lava flows which characterize that region, but there is no evidence of such a thing. To base active prospecting upon such a remote possibility is not at all advisable.

Analyses of the incrusted material are given in the excerpt cited above, and as it is believed that this sampling was thoroughly done by Doctor Phillips, no samples of the nitrate incrustations were collected by Mr. Robinson. He did, however, gather samples of the black dirt overlying the cave that contained nitrate incrustations and of a porous carbonated material from a small cave about 1,000 feet northeast of the southwest corner of section 120. (See fig. 7.) These were examined in the laboratory of the Geological Survey by E. T. Erickson, who made simple chemical tests. The black dirt gave negative results for soluble potash and nitrates, but it contained a trace of soluble chlorides and sulphates. There was no soluble lime. The porous carbonated material yielded a small quantity of soluble potash and a trace of nitrates. It contained much soluble sulphate and some lime.

Mr. Robinson estimated the total quantity of nitrate incrustations available at this locality to be less than 200 pounds. As the associated rock contains little or no nitrate the commercial possibilities of the deposit are nil, notwithstanding the high quality of the nitrate material present.

Nitrate in bat caves.—In the course of his examination of reported nitrate deposits in Brewster County Mr. Robinson collected information regarding some bat caves in that county, because of the association of nitrate with the guano of these caves. He did not himself visit these caves but obtained information about them from W. E. Caldwell, a business man of Alpine, Tex., who was regarded as a trustworthy source. Mr. Caldwell had taken guano from three of these caves.

At station 7 (pl. 4) there is reported to be a cave containing some bat guano, in section 5, block 248, Texas & St. Louis Railroad survey. Mr. Caldwell stated that he had taken out about 20 tons of guano from this cave and that there was between 5 and 10 tons left in the cave. At one time the guano in this cave was burned.

At station 8 (pl. 4) there is reported to be a cave that at one time contained bat guano. This cave is in section 18, block 1–A, " B. B. B. & C. R. R." survey. Several smaller caves are reported in this section. Practically all of the guano has been taken out of this cave, but the floor is covered with dirt that may carry as much as 0.5 per cent of nitrate. Mr. Caldwell estimated that there was possibly two carloads of this dirt in sight.

At station 9 (pl. 4) there is reported to be a cave containing bat guano. This cave is in section 2, block G–17, near the southernmost point of Brewster County, Tex. Mr. Caldwell estimated that this cave contained between 8 and 10 carloads of guano and dirt (20 tons of guano is considered a carload). An analysis of the guano near the mouth of this cave showed 2 per cent of nitrate, and the dirt contained 0.5 per cent of nitrate.

In addition to the above well-authenticated reports of caves containing bat guano there are other reports concerning the locations of bat caves. Limestone is a common rock in this region, and the country contains numerous caves. Probably the larger and more accessible of these caves have been visited by people in search of guano, but it is probable that smaller caves not so easily accessible will be found in the future.

If the one analysis cited above showing the nitrate content of the guano is taken as typical of the guano in these caves described above, and if 10 carloads is taken as the maximum amount of guano in these scattered localities, it would seem that these cave deposits would yield about 4 tons of nitrate. This figure is a maximum and probably is too high. The quantity of the dirt in the bottom of the caves which by one analysis contained 0.5 per cent nitrate is not known but is probably small. The doubtful quantity and low quality would probably make this dirt of little or no economic value as a source of nitrate. All things considered it seems clear that these bat caves in Brewster County, Tex., can not be considered a commercial supply of nitrate.

Bat guano caves have been reported in other counties in Texas by Phillips,[83] who does not mention the localities in Brewster County. He estimated that a maximum of 10,000 tons of guano had been shipped from these caves. The counties listed are: Lampasas, Burnet, Llano, Mason, Comal, Williamson, Blanco, Gillespie, Edwards, Hays, Uvalde, Kerr, and Medina.

CULBERSON COUNTY

Van Horn area.—Several localities in the vicinity of Van Horn, Tex., have been brought to the attention of the Geological Survey

[83] Phillips, W. B., The bat guano caves of Texas: Mines and Minerals, vol. 21, p. 440, May, 1901.

by different correspondents. Two of the letters are given below. The first, dated January 21, 1913, was from E. M. Skeats, a chemist then residing in Los Angeles:

The cave containing nitrate was near the top of a limestone hill in the plains north of Van Horn, Tex. * * * The cave opened toward the west. In it (it was a small cave) I found * * * bat manure, rabbit manure, fur, and rat manure. Rain from the top of the hill leached through crevices in limestone and washed in [lime] together with other débris. I had no doubt in my mind that the veins * * * of nitrate * * * were due to waters leaching the various manures, as I found no nitrates outside this small area. If I remember right, the veinlets consisted of nitrate of soda and potash, but I can not find any analysis. The samples I sent to Professor Phillips, University of Texas.

The other letter, dated August 4, 1915, was from W. L. Lansing, of Van Horn, Tex., who wrote:

I am sending a sample of the nitrate mentioned in my previous letter. This deposit is in layers contained in sandstone, the layers being some 6 inches apart. From the surface up, on the exposed rock, for 4 feet or more this deposit exists. I do not know how deep below the surface this continues, as I have done no development work, wanting first to learn the value. Myself and associates are metal miners and prospectors. * * * We have no idea of the value of the crude material at this place or what disposition to make of same if we had a supply.

The sample submitted by Mr. Lansing was reported by R. K. Bailey, of the Geological Survey, to consist essentially of potassium nitrate (KNO_3) with only a trace of sodium. There was a little calcium and a little of the sulphate radicle, but only a trace of chlorine.

The two letters doubtless refer to different localities, for one speaks of a cave in limestone and the other of an outcrop of sandstone. The nitrate material in each, however, is much the same, though in one potassium may predominate and in the other sodium. The quantity present in both localities is probably small.

HUDSPETH COUNTY

"*Potash mine*" *near Van Horn*.—The site of the "potash mine," a large outcrop of massive sandstone, is reached by traveling 7.2 miles by highway west from Van Horn and thence 1.6 miles northeast by trail through a narrow cut. The sandstone outcrop lies N. 20° E. of the exit from the cut, which was formerly used as a dam site. This occurrence was examined in July, 1929, by W. B. Lang, of the Geological Survey, and the following account is taken from his report. The sandstone is of Lower Cretaceous age and is of variable texture, being in part conglomeratic, arkosic, and cross-bedded. The dip is approximately 6° SE. The southeast end forms a cliff that has a prominent overhanging ledge, which at some places extends out

15 feet at a height of 8 to 12 feet. (See pl. 9, *A*.) The overhang runs approximately 200 feet and has afforded and still affords resting places for bats. There is also abundant evidence of the use of the place as a shelter by Indians. The walls are scored, frescoed, and blackened, and the ground at the base contains charcoal, bones, and other organic matter.

Prospecting by digging, tunneling, and blasting had been carried on for a length of about 150 feet at the base of the cliff and to a depth of 2 or 3 feet but was not in progress at the time of Mr. Lang's visit, though some shipments are reported to have been made. Samples collected by Mr. Lang gave the following results upon analysis:

Analyses of samples from "potash mine" near Van Horn, Tex.

[E. T. Erickson, analyst]

	Material	Soluble salts (per cent)	N_2O_5 in soluble salts (per cent)	K_2O in soluble salts (per cent)
1	Surface soil and fresh bat guano	5.1	10±	10±
2	Indian trash heap at east end	.4	1.5±	5±
3	Detrital soil 5 feet from base of cliff at point of greatest overhang	.5	5.0±	10±
4	Dug rock from trench, prepared for shipment	2.4	5–10±	10±

The amounts of potash and of nitrate in the samples examined are relatively insignificant, neither of these substances exceeding one-half of 1 per cent. The organic and surficial origin of the nitrate is evident. The material in sight may continue to supply a few shipments, but the deposit is obviously not commercial in any but the most limited sense.

LUBBOCK COUNTY

On July 16, 1917, J. O. Whittington, of Lubbock, Tex., wrote to Senator Sheppard in substance as follows:

> The ore mentioned was analyzed by the Fort Worth laboratories and assayed 22.24 per cent K_2O. This ore is located in the mountains and lies flat between hard rock, of which we are sending you a piece of the rock lying next to the ore as well as a sample of the ore. The ore lies in a flat vein from 1 to 3 inches thick. That is, it shows that amount on the exposed bluff or rock.

Mr. Whittington's letter and samples were referred to the Geological Survey. When tested the ore sample was found to consist of sand, gypsum, and potassium nitrate, the last comprising as much as 25 per cent of the sample. The accompanying rock sample was sandstone. Mr. Whittington's letter does not state the locality and gives nothing very definite about the quantity of nitrate present aside from his statement of the assay. The last sentence quoted, however, suggests that, like many other nitrate accumulations, this is a surface incrustation.

PRESIDIO COUNTY

CANDELARIA

Candelaria, a small settlement in Presidio County, Tex., across the Rio Grande from the Mexican village of Upper San Antonio, is a convenient base from which to explore nitrate deposits in that general region. (See pl. 4, No. 10.) The climatic and topographic conditions in that part of Texas are very favorable for the development of cave niter. It is therefore not surprising that some of the more striking occurrences there should have attracted the attention of prospectors and others, who saw in them a possible chance to capitalize a supposed abundant natural resource. The portion of the area most extensively opened up is that in the vicinity of Capote Creek, about 7 miles northeast of Candelaria. (See pl. 10 and fig. 8.) During the World War a mill was built here and pits and tunnels were opened at a total cost, it is claimed, of more than $150,000. Other deposits in the vicinity have been less extensively explored.

CAPOTE CREEK DEPOSITS

Location.—In August, 1918, H. M. Robinson, of the Geological Survey, spent a week at the mining camp of C. E. Parsons and G. C. Simpson, who, under the name of the Parsons & Simpson Co., New York, were attempting to start operations as a nitrate-producing concern. The facilities of the camp were placed at his disposal, and aid was freely rendered by officials of the company and others. The mining camp was in the NW. ¼ sec. 93, block 12, Galveston, Harrisburg & San Antonio Railroad survey, about 10 miles by road from Candelaria and 33 miles from Valentine, the nearest shipping point on the Southern Pacific Railroad. Marfa, the county seat of Presidio County, is about 53 miles by road northeast of the camp site. The road from the camp site to either Valentine or Marfa is very steep and winding where it crosses the "rim rock." The trucking of heavy loads from the camp or mine to the railroad might therefore present a problem. Water is available from the creek, which is a small permanent stream, and from numerous springs. The area studied in detail by Mr. Robinson is indicated in Figure 9, in which the area included in the holdings of the company is also shown. In addition to his detailed studies Mr. Robinson made a reconnaissance examination of the geology within 5 or 6 miles of the camp. (See pl. 10 and fig. 8.)

Geology.—The following section shows the thickness, character, and general relations of the rocks found in the vicinity of the mining camp. Their areal distribution is shown in Plate 10 and Figure 8. Specimens of the igneous rocks have been examined and determined by E. S. Larsen, of the Geological Survey, and the fossils found in the lowest beds described have been reported on by T. W. Stanton, of the Geological Survey. The rocks above the "rim rock" were seen only from a distance, so that their description and their stated thicknesses are only approximate.

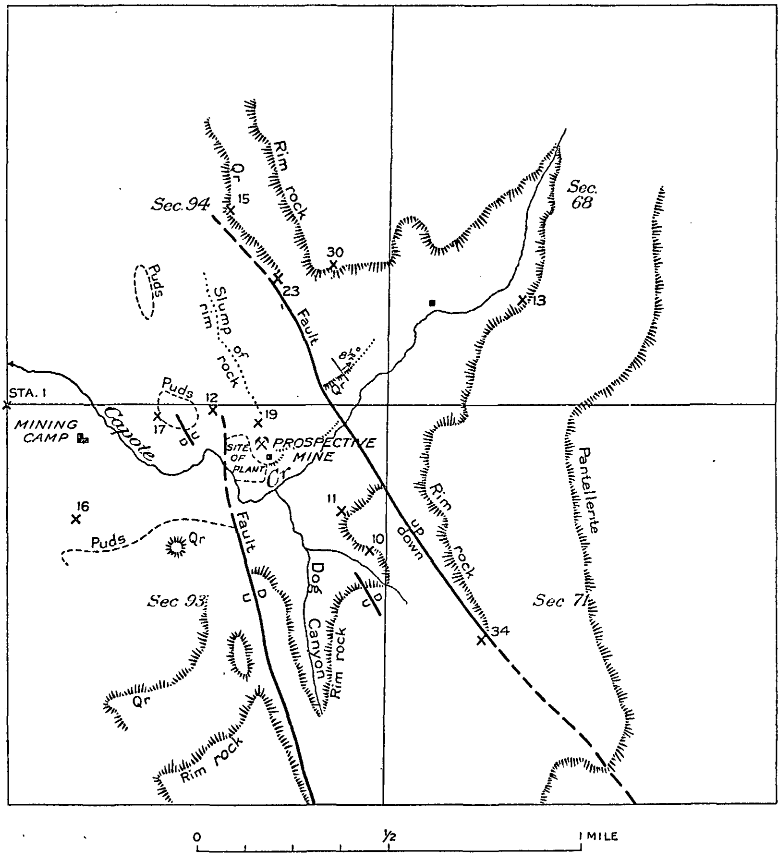


FIGURE 8.—Sketch map of Capote Creek nitrate area, showing location and geologic relation of nitrate deposits in block 12, Galveston, Harrisburg & San Antonio Railroad survey, Presidio County, Tex. Puds, "Puddingstone"; Qr, "Quiros Bluff rock"

Columnar section of rocks in the vicinity of the Capote nitrate deposits, Presidio County, Tex.

Top of section.	Feet
Rhyolite; classified by E. S. Larsen after a brief examination of a hand specimen; occurs as a sheetlike mass; locally known as a "pantellerite"; weathers into cliffs with columnar jointing	[a] 300
Sandstone and shale; predominant color white	[a] 500
Shale, clay, and sandstone; predominant color red	[a] 300

[a] Estimated.

	Feet
Rhyolite rich in soda; classified by Mr. Larsen after a brief examination of the rock in thin section and in the hand specimen; locally known as the "rim rock"; occurs in sheetlike masses; vesicular phases noted in a few places near its base; weathers into cliffs with columnar jointing	125
Sandstone, white to light gray, interbedded with clays; immediately below the "rim rock" the sandstone is red, probably due to the baking effect of the igneous rock	475
Rhyolite; classified by Mr. Larsen after a brief examination of the rock in thin section and in the hand specimen. Quiros Bluff is composed of this rock and in this report the rock is described as the "Quiros Bluff rock"; the rock is fine grained, and in places the texture is glassy; it is vesicular in practically all outcrops visited and in places is entirely honeycombed with cavities due to the expansion of gases while the rock was molten	10-50
Tuff, dark gray to red	35
Sandstone, white; contains stringers of conglomerate and thin beds of shale, probably tuffaceous	18
Tuff interbedded with conglomerate and clay; dark gray and red are the predominant colors	200
Volcanic breccia; locally known as a "puddingstone"; contains rock fragments as large as 5 feet in diameter; after examination in thin section and hand specimen one of these fragments classed as a latite; very large and well-developed crystals of analcite were found in the base of this member, suggesting that the rock is rich in soda; the sorting of the rock fragments is poor, some of the fragments being very well rounded and others angular to subangular	75
Limestone, gray	3
Clay, gray	125
Clay, yellow; in places slightly sandy; a fossil collection from beds near the top of this member was examined by T. W. Stanton. September 24, 1918, Mr. Stanton wrote that "the species which forms the bulk of the collection is *Gryphaea aucella* Roemer. Fragments of *Inoceramus* and of a *Pecten* are also recognized. The fossils indicate Upper Cretaceous and a horizon probably not far from that of the Austin chalk"	100

The rocks described above aggregate in thickness about 2,300 feet. The breccia and tuffs are volcanic in origin, and most of the sheetlike masses are probably old lava flows. Some of the igneous rocks are rich in soda, and the age of the lowest member described is Upper Cretaceous.

The rocks in general dip about 8° NE. Faults with northwest trend are common and appear to be normal. The two major faults shown in Figure 8 have vertical displacements of 300 to 400 feet, but some of the faults shown in Plate 10 are undoubtedly larger. Practically all the igneous rocks of the area are characterized by columnar joints upon their weathered surfaces, and their outcrops form precipitous bluffs.

Nitrate deposits.—Sodium and potassium nitrates, sodium nitrate predominating, are found at many places throughout the area. They occur only on altered surfaces protected from rains and water seeps or running water; hence they are found in caves and under overhanging cliffs. The cliffs formed by igneous rocks in places contain large cracks, where masses of rock have split off, and have concave surfaces, which are protected from rains. Some of these cliffs in places 20 to 30 feet above the base contain rich crusts of nitrate along the walls, in exfoliation cracks, and in the vesicles of the rock a quarter to half an inch in diameter. In some of the caves the nitrate is associated with organic material obviously supplied by animals. More frequently it is found without direct association with organic matter.

The volcanic breccia or "puddingstone" in the section given above is the lowest rock mass observed to contain nitrate. (See station 17, fig. 8, and station 35, pl. 10.) The "Quiros Bluff rock," 250 feet higher, appears to have the richest accumulations of nitrate, owing to its vesicular character. At station 7 (mine site) and station 15 (fig. 8), the nitrate was particularly abundant, crusts as thick as 1 inch being found at both localities. At these places there seems to be little chance for direct contamination by organic matter. The "rim rock" about 475 feet above the Quiros Bluff contains nitrate at many localities along its base, where the rock is vesicular. The underlying partly baked sandstone also has cracks here and there which contain nitrate. Two analyses of this sandstone showed 4.73 and 8.5 per cent of soluble salts, of which 80 and 90 per cent, respectively, was sodium nitrate. It is reported that nitrate occurs in a rock similar to the "pantellerite," which is perhaps 800 feet or more above the rim rock, but these localities were not visited.

Quality of the deposits.—Many analyses of the nitrate deposits were furnished to Mr. Robinson by Mr. Simpson and his associates. Those of the concentrates or of the crusts showed that much of this material was a mixture of nearly pure sodium and potassium nitrate, with sodium nitrate predominating. Disregarding this richer material, which was obviously present only in minor quantity, he directed attention to the rock mass with which the nitrate was associated, for upon the nitrate content of this rock the success of any attempted large-scale production must necessarily depend. Of 20 analyses furnished by Mr. Simpson from the "Quiros Bluff rock," "the average solubility"—that is, the total quantity of contained soluble salts—was about 5 per cent, of which 50 to 60 per cent was sodium nitrate and 5 to 6 per cent potassium nitrate. The ratio of sodium nitrate to potassium nitrate was thus about 10 to 1, and the apparent average nitrate content of the "Quiros Bluff rock," the richest of the nitrate-bearing masses, was about 2.5 to 3 per cent. Company officers at that time, however, were figuring that they could operate at a profit if their material averaged as much as 1 per cent.

The openings from which the samples analyzed as mentioned above were taken were all relatively shallow. Mr. Robinson himself collected several samples, and two of them, taken from the faces of two of the prospect entries in Quiros Bluff, represented fresh material, which could fairly be used for comparison with the company analyses. These samples were anaylzed in the laboratory of the Geological Survey by E. T. Erickson, with the following results:

Sample 26. Rock from Quiros Bluff, taken from a prospect tunnel 3 to 6 feet from the face of the bluff, about 200 feet north of station 19 (fig. 8):

	Per cent
Ammonia nitrogen in whole sample	0.0001
Albuminoid nitrogen in whole sample	.0003
Nitrite nitrogen in whole sample	.00025
Nitrate nitrogen in whole sample	.003
Nitride nitrogen in whole sample	.0025

Sample 27. Rock from Quiros Bluff, from a prospect tunnel about 150 feet south of locality of sample 26 and 3 to 5 feet from face of bluff:

	Per cent
Ammonia nitrogen in whole sample	0.0001
Albuminoid nitrogen in whole sample	.00015
Nitrite nitrogen in whole sample	.00025
Nitrate nitrogen in whole sample	.003
Nitride nitrogen in whole sample	.0020

The percentages of nitride above reported represent the amount of nitrogen recovered in the form of ammonia after treating the sample with superheated steam at 800° to 900° C.

If all the nitrogen present in these samples were computed as sodium or potassium nitrate the total quantity represented at each locality would be less than 1 per cent of the rock mass.

Some months after Mr. Robinson left the field he received a letter from Mr. Simpson stating that he had driven five tunnels into the bluff to a distance of about 15 feet each and that he had carefully sampled each foot in the tunnels by "ringing the section" on them. He had then made a composite sample to indicate how the mass was running and had found it to run about 18 pounds of combined salts of potassium and sodium nitrate per short ton of ore. He further wrote:

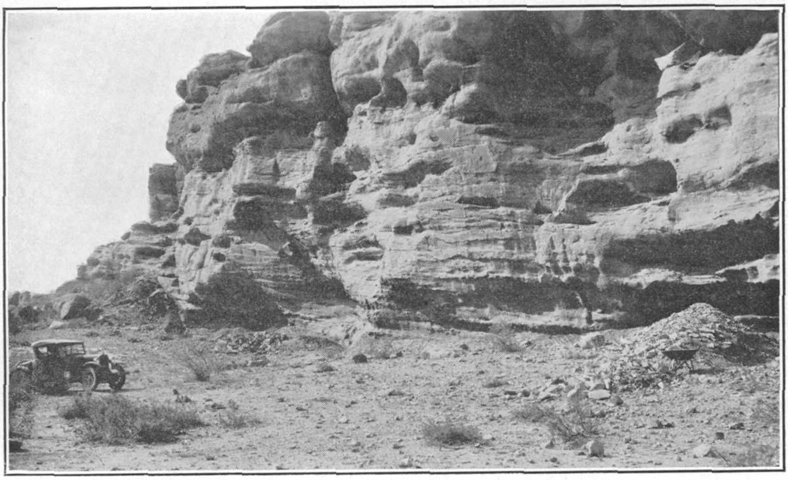
We have found several sections where the showing seems to be a good [bit] better than this and in [some] courses we believe that we can run on an average in excess of 3 per cent nitrate of K and Na in the rock.

The combined sample from the five new tunnels that contained 18 pounds of nitrates to the ton represented rock with a nitrate content of slightly less than 1 per cent. The 3 per cent material to which he refers is doubtless the same as that above described as containing 2.5 to 3 per cent.

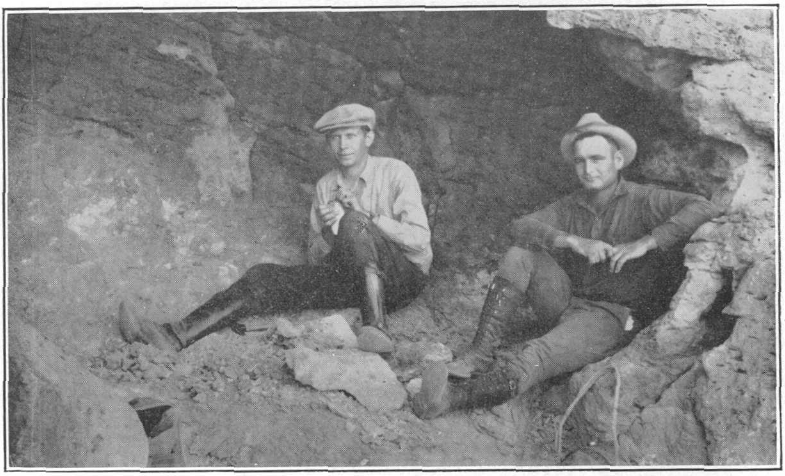
Quantity of deposits.—Mr. Robinson did not attempt an estimate of quantity of the nitrate present in any of the rock masses. The relatively shallow surface workings gave no basis for such an estimate, though they did supply sufficient evidence to cast grave doubt upon the practicability of the entire enterprise. Mr. Robinson's samples (Nos. 26 and 27) and the later samples obtained in the deeper tunnels by Mr. Simpson both pointed very strongly to the conclusion that fresh rock a few feet back from the surface in the most promising of the nitrate-bearing rock masses contains less than 1 per cent of nitrates. In the face of such a showing it is clear that the cost of any proposed further exploration should be carefully weighed against the probability that the nitrates rich enough to work are confined within a few feet (or perhaps a few inches in many localities) from the surface. As a matter of fact, at one locality within the area the excavation of 15 to 20 tons of material practically exhausted that particular deposit.

Origin of the deposits.—Mr. Robinson gave considerable attention to the problem of origin because it was clear that to discover nitrates in commercial quantity in the rocks back from their face rich beds within the rock or local enrichments analogous to metalliferous veins and derived from subterranean sources would have to be found. No evidence for rich beds within the rock was forthcoming, and for local enrichments the only evidence available was the fact that some of the spring waters, both warm and cold, in Capote Creek and its vicinity upon analysis were found to contain small amounts of nitrates and the further fact that so much of the country rock was volcanic. At some localities the connection of the accumulations of nitrate with organic matter was obvious, but at most places such a connection was not evident, though an indirect association was not precluded. Mr. Robinson came to no definite conclusion but thought the data sufficiently interesting scientifically to justify further exploration, though he doubted the practicability of the whole enterprise as a commercial venture. A fuller discussion of the origin of nitrate deposits is given on page 3.

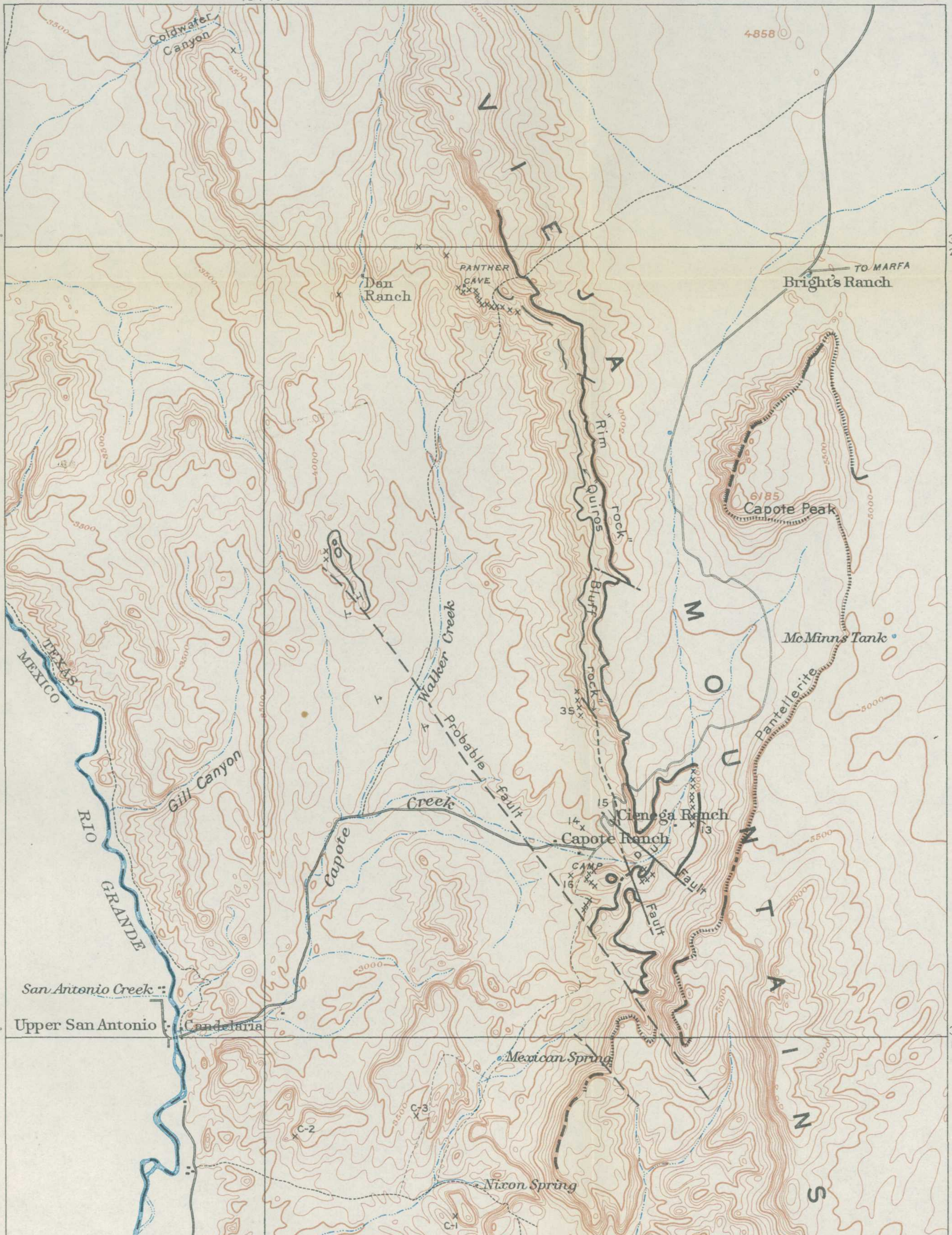
Development.—Prior to the operations of the Parsons & Simpson Co. considerable prospecting for nitrate had been done along cliffs both north and south of Capote Creek. The location of many of these prospects is shown on Plate 10. At the time of Mr. Robinson's visit the company had already selected a mill site on Capote



A. SANDSTONE LEDGES 6 MILES NORTHWEST OF VAN HORN, TEX.
Showing Indian shelter at base of cliff (left center) and prospect tunnel (right).



B. NITRATE PROSPECT OF U. S. NITRATE CORPORATION OF AMERICA ABOUT 3 MILES SOUTHEAST OF CANDELARIA, TEX.
Note saline incrustations.



MAP OF PART OF SAN CARLOS QUADRANGLE
PRESIDIO COUNTY, TEXAS

1 0 1 3 Miles

Contour interval 100 feet
Datum is mean sea level

1932

Creek, machinery was being installed, and more machinery destined for the plant could be seen at Valentine. A force of 30 to 50 Mexicans was employed building roads and houses and preparing the site for the plant and mine. All the mining was then confined to the Quiros Bluff, which extends southward 500 feet from station 19 to station 7 (approximately the same as the mining site, fig. 8). Three prospecting entries about 5 feet high, 5 feet wide, and 3 to 4 feet long had been opened, the whole representing about a week's work of six or eight Mexican laborers. By November the five tunnels mentioned above had been driven. Then came delays, and by the following May little further progress had been made. So far as the Parsons & Simpson Co. was concerned, the project was abandoned not long afterward.

RELATED PROJECTS

McRae claims.—In October, 1918, while the Parsons & Simpson Co. was operating on Capote Creek, J. W. McRae, of Houston, Tex., with associates was trying to finance a nitrate project in sections 40 and 780, block 2, and sections 127 and 128, block 12, in the same general region. These sections adjoin each other and lie about 3 miles northeast of Candelaria. (See fig. 9.) This ground was not seen by Mr. Robinson or by any other Geological Survey representative, but from samples submitted to the Geological Survey for examination it is evident that the type of deposit is the same as that at Capote Creek and that any commercial development of it is subject to the same limitations as those discussed for that area.

The McRae claims either at that time or shortly thereafter were controlled by the Texas Potash & Sodium Nitrates Co., of Houston, Tex., of which A. A. Snell, W. E. Langley, and C. E. Young were officials. Mr. McRae's relation to that company was not stated. From the descriptions in Mr. McRae's letters it seems probable that these claims were among those described by Phillips [84] in an article to which reference has already been made. The two descriptions tally closely. Phillips writes:

> Some time ago I was called to Presidio County, Tex., to examine a so-called discovery of nitrate of soda. The samples that had been sent in were of an excellent character, running as high as 71 per cent of nitrate. The locality is about 2½ miles east, a little north, from Candelaria, a little settlement on the Rio Grande, 45 miles south of Valentine, a station on the Southern Pacific Railway.
>
> The nitrate was found as thin veins in a dense, hard trachyte, which had been eroded near the top of a small canyon so that cavelike excavations had been formed. A similar occurrence was noted several miles to the west of

[84] Phillips, W. B., Investigations of sources of potash in Texas: Am. Inst. Min. Eng. Bull. 98, pp. 124–126, 1915.

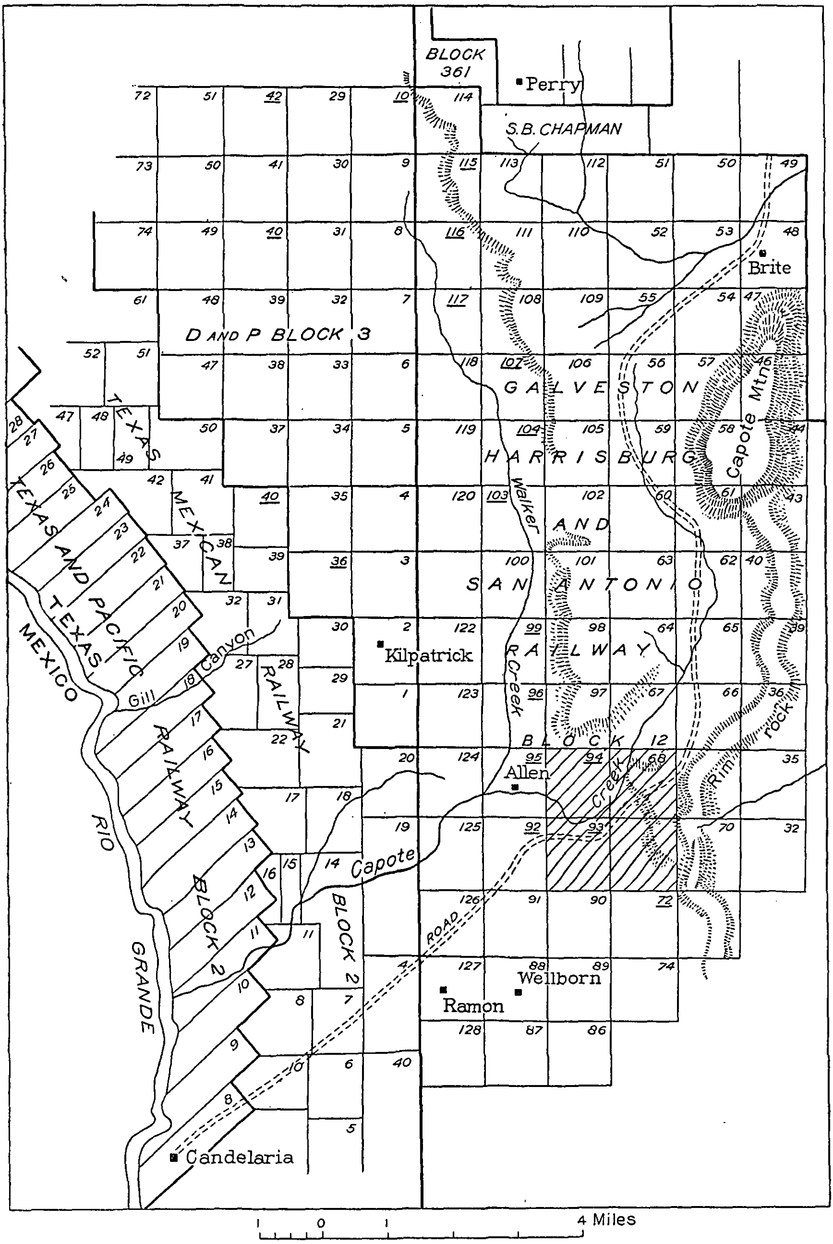


FIGURE 9.—Plat showing area claimed by Parsons & Simpson Co. in Candelaria district, Presidio County, Tex. The area shown in Figure 8 is crosshatched. Sections indicated by underscored numbers filed on by Parsons & Simpson Co. for prospective nitrate mining

Candelaria, and at this place some old workings were plainly visible. Many samples of the nitrate and of the inclosing rock were examined, but in no case did there seem to be any reason for further prospecting. The thin veins of nitrate are highly localized, and, while rich specimens were obtained, the commercial possibilities are of no moment.[85] * * *

Several years ago there were reports of the discovery of nitrate of potash in El Paso County, but investigations showed that while the mineral did exist in almost pure condition, the amount was extremely small.

From time to time during the last 10 years I have examined many localities in west Texas from which specimens of nitrate of soda and nitrate of potash were obtained, but I have yet to see a place which presents commercial possibilities of any moment whatsoever. I make this statement at this time to allay certain reports which have found some credence among those whose hopefulness has run away with their judgment. Rich specimens have been found at more than one locality, but in every case the situation has been such as to forbid any expectation of the finding of workable deposits.

U. S. Nitrate Corporation of America.—In June, 1927, it was announced in the press that A. A. Snell, of Houston, Tex., and associates were testing out the richness and extent of certain nitrate deposits in Presidio County, Tex., and that it was proposed to truck the material to Marfa and to construct a refining plant at Houston. In view of these announcements and of others of similar purport relating to other localities, G. R. Mansfield, in company with J. W. Vanderwilt, of the Geological Survey, visited Candelaria on June 14 and 15, 1928. Mr. Snell's organization, the U. S. Nitrate Corporation of America, was maintaining a nitrate camp there at that time in charge of C. A. Hale. Although Mr. Snell was not there on those dates, the facilities of the camp were kindly extended to the Geological Survey party by Mr. Hale, who, together with Messrs. Martin and Dickens, of the nitrate camp, assisted in the examination of the deposits. The places visited were two prospects and a small cave, designated C–1, C–2, and C–3 on Plate 10. The occurrences were all much alike. At locality C–1 a pit had been blasted out about 20 feet long and 5 feet deep in white porous rhyolite. The rhyolite is part of a lava flow about 30 feet thick, which forms a cliff above a steep slope that rises about 200 feet from the floor of the little valley to the southwest. The rhyolite dips gently northward and overlies white volcanic ash. (See fig. 10.) The prospect is at the base of the cliff. White incrustations of salts were noted as fillings and as coatings in some of the cracks. The sugary appearance and sweetish, cooling taste of this material indicated that it contained nitrates. Chemical tests by means of the delicate brown-ring reaction (see p. 10) confirmed the presence of nitrate in the

[85] See articles by the writer [W. B. Phillips] in Eng. and Min. Jour., vol. 90, p. 1303, Dec. 31, 1910; Manufacturers' Rec., Jan. 19, 1910, and Aug. 11, 1911; Mexican Min. Jour., vol. 13, No. 3, p. 21, September, 1911; and Mineral Industry, vol. 19, p. 616, 1910).

salts but showed the unaltered rhyolite to be practically barren. Samples considered representative of the purer nitrate, of the mixed salts, and of the rhyolite were collected for analysis in the laboratory at Washington. The results of the analyses are given below.

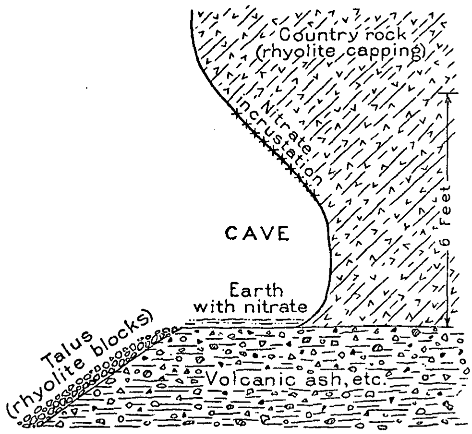


FIGURE 10.—Sketch showing mode of occurrence of nitrate at locality C-1, Plate 10, Candelaria district, Presidio County, Tex.

Analyses of samples from locality C-1 near Candelaria, Presidio County, Tex.

[E. T. Erickson, analyst]

Specimen	Total salts (per cent)	K_2O in sample (per cent)	N_2O_5 in sample (per cent)	KNO_3 [a] (per cent)	$NaNO_3$ [b] (per cent)
Rhyolite	2.64	0.17	0.69	0.37	0.77
Rhyolite and salts	12.76	.31	5.31	.67	7.79
Nitrate crusts	87.40	.72	44.92	1.55	69.40
Mixed salts	90.60	.57	40.46	1.22	62.66

[a] Total K_2O calculated as KNO_3. [b] The remaining N_2O_5 calculated as $NaNO_3$.

One of the samples of rhyolite, which may be considered fairly typical of the main rock mass, contained only enough K_2O to be equivalent to 0.37 per cent of potassium nitrate. The remaining N_2O_5 was sufficient to be calculated as 0.77 per cent of sodium nitrate. Thus a total of 1.14 per cent of nitrates was obtained. The other rhyolite sample, more affected by surface conditions, contained the equivalent of 8.46 per cent of potassium and sodium nitrates. The other samples were high in nitrate, but the quantity of material of this kind in sight at this locality is certainly less than 100 pounds. The table shows that the nitrate present in the samples does not account for all the soluble salts. The remaining salts were not determined but were presumably chiefly sodium chloride and calcium sulphate.

The conditions at locality C–2 were much the same as at C–1. A small cave about 15 feet long and 8 feet deep at the base of a rhyolite cliff had been enlarged a little at the mouth by blasting. The country rock is relatively fresh rhyolite, and there are on the roof of the cave and as fillings in cracks in the rock a few incrustations a quarter to half an inch thick of salts containing nitrate, but the rock itself is relatively barren. The general appearance of the cave and of the porous rhyolite is shown in Plate 9, *B*. Chemical tests were made on the ground with results similar to those obtained at C–1. Check samples were taken of the rhyolite, of the nitrate incrustations, and of material gathered from the floor of the cave. These were analyzed in the laboratory of the Geological Survey with the following results:

Analyses of samples from locality C–2 near Candelaria, Presidio County, Tex.

[E. T. Erickson, analyst]

Specimen	Total salts (per cent)	K_2O in sample (per cent)	N_2O_5 in sample (per cent)	KNO_3 [a] (per cent)	$NaNO_3$ [b] (per cent)
Rhyolite	6.28	0.19	1.95	0.41	2.72
Salt from floor of cave	96.80	.34	43.65	.73	68.09
Incrustation	97.50	.42	61.60	.90	96.20

[a] Total K_2O calculated as KNO_3. [b] The remaining N_2O_5 calculated as $NaNO_3$.

The analyses confirm the qualitative chemical tests made in the field and the general observations at the cave. The incrustations are relatively pure sodium nitrate, but the rock itself contains very little nitrate. Even the small quantity present in the rock near the surface may be expected to decrease rapidly as the rock is worked back from the face of the cliff. As at locality C–1, the total quantity of nitrate in sight at C–2 is commercially insignificant.

At locality C–3 the conditions are practically identical with those at C–2, except that no blasting had been done there. There is a small cave in the rhyolite produced by the spalling of the rock as it weathers. The rhyolite is fresh, and there are a few incrustations of nitrate, but it is evident that very little nitrate is present.

The work of the nitrate camp had been devoted mainly to road building, to laying out a plant site, and to moving machinery across country from the Capote Creek locality. Very little work had been done in actual prospecting.

The U. S. Nitrate Corporation of America seems to have taken over the effects of the earlier enterprises in that region. On the way to the Capote Creek locality Messrs. Mansfield and Vanderwilt observed machinery stranded at several places along the road, and the mill at the Capote Creek site was largely dismantled. It was obvious that no exploratory work had been done there for a long time.

In view of Mr. Robinson's former work and results, it did not seem advisable to devote further attention to that locality, though a brief reconnaissance up the creek from the mill site was made and a sample of water from a spring near the site of the old Cienega ranch, about a mile above the mill site, was obtained. This sample was analyzed in the Geological Survey laboratory by E. T. Erickson, who found that the salinity of the water was 0.033 per cent, of which 9.38 per cent was K_2O. A qualitative test of the salts by the phenol-sulphuric acid method indicated that a small quantity of nitrates was present. If the potash present is assumed to be all combined in the form of nitrate, the potassium nitrate in the water would amount to 0.0066 per cent. There was doubtless some sodium nitrate present also, but the amount of material in the sample did not permit further determinations. Sodium nitrate in the samples of salt ranges from 2 to 10 times as much as the potassium nitrate. A private analysis of a composite sample of spring water from the Capote Creek district, furnished to Mr. Robinson by Mr. Simpson, contained 100.19 grains of total solids per United States gallon, of which sodium and potassium nitrate together constituted 18.9 grains, or about one-fifth. These figures correspond to 0.17 per cent of solids in the water, 0.03 per cent being nitrates. Mr. Mansfield's sample, though more dilute than Mr. Simpson's, confirmed the presence of nitrate in some of the spring waters of the district. The spring waters, judged by the available analyses, are very dilute and have too little nitrate to be commercially significant, but the presence of nitrate in such water may have a bearing on the origin of the nitrate deposits.

GLASSCOCK CLAIM

The Glasscock claim is about 44 miles nearly due south of Marfa in section 12, block 205, Texas & St. Louis Railroad survey (see pl. 4, No. 11, and figs. 11 and 12), but the distance by road is about 50 miles. The road except for the last 5 miles is fairly good for automobiles. There is no surface water near the deposit except that within a radius of about 2 miles there are several dams and tanks, built by cattlemen, that could furnish a temporary supply.

The rock in the immediate vicinity of the deposit is igneous, fine grained, and dark and is tentatively classed as a basalt. The nitrate is found in a cave in this basalt, a profile of which is shown in Figure 13. It is probable that this igneous rock represents an old lava flow over 60 feet thick that while still molten became honeycombed with cavities that range from cracks a fraction of an inch in diameter to openings as large as the caves shown in Figure 13, owing to the expansion of gases in the rock. In addition to the cave at station 2 (fig. 11) there are, at stations 3 and 4, rough holes or

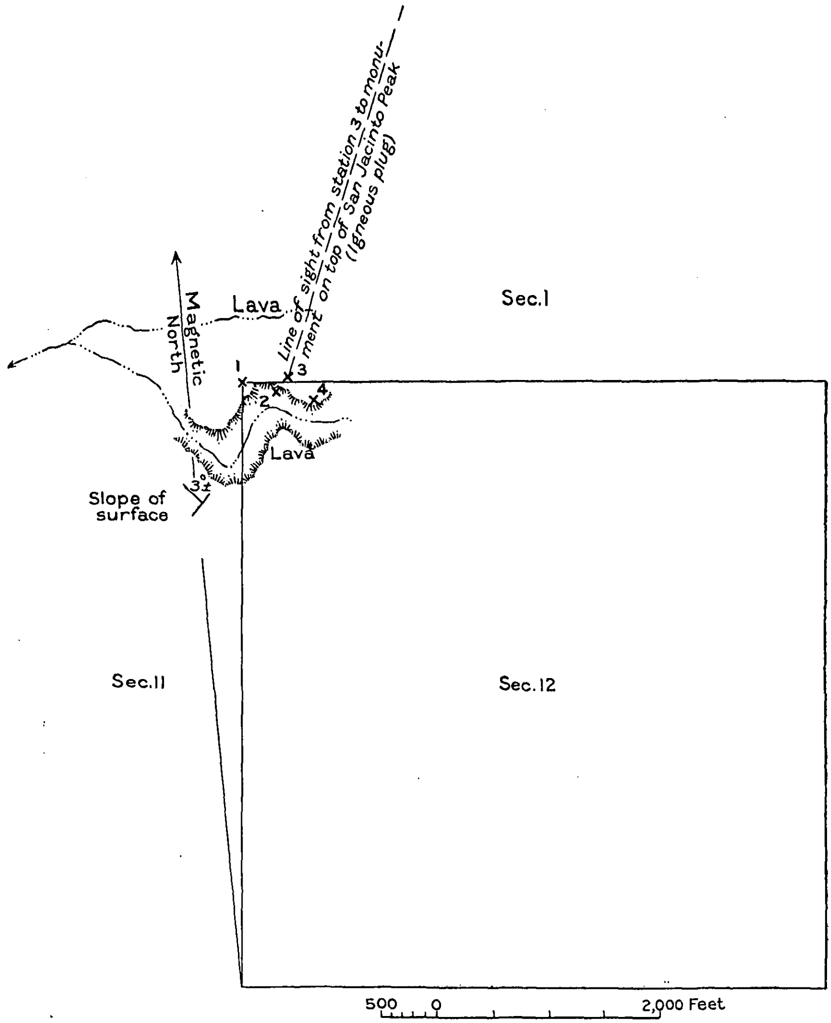


FIGURE 11.—Map of Glasscock Cave nitrate deposit, in block 205, Texas & St. Louis Railroad survey, Presidio County, Tex.

openings in the rock locally known as "blowholes." The cave is in the face of a steep bluff of basalt that is fractured along planes at right angles to the face of the bluff. These fracture planes and the cavities made by the expansion of gases afford a route for the circulation of waters carrying salts in solution.

The nitrate is found as incrustations on the walls of the nitrate prospect cave (fig. 13) and in caked masses in the dirt in this cave.

At the time of Mr. Robinson's examination of this deposit there was very little nitrate incrusted on the walls, but on the floor of the cave there were piled between 150 and 200 sacks containing material that had been scraped from the walls and floor of the cave. According to local reports, the prospect cave at one time had only a small opening, scarcely large enough to admit a man; its present opening, as shown in Figure 13, is due to blasting and excavation. More or less blasting has been done inside the prospect cave.

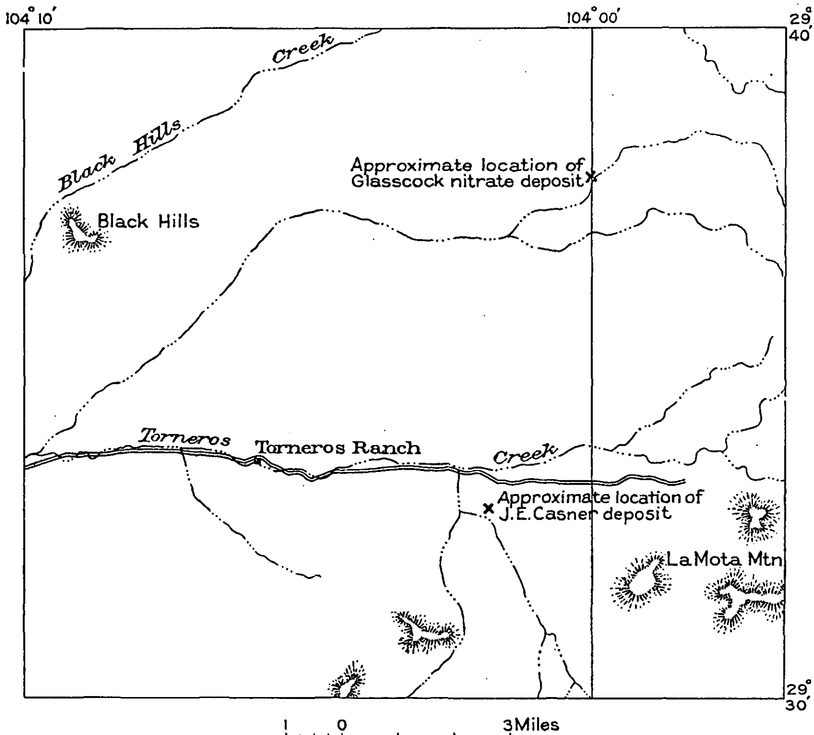


FIGURE 12.—Map of parts of Tascotal Mesa and Shafter quadrangles, Presidio County, Tex., showing areas in vicinity of Glasscock and Casner claims

Just above the prospect cave there is a natural cave that at one time was, in all probability, an old Indian camp. On the wall are figures in red paint, and the floor of the cave contains black dirt, presumably the ashes from old camp fires mixed with other camp refuse containing a large percentage of organic matter. In many places the walls are covered with a black tarlike smut, as much as a quarter of an inch thick, which presumably is derived from the organic matter in the cave. The putrefaction of organic matter in contact with alkaline materials, such as wood ashes, is a process that is thought to have caused the formation of many small nitrate deposits in the United States. It seems evident that there is enough organic matter in sight in the natural cave here described to form a source for the nitrate that has been sacked up in the prospect cave. The fractures in the rock and the cavities due to the expansion of gases permitted the circulation of water-carrying nitrate in solution, and the caves afforded enough protection from the weather to allow the very soluble nitrates to accumulate. Under this interpretation, which is believed to be correct, the nitrate is confined entirely to the cavities and cracks in the rock near the organic matter of the old Indian cave, and the surrounding rock may be expected to be barren of nitrate.

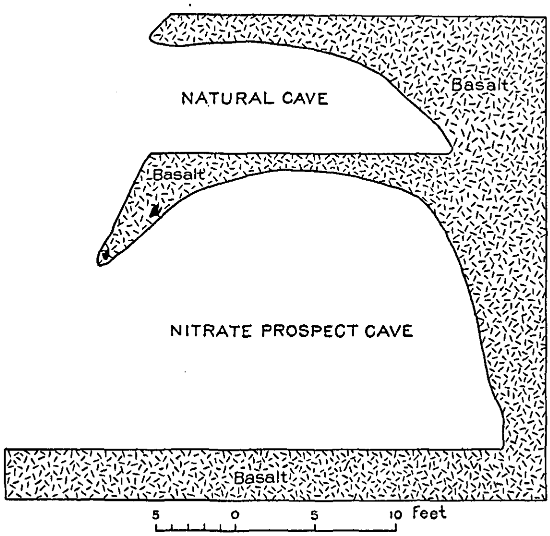


FIGURE 13.—Profile of Glasscock Cave, Presidio County, Tex.

Four representative samples of material taken from the two caves illustrated in Figure 13 were analyzed in the laboratory of the Geological Survey with the following results:

Analyses of samples from Glasscock claim, Presidio County, Tex.

[E. T. Erickson, analyst]

	Material	Total soluble salts, 180°–190° C. (per cent)	NO_3 in sample (per cent)	Remarks
9	Incrustation	3.6	2.76	Chipped from side of prospect cave (lower).
10	Sacked material	59.8	33.54	From open sack; probably better than average.
11	Basalt	.48	Trace.	Wall of prospect cave, apparently free from incrustations.
12	do	.69	.36	From material in upper cave. Had coating of tarlike organic smut.

The analyses show that some of the caked material in sacks is very rich in nitrates, but the incrusted material on the wall is rather lean, whereas the rock itself is practically barren of nitrates.

Probably all the nitrate rich enough to have commercial value had already been gathered and sacked. The quantity in sight was estimated by Mr. Robinson to weigh between 5 and 6 tons. If, as suggested by sample 10, about 60 per cent of this material was nitrate, a most liberal estimate, the total nitrate then available at the Glasscock claim would have been about 3 to 3½ tons, a commercially negligible quantity.

CASNER CLAIMS

In June, 1927, samples of nitrate reported to have come from Presidio County were received from S. W. Casner, Marfa, Tex. Upon examination in the laboratory of the Geological Survey they were found to consist of volcanic rock coated with salts containing potassium nitrate and were thus similar to material already described from other parts of Presidio County. From information gained from J. E. Casner, at Alpine, the location of these claims appears to be about half a mile south of the road up Torneros Creek and about 4½ miles east of the Torneros ranch, as shown on the topographic map of the Shafter quadrangle. (See pl. 4, No. 11a, and fig. 12.)

OTHER DEPOSITS

Nitrates are widely distributed in Presidio County, and though the more conspicuous examples are probably included among those described above, there are doubtless many others that may sooner or later attract notice. The Geological Survey has received samples of nitrate from Presidio County from several correspondents who did not give the location of their deposits. In all these occurrences, however, the samples were of the same general type as those already discussed, and may, indeed, have come from some of the same localities. None of them afford any hope of successful commercial development.

REEVES COUNTY

Toyah.—The deposit near Toyah, owned by A. A. Snell, was brought to the attention of the Geological Survey by B. F. Quicksall, of Beaumont, Tex., in a letter dated March 23, 1917, accompanied by a statement of analyses showing high percentages of potassium nitrate and smaller amounts of common salt. The associated rock was said to be sandstone. The samples submitted to the Geological Survey were selected from the surface and from diggings then recently opened. Upon examination in the Geological Survey laboratory the samples proved to consist of porphyritic rock with an incrustation of soluble salts amounting to as much as 3 or 4 per cent of the sample. The soluble salts were essentially a mixture of sodium nitrate and sodium chloride, the nitrate apparently predominating.

SAN SABA COUNTY

SAN SABA AREA

Among the nitrate deposits that have been repeatedly brought to public notice are those near San Saba, in central Texas. (See pl. 4, No. 13, and pl. 11.) These deposits were examined in June, 1916, by H. S. Gale, then in charge of all the Geological Survey's investigations of nonmetallic mineral resources but specializing in potash and nitrates. Mr. Gale prepared a report embodying his findings, but as these indicated that the deposits were not of commercial value it was deemed unnecessary to publish the report at that time. However, as these deposits have received considerable later publicity and have been the subject of much official correspondence, it has been thought advisable to include them with the other deposits already discussed in a general review of Texas nitrate deposits. Accordingly in June, 1928, G. R. Mansfield, with J. W. Vanderwilt as assistant, spent four days in the vicinity of San Saba interviewing interested persons and reexamining the deposits themselves in company with their owner, Judge Thomas F. Hawkins, of Georgetown, Tex., and some of his associates. It soon appeared that little actual development of the deposits themselves had taken place since Mr. Gale's visit, though a small plant and one or two neighboring buildings had been erected, the plant being connected with a 40,000-volt power line and equipped with a 100-horsepower motor and with crusher, weigher, and sacker.

As Mr. Gale's report is still largely applicable to the San Saba district it is here presented practically entire.

NITRATE DEPOSITS NEAR SAN SABA, TEX.

By Hoyt S. Gale

Present interest.—Saltpeter, or nitrate of potassium, in natural occurrences has frequently attracted the attention of prospectors, as it has been found in many parts of the United States. One such deposit that has recently proved a source of local interest and speculation as to possible commercial value occurs near the town of San Saba, San Saba County, Tex.

This deposit was reported to the United States Geological Survey by Lieut. R. C. Burleson, United States Army, in June, 1915, and later by Mr. J. H. Cumley and several others, who forwarded samples for testing. The samples contained considerable percentages of practically pure saltpeter, which would undoubtedly have been of considerable value if the samples had represented deposits of sufficient size, available to mining and to transportation. However, the descriptions given indicated that the deposit is of a type which is common in many parts of this and other countries and which seems to offer little hope of occurrence in sufficient quantity to be of practical importance, except perhaps in the most extreme and absolutely dry of desert climates.

Location.—The deposit lies about 4 miles east of San Saba, about 1 mile south of the San Saba-Lometa road. Here the valley of the San Saba River is bordered by a rim of limestone bluffs, 100 feet or more above the meadowlands at their base. An old tunnel and several prospect pits and shafts are situated near the mouth of Fort Hollow, a generally dry stream channel which breaks through the limestone ledges and bluffs on the south side of the A. E. Petty farm. The saltpeter has been found in the ledges above the largest of these prospects, which is an old tunnel run in at the base of the cliff to a distance of about 75 feet. It is reported that there are other similar deposits in the general vicinity of San Saba, and specimens of nitrate that have been submitted are reported to have come from ledges and cliffs along or near the Colorado River.

Development.—It is stated by Mr. J. J. Devers that a tunnel was opened on the Frier place, about 5 miles east of San Saba, by A. C. Schryver, of San Antonio, Tex., in 1902, in the search for saltpeter. The description given indicates that the locality mentioned is that now again attracting attention, and the tunnel is undoubtedly the old one referred to above. The farm near by has been known successively as the Frier place and the Frye place and is now the property of Mr. A. E. Petty. It is stated by Mr. Devers, who worked in the old tunnel when it was first put in, that all signs of the saltpeter were lost beyond the first few feet from the surface and that it was decided that the saltpeter had been derived from guano or refuse in an old cave above. There is at present a cavelike depression in the ledge above the old tunnel, in which there are crusts of saltpeter and, as usual in such places, some animal refuse. Among other old workings in the vicinity, now fallen in, the principal one is a shaft at the foot of a cliff just across the creek channel from the tunnel. It is not known what this was made for. No recent work of any consequence seems to have been done in this vicinity.

General features.—The principal occurrence of saltpeter is in two caves in the face of the exposed limestone ledges, rugged and broken cliffs of which border the channel on each side at its mouth. The caves occur in the higher ledges on the southwest side of the channel. The saltpeter is found chiefly in the larger of the two caves, about 10 to 15 yards southeast from the mouth of the old tunnel and a few feet above the creek level. Thus the old tunnel runs in somewhat beyond and below the smaller cave or cavelike depression.

There are crusts of white granular saltpeter on the surface in certain parts of the cave, and similar salts have been deposited in fractures and cavities in the broken and porous limestone. In some parts the limestone seems thoroughly impregnated with this substance. Some of this material has been broken off in small quantities, mostly for samples, but there is no digging within the cave that goes into the more solid body of the rock. The limestone in which the caves occur is very irregular and full of cavities, and it is also much broken by a network of fractures. This rock is of a travertinelike character, as if a spring deposit, but is of so large a mass and so continuous along the front of the escarpment ridge that it may be considered a distinct geologic formation. Its outcrop is a narrow belt along the front of the ridge, beyond which is massive limestone forming a higher country. The travertinelike limestone is filled with fossil impressions of tree leaves, irregularly embedded, and many occur in folded and curled positions, some very perfectly preserved, which also indicates a travertine and surficial origin of the rocks as most likely. Doubtless the rock originally contained a large proportion of organic matter. A similar rock is now in process of formation just below the Barnett Spring, near by, where lime is precipitating from the spring water over a thick growth of moss, which finally loses its distinct identity as the mass becomes a solid limestone.

Mr. Cumley has a tooth which resembles a human tooth and which he says he found embedded in the rock in this cave. It is possible that the tooth may have been lodged in one of the cavities of the rock and later cemented into place by recrystallization of the lime.

Samples.—A series of samples was taken in and about these caves, and partial analyses of these have been made in the Geological Survey laboratory, by R. K. Bailey, as follows:

No. 2. An average portion broken from ledges at the top of the bluff above the nitrate caves. This sample gave no test for nitrates, and only 0.19 per cent of the original sample was soluble in pure water.

No. 3. A carefully taken average cut from the face of the ledge in the larger of the two caves referred to above. Of this sample but 4.71 per cent proved soluble in pure water (as indicated by residue when dried to constant weight) at 180° C., and nitrate as NO_3 is reported as 21.73 per cent of this soluble portion (which is 1⅔ per cent of saltpeter in the original sample).

No. 4. A portion of dark woods earth taken from among the limestone ledges at the top of the ridge just above the saltpeter cave. This earth gave no appreciable test for nitrate salts.

No. 9. Fragments of limestone from a surface outcrop a mile or more east of the Fort Hollow caves. This rock was reported to have given indications of nitrate, but the sample gave no appreciable nitrate test.

Besides the rock and earth samples described above, two water samples were taken. One was drawn from an abandoned well at the Petty farmhouse. The flow at the well is said to be very small and to have been obtained at a depth of about 50 feet. The water contained 0.18 per cent of dissolved matter (1,800 parts per million), being unfit for stock use or irrigation. Of the salts dissolved in this water about one-fifth (21.10 per cent determined) is reported as NO_3. In terms of saltpeter or potassium nitrate this water therefore contains 6 parts of potassium nitrate or saltpeter in 10,000 of water, which is equivalent to a solution of 6 pounds of saltpeter to 5 tons of water. Although this is actually a very small proportion, it is high as a nitrate content in natural water and may be of some significance.

The other water sampled was from the Barnett Spring, which issues from among ledges of travertine limestone similar to and perhaps directly continuous with that in which the saltpeter caves occur. The spring is about 1 mile east of the saltpeter caves. This water contains only 0.04 per cent dissolved matter (4 parts in 10,000) and showed no test whatever for nitrate. This is a spring which it was locally supposed might indicate a derivation of nitrate from the travertine limestone country rock.

San Saba deposits not of probable importance as a source of saltpeter.—General judgment, based on the quantity of saltpeter in evidence in the San Saba occurrence, is decidedly unfavorable as regards the probable importance of the deposit as a source of saltpeter. So far as indicated by the exposures that had been made at the time of examination, only a very small quantity of saltpeter had been proved to exist in this locality, and that of so low a general percentage (as indicated by sample 3) as to be very doubtfully recoverable commercially.

The other practical point at issue is, Do the surface showings indicate other or richer deposits at depth? The only answer that can be given to this is that general experience, such as that reported from the 75-foot tunnel on this property and from similar prospecting at other deposits of like character elsewhere, has always led to negative results. The understanding as to the probable mode of origin of such deposits argues against the extension of these deposits in depth. Very little hope can be held out that deposits of this type in a semiarid or a moister region can be very extensive or could exist in the presence of an abundance of surface water and ground water, such as are present at least during certain parts of each year in the San Saba region.

On pages 3–8 a discussion of the origin of saltpeter is given. This is believed to be applicable to the San Saba occurrence.

Although Mr. Gale's report was not published at that time its general tenor was made known by official correspondence and in a press statement, which, though not specifically mentioning the San Saba or other Texas occurrences, did give a summary of Mr. Gale's findings relating to nitrate deposits of this type.

LATER ACTIVITIES

Two years later the question of the commercial availability of the San Saba deposits was again raised independently by different correspondents, and unexpected confirmation of Mr. Gale's findings was obtained from one of them, E. C. Breedlove, of Seymour, Tex. In response to a query from the Geological Survey, Mr. Breedlove, who had previously submitted interesting specimens of nitrate for examination, wrote as follows July 13, 1918:

After receiving a report on the potash proposition from the late Dr. W. B. Phillips we did not investigate it further. Doctor Phillips said in his report that he had investigated this proposition several years ago and did not find potash in quantities enough to pay to work.

The bed from which I obtained the sample is close to San Saba, Tex., in San Saba or Burnet County. I did not learn which, for after receiving Doctor Phillips's report I dropped the matter. Doctor Phillips said that the deposit was surface stuff and not much of it.

Doctor Phillips's long connection with the University of Texas, his familiarity with geologic conditions in Texas, and his general experience with nitrate deposits in that State (see p. 62–65, 75–77) had undoubtedly entitled him to an authoritative opinion on such matters.

Investigation of 1928.—In 1927 a vigorous revival of interest in the San Saba deposits occurred. Substantial beginnings at actual development were made, as indicated by the construction of a plant (p. 85), and there were urgent appeals from many sources for a new investigation. It was claimed that the deposit contained an abundance of potash and other chemicals to a depth of at least 267 feet and covered an area that could yield thousands of carloads of these substances.

When G. R. Mansfield and J. W. Vanderwilt visited San Saba in June, 1928, they went equipped to make any survey or examination of the ground that the circumstances might justify. The owner, Judge Thomas F. Hawkins, had acquired not only the deposit near San Saba, including the Petty place, mentioned by Gale and in 1928 occupied by J. H. Dalton, but also the ownership or control of the entire strip of deposits, which, according to his own statement, extends about 27 miles to the southeast from San Saba. Judge Hawkins kindly arranged to go personally with the Geological Survey party to three localities which he considered representative of his best ground. These were the original locality studied by Gale, including the Barnett Spring; a cave in the bluff above the Colorado River near Postoak Falls, about 7 miles in a direct line below Bend and about 20 miles southeast of San Saba; and the Parker place, about halfway between San Saba and Postoak Falls. W. B. Wilson, of the local chamber of commerce, and Messrs. Peffley and Wright, employees of Judge Hawkins, accompanied the party. Tests of material from each locality were made by means of the delicate brown-ring reaction, described on page 10, and samples for analysis were collected at the first two localities.

San Saba area.—Aside from the erection of the plant the principal development at the original locality since Mr. Gale's visit was the breaking down of a quantity of the porous travertine rock, which lay on the ground to the west of the plant and probably represented a few hundred tons of material. There was also a relatively fresh pit in the flat about 6 feet deep and about 50 yards east of the plant. The rock pile, the pit, the old tunnel, and the caves near the tunnel were all carefully examined for nitrate salts, but none were detected. Field tests of pieces of rock from these places yielded essentially negative results, but five samples were collected and sent to the laboratory of the Geological Survey in Washington, where they were analyzed with the following results:

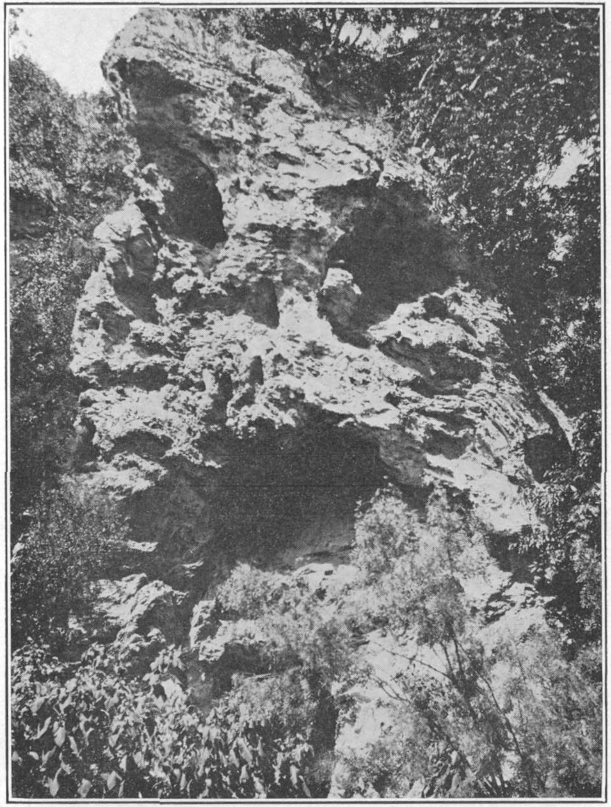
Analyses of samples of nitrate-bearing rock from vicinity of San Saba, San Saba County, Tex.

[E. T. Erickson, analyst]

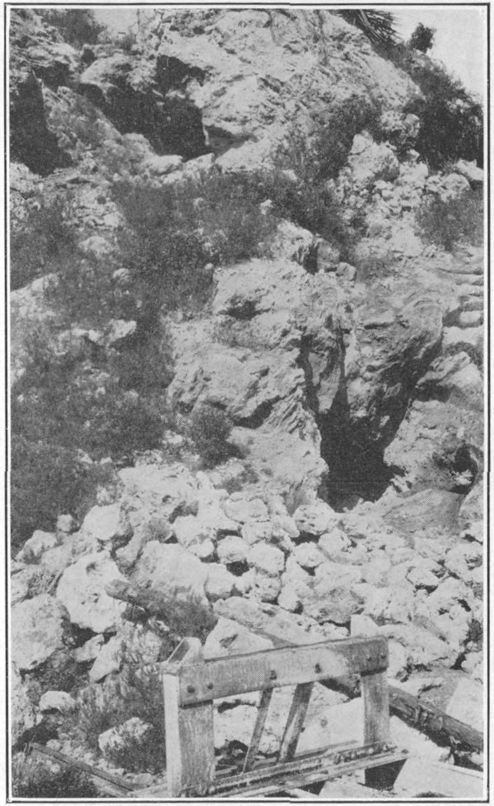
Sample	Material	Total soluble salts dried at about 180° C. (per cent)	K_2O in sample (per cent)	K_2O in salts (per cent)	N_2O_5 in sample (per cent)	N_2O_5 in salts (per cent)
S-1	Limestone débris (probably not in place) underlying 2 feet of soil in pit. Sample represents the average of material cut from 28-inch vertical strip 6 inches wide and one-half inch thick.	0.94	0.13	13.8	0.03	3.20
S-2	Sample of soil and rock forming surface of pit about 6 feet deep.	.88	.14	15.9	.02	2.28
S-3	Surface material from inside of cave above tunnel.	2.30	.09	3.9	.11	4.69
S-4	Represents about 2 feet of wall of tunnel about 30 feet from entrance after knocking off 6 inches to 1 foot of irregularly breaking material to get fresh surface.	.48	.10	20.9	([a])	----------
S-5	Face of tunnel 75 feet from portal	.54	.08	14.8	([a])	----------

[a] Less than 0.01.

All five samples were qualitatively tested for phosphate. Samples 1 and 2 each contained less than 1 per cent. Sample 3 contained not more than 1 per cent, and samples 4 and 5 contained only a trace.



A. CAVERNOUS TRAVERTINE PINNACLE (NOW DESTROYED) WHICH FORMERLY CONTAINED RICH NITRATE INCRUSTATIONS



B. TRAVERTINE CLIFF SHOWING OLD TUNNEL (LOWER RIGHT) AND NITRATE-BEARING CAVES

VIEWS OF NITRATE-BEARING TRAVERTINE ABOUT 4 MILES SOUTHEAST OF SAN SABA, TEX.

According to Clarke,[86] the average potash content of 345 limestones analyzed in the laboratory of the Geological Survey was 0.33 per cent, and that of 466 soils from humid regions of the Southern States cited from Hilgard was 0.216 per cent. On the basis of these figures none of the samples whose analyses are given in the table above contained as much potash (K_2O in sample) as the average limestone or the average soil from humid regions in the Southern States. San Saba, with a mean annual rainfall of 25 to 30 inches, may be considered a fairly humid area. Figures for the average nitrate (N_2O_5) content of limestones and soils are not given by Clarke, but the small amounts shown in the column headed "N_2O_5 in sample" in the above table suggest that these amounts may reasonably be expected to fall within such an average. Similarly the phosphate content of the samples cited is not unusual. Clarke gives the average phosphate (P_2O_5) content of limestones as 0.04 per cent and of soils in humid regions of the Southern States as 0.113 per cent.

At the Barnett Spring, which lies at the mouth of a small valley, travertine was observed in the process of formation as coatings on wood, moss, and other substances, and older material of the same sort, practically identical in character with the travertine near the plant, was seen. Here, however, water falls over the travertine, and therefore no places favorable for nitrate accumulation were observed. The valley above the falls was ascended for perhaps half a mile. There were limestone ledges on each side. Here and there recesses were noted in some of the ledges and these were examined for incrusted salts, particularly nitrates. None were found.

Inquiry of Judge Hawkins and of others in San Saba failed to bring out any specific data in support of the statement cited on page 89 that potash had been obtained in the area from depths as great as 267 feet.

Postoak Falls locality.—The deposit near Postoak Falls on the F. E. Edwards ranch, San Saba County, was considered by Judge Hawkins to be perhaps the best in the entire nitrate-bearing belt, of which it practically marks the southeast end. Postoak Creek, a small tributary of the Colorado River from the west, here forms a cascade about 250 feet to the river below. At and near the brink of the falls travertine is in process of formation in much the same manner as at Barnett Spring, and older travertine continues northward along the river bluff an undetermined distance. About 100 yards north of the falls and on the top of the bluff a small opening a few yards across leads into a cave estimated to be about 75 feet deep and 50 feet in diameter. There are small side chambers, and the main cave

[86] Clarke, F. W., The data of geochemistry, 5th ed.: U. S. Geol. Survey Bull. 770, pp. 30, 494, 1924.

opens out at the bottom on the valley side at about the level of the base of the cliff. There is a steep descent from its mouth to the river. The cave had evidently been a refuge for goats and possibly other animals.

The walls of the main cave and the principal side chambers were carefully examined with a flash light, and small amounts of incrustations were observed here and there. These incrustations were mostly of calcium carbonate, but some were of other substances, and in one place there was a small accumulation of white crystalline salts about half an inch thick. Four samples were taken of material from the roof of the cave in what seemed to be the more favorable places. As these came from the surface rock of the cave rather than from areas from which the surface rock had been removed, they might be expected to contain more nitrate salts than would be found in fresh rock. When tested with the brown-ring reaction all but one gave negative results or showed merely traces. One sample gave a distinct ring but not so vigorous a reaction as might have been expected had the salts been pure nitrates. Nevertheless the samples were sent in to the Geological Survey laboratory for checking and were analyzed with the following results:

Analyses of samples from cave near Postoak Falls, San Saba County, Tex.

[E. T. Erickson, analyst]

Sample	Material	Salts in sample at 180° C. (per cent)	K_2O in sample (per cent)	K_2O in salts (per cent)	N_2O_5 in sample (per cent)	N_2O_5 in salts (per cent)
a	Roof of cave	1.72	0.25	14.5	0.09	5.22
b	do	2.56	.26	10.2	.06	2.34
c	do	1.34	.20	14.9	.26	19.40
d	do	1.20	.18	15.0	.24	19.95

The percentage of water-soluble material in the salts present in all samples was small. Moreover, these salts were not pure nitrates. For example, in sample b, which contained 2.56 per cent of soluble salts, only 0.26 per cent of the sample was potash and only 0.06 per cent was nitrate. As the nitrate present, if all combined as potassium nitrate (saltpeter), could utilize only about 0.035 per cent of potash, the remainder of the potash in the sample ($0.26-0.035=0.225$) must be combined in other forms, such, for example, as chloride or sulphate. Similarly, sample d contains 0.18 per cent of potash and 0.24 per cent of nitrate. The nitrate, if all combined as potassium nitrate, could utilize about 0.14 per cent of potash, so a margin of 0.04 per cent of potash is left to be combined in other ways. The percentage of potash and of nitrate in all these samples, in terms of soluble salts, is, however, too small to have commercial significance.

Moreover, the samples analyzed did not represent a fair average of the rock mass; instead they represented material presumably richer than the average because more favorably located for the accumulation of nitrate salts.

The cave at Postoak Falls is thus a place where typical cave nitrates might be expected but where they are more sparsely represented than at many localities in other regions.

Parker place.—At the Parker place a storage cellar has been excavated in a bank of sandy material a short distance back from the road. The walls and timbers show efflorescence here and there, some of which took the form of tufts of long, delicate needles. These were not nitrates but were considered by Mr. Vanderwilt to be crystals of magnesium chloride, though their composition was not determined. Samples of the incrustations and of the material in the bank to a depth of 1½ feet were tested for nitrate by the use of the brown-ring reaction. Only traces of nitrate were indicated for the surface material, and none at all was found at the depth of 1½ feet. Areas of travertine were noted in pastures east of the road near the Parker place, but none of the exposures examined were favorably situated for the accumulation of nitrate, and none was seen. Altogether the indications at and near the Parker place are distinctly unfavorable for the occurrence of commercial quantities of potash or nitrates.

End of investigation.—As the Geological Survey representatives had been shown three of the supposedly most favorable parts of the San Saba nitrate-bearing area, and as each of these parts when tested had yielded only meager evidence of the presence of nitrate and no evidence whatever of the existence of commercial quantities of that substance, further investigation of the area was abandoned. It is possible that other parts when tested may yield evidence of the presence of nitrate similar to that seen or perhaps even greater amounts than those already known. This contingency, however, does not have sufficient weight to justify further exploration of the nitrate except for such scientific interest as it may possess in broader geologic studies of the region.

The failure to find even moderately good specimens of nitrate at places where earlier observers found much better material may have been accidental, but it suggests that the supply of the better nitrate is already exhausted. For example, the pile of broken rock near the plant represents a mass that formerly stood in place as a rock pinnacle and afforded protection for pockets or patches of nitrate salts. (See pl. 11, *A*.) These broken pieces have now been exposed to the leaching action of many rains, and whatever nitrate they may once have contained has long since been washed away.

CONCLUSIONS REGARDING SAN SABA NITRATE DISTRICT

The nitrate deposits in the vicinity of San Saba, Tex., have been known for 25 years or more and have been the subject of recurrent interest during that period. From time to time extravagant claims have been made about their content of potash or nitrates. As recently as early in 1928 considerable publicity had been given to them as possible large-scale sources of potash. They have been examined independently by at least three geologists experienced in the examination and study of nitrate deposits. The first of these three was Dr. W. B. Phillips, well known for his geologic work first in the Southeastern States and later in Texas. His work in Texas had included a special study of the potash and nitrate resources of the State. (See p. 62.) He did not publish any statement of his observations relating to the San Saba deposit, but his opinion is recorded indirectly through the letter of E. C. Breedlove, cited on page 89. H. S. Gale, who followed Doctor Phillips, had for some years been in charge of the Geological Survey's investigations of potash and nitrate and had personally investigated deposits of both in many States. His hitherto unpublished report on the San Saba nitrate field, given on pages 85–88, supplies the principal data for the present discussion. The third geologist, who in 1922 succeeded Mr. Gale as geologist in charge of the Geological Survey's investigations in potash and nitrate, was G. R. Mansfield. His findings fully supported the adverse judgment of his predecessors.

Some of those interested in the San Saba district have stated that the official investigations made were too brief and not sufficiently thorough to demonstrate the presence or absence of potash and nitrate deposits of commercial value in that district. To such criticism it is replied that judgment in geologic investigations, no less than in other business, must be based on training and experience as well as upon the immediate data available. On the basis of past experience and of information gained at San Saba and in the laboratory the authors are thoroughly convinced that no commercially valuable deposits of potash or of nitrate exist in that district and that the rocks there contain no unusual amounts of phosphate, the third mineral constituent of the fertilizer trio.

VAL VERDE COUNTY

Shumla area.—Mr. Robinson had heard through the Texas Bureau of Economic Geology and Technology of a nitrate-bearing cave in the Edwards limestone near Shumla, Tex., a flag stop on the Southern Pacific Railroad about 12 miles east of Langtry. Analyses of the nitrate from this cave, as reported to a representative of the bureau, indicated a nitrate content of 12 to 25 per cent for the incrusted material, 2 to 8 per cent for the dirt in the cave, and 2 to 5 per cent for the wall rock of the cave. This nitrate was believed to be confined largely to the incrusted material and to be of little economic value.

In September, 1918, when Mr. Robinson attempted to find this locality by himself, he was unable to do so, and local aid proved unavailing. He did, however, hear of an abandoned railroad tunnel in that vicinity which was thought to contain nitrates in association with bat guano.

Several years ago the Southern Pacific Railroad instead of spanning the Pecos River Canyon by a very high bridge, as it now does, turned south from Shumla and followed the precipitous north wall of the Rio Grande Canyon until it crossed the Pecos River near its mouth. About 4 miles southeast of Shumla it was necessary to tunnel out part of this old road bed. When visited by Mr. Robinson the tunnel was about 1,500 feet long, 30 feet from roof to floor, and 15 feet from side to side and was inhabited by bats. An automobile could be driven on top of the high plateau to a place within a few hundred feet of the western portal. He estimated the amount of guano in the tunnel roughly as a mass 1,300 feet long, 12 feet wide, and 2 inches deep. No incrustations of nitrates were seen.

In the country near Shumla are numerous small caves, and some of them may contain nitrate like the one seen by the representative of the Texas bureau. The local inhabitants, however, some of whom had lived for a long time in the region, knew of no nitrate deposits save the guano of the tunnel mentioned above. The commercial prospects for nitrate in that region would therefore seem to be nil.

Devils River.—An occurrence of niter on Devils River, under an overhanging cliff of limestone, about five-eighths of a mile from the place where Indian Creek flows into it, has been reported.[87]

UTAH

BEAVER COUNTY

G. B. Loring, of Monroe, Utah, reports beds of nitrate salts, proved by tests or analysis made by Professor Talmadge, from a locality 2½ miles above the Rob Roy mine, in Wildcat Canyon, about 8 or 9 miles northeast of the town of Beaver. The salt is said to occur disseminated in limestone and lava, where exposed in cliffs.[88]

GRAND COUNTY

[See Colorado, p. 30]

In 1918 J. T. Pardee, of the Geological Survey, forwarded several samples from Tps. 21 and 22 S., Rs. 16, 17, and 18 E., only one of which contained nitrate, 1.04 per cent of sodium nitrate being found.

[87] Schrader, F. C., and others, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 293, 1916.

[88] Gale, H. S., Nitrate deposits: U. S. Geol. Survey Bull. 523, p. 16, 1912.

IRON COUNTY

Mineral Resources for 1887 contains a reference [89] to several small beds of niter near Parowan and other places in Iron County.

MILLARD COUNTY

Mineral Resources for 1887 contains a reference [90] to saltpeter or nitrate of potash occurring near Fillmore, Millard County. Deposits in Snake Valley a few miles east of Gandy and in White Valley, known locally as "Tooley," were reported to William Peterson, of Logan, Utah, to be high in nitrate, but samples received from those areas and tested by him in 1916 contained no nitrate.

PIUTE COUNTY

Nitrate has been found in Greenwich Canyon, Piute County, on the east margin of the Sevier Plateau, 5 miles S. 70° E. from Marysvale Peak, near the north boundary of the county. This occurrence has been described by Gale.[91] The salts are found in caves or brecciated cliffs and ledges that border the canyon valley. Evidences of habitation by bats or other nest-building animals are seen in the same cliffs. The deposits have no commercial value.

SALT LAKE COUNTY

The discovery of a deposit of nitrate in T. 1 S., R. 2 E., was reported in 1910 by E. L. Jensen, of Salt Lake City.

SANPETE COUNTY

A sample forwarded by P. O. Perkins, of Salt Lake City, in 1917, said to have been obtained from Sanpete County, was found to be a saline incrustation containing probably as much as 50 per cent of soluble material, mainly potassium nitrate and calcium sulphate. A deposit of potassium nitrate near Ephraim was reported in 1917 by R. A. Hart, of Salt Lake City.

SEVIER COUNTY

Incrustations near springs or seeps on the eastern edge of Sevier County were reported by William Peterson, of Logan, Utah, in 1918, to contain 8 per cent of sodium nitrate, accompanied by large quantities of sodium sulphate and sodium chloride and very small amounts of potassium.

---

[89] Williams, Albert, List of useful minerals of the United States: U. S. Geol. Survey Mineral Resources, 1887, p. 796, 1888.

[90] Idem.

[91] Gale, H. S., op. cit., pp. 16–19.

SUMMIT COUNTY

A deposit of potassium nitrate in sec. 10, T. 1 S., R. 6 E., has been reported by H. T. Rasmussen, of Park City, Utah.

UINTAH COUNTY

A property in Uintah County was reported by H. A. Wentworth in 1918 to contain material that shows 6 per cent of potassium nitrate.

UTAH COUNTY

Nitrate salts are reported by George T. Henry, of Marysvale, to have been found by chemical test in specimens of a pure-white salt taken from rock ledges in Hobble Canyon, which is the next canyon south of Provo, Utah.[92]

A sample obtained from the valley of Indian Creek, near Tucker, containing considerable quantities of sodium nitrate, was forwarded to the Geological Survey in 1915 by J. C. Benedict, of Thistle, Utah. The locality was visited on September 21, 1916, by H. S. Gale, who reports that the nitrate samples were obtained from the under edges of a large boulder consisting of tufa, evidently a spring deposit, and that Mr. Benedict had traced outcrops of rock of this character for about 4,000 feet up the canyon of Indian Creek. Gale states that the nitrate may be of the usual cave type or that the decomposition of included moss and algae may give rise to the nitrate salt.

A nitrate deposit near Fairfield was reported in 1916.

WEBER COUNTY (?)

A sample submitted by N. J. Teibush, of Ogden, Utah (no locality given), was found to consist of limestone incrusted and impregnated with nearly pure potassium nitrate.

VIRGINIA

Niter occurs in numerous caves in Shenandoah limestone in the valley on the west side of the Blue Ridge, where it has been procured for local use.

BOTETOURT COUNTY

Information concerning a saltpeter cave about 300 yards northeast of Saltpeter Cave, Va., was given to the Geological Survey in 1916 by the postmaster of that place. The owner of the cave, Mrs. Mary Goodwin, of Washington, D. C., stated in 1917 that the cave had been worked extensively during the Civil War.

---

[92] Gale, H. S., op. cit., p. 16.

ROCKBRIDGE COUNTY

A deposit of saltpeter near Goshen was reported to the Geological Survey in 1917 by J. W. Bell, of Goshen, Va. The material was said to occur on the face of a cliff of black shale and had the appearance of white powder.

WASHINGTON

GRANT COUNTY

Samples supposed to contain nitrate have been received by the Geological Survey from Herbert H. Luce, of Spokane, Wash. The samples came from a locality 3 miles east of Steamboat Rock, in Northrop Canyon, where two tunnels 30 feet and 15 feet long had been driven. The country rock is a weathered basic igneous rock. Some organic matter is present. The salt incrustations were chiefly sodium and aluminum sulphate, but there were traces of nitrate and phosphate.

WEST VIRGINIA

GREENBRIER, MONROE, AND POCAHONTAS COUNTIES

Saltpeter or " peter dirt " is found in caves in Greenbrier, Monroe, and Pocahontas Counties and has been mined there.[93]

MINGO COUNTY

Thomas West, of Williamson, W. Va., reported in 1917 that he had received information from Alex Stafford concerning a saltpeter mine in that county.

PENDLETON COUNTY

Three caves, one much larger than the others, containing nitrate were reported to the Geological Survey in 1916 by Miss Margie Boggs, of Petersburg, W. Va., about 4 or 5 miles south of Franklin. She also stated that a cave containing nitrate had been reported in the vicinity of Uppertract.

RALEIGH COUNTY (?)

A sample consisting of a good grade of potassium nitrate with some sulphate of potash and sandy material, was forwarded to the Geological Survey in 1920 by Wayman Redden, of Grandview, W. Va. No locality was given.

WETZEL COUNTY

Sandstone " rich in saltpeter " in the vicinity of Jacksonburg was reported to the Geological Survey in 1917 by L. E. Lantz, Jacksonburg, W. Va.

[93] Gale, H. S., op. cit., p. 12.

WYOMING

CONVERSE COUNTY

Application for a lease on sodium nitrate deposits covering five sections of land 14 miles south of Glenrock, on Little Deer Creek, was filed in 1925 by W. D. Turner, of Kansas City.[94] This reported deposit was examined in the fall of 1925 by A. B. Bartlett, State geologist, who reported to the Geological Survey that analyses of material from the deposit showed no nitrate except in one sample, which contained a slight trace of nitrate.

SWEETWATER COUNTY

Cross [95] describes an occurrence of potash niter in the Leucite Hills, on North Table Butte. The nitrate was found to occur in a cavity or recess with overhanging roof, several feet in length and depth, in nearly massive rock. The salts occurred in sufficient quantity to allow collection of specimens several inches in diameter. They seemed to occur as a partial crust to the cavity and as a filling for irregular fissures that extended downward and backward into the body of the rock. Analysis of the substance showed it to be essentially nitrate of potash. In several places where the breccia (which composes the mass of the column known as the Boar's Tusk) was open and cavernous a scanty white coating was observed on protected rock faces and proved to be a soda niter containing a little potash.

WASHAKIE COUNTY

R. G. Newborne, of Louisville, Ky., reported to the Geological Survey in 1917 that he had obtained sodium and potassium nitrate from the sandstone ledges on the flank of Bighorn Mountain above Tensleep, but that he thought the nitrate occurred in "pockets" and not in sufficient quantity in any place to be of commercial value.

SUMMARY OF INVESTIGATIONS

Certain nitrate-bearing areas in what from available evidence seemed to be the most favorable localities have been more or less intensively studied by successive Geological Survey parties. The results of all these investigations have shown that the mode of occurrence and the quantity of nitrate present at each locality do not justify commercial exploitation. The many samples of nitrate analyzed by the Geological Survey from different parts of the country confirm the view that the investigated areas are indeed typical of

[94] Eng. and Min. Jour., vol. 120, p. 708, Oct. 31, 1925.

[95] Cross, Whitman, Igneous rocks of the Leucite Hills and Pilot Butte, Wyo.: Am. Jour. Sci., 4th ser., vol. 4, pp. 115–141, 1897.

the better nitrate occurrences and that the hope of finding commercial bodies of natural nitrates in the United States is very remote.

EXPERIENCE OF PROSPECTING COMPANIES

Several companies have spent considerable money in attempts to produce commercial quantities of nitrate at some of the localities mentioned in this report. (See, for example, the experience of the Parsons & Simpson Co., cited on p. 75.)

The American Nitrate Co. spent large sums in trying to develop nitrate properties in Oregon and southeastern Idaho. The open letter published by President C. R. Cole, of that company, in one of the technical journals some years ago should give pause to those whose optimism at this day would lead them to cast aside accumulated knowledge regarding nitrate deposits and to enter upon new projects for their exploitation. It would seem fair to question either the business judgment or the good faith of those who in the face of this experience would persist in such a course. President Cole's letter is reproduced in part below:[96]

> With reference to northwestern nitrate promotions, now being advertised in some Oregon papers, I believe that money so invested will be practically a total loss. As I understand that some western men are trying to interest capital for the development of such deposits, the experience of the American Nitrate Co. should be given publicity.
>
> The American Nitrate Co., in which I was interested, spent about $140,000 in prospecting four or five nitrate deposits in southeastern Oregon that had been selected as the most promising among many similar discoveries. * * * In canyons deposits were found assaying all the way from 2 per cent up to 10 per cent in potassium and sodium nitrates. These were usually in crevices, although not always, and in some cases the nitrates were in the rock itself, the latter being of a somewhat porous character. * * *
>
> A good many tunnels were driven into the canyon walls for from 5 to 30 feet; in other places drilling was done, as occasionally clay beds would be found carrying from 1 per cent to even as high as 4 per cent of nitrate. In the case of the clays, the richest findings were on the surface and for but a few inches down. With depth the percentages became almost negligible. In the canyon walls the rich deposits seldom extended more than 2 to 5 feet.
>
> As to the origin of the deposits I shall not speak further, but the exploration work of the American Nitrate Co., covering a 2-year period on five properties which were selected as the best to be found in southeastern Oregon, convinces me and my associates that the nitrates do not exist in commercial quantities.

THE NITRATE INDUSTRY IN THE UNITED STATES

Although the United States is, so far as known, without natural deposits of nitrate of suitable size and quality to serve as the basis of a nitrate industry, it is not without the industry itself. Nitrogen is present in large quantities in coal and in the atmosphere, and in re-

---

[96] Oregon nitrate promotions: Eng. and Min. Jour., vol. 104, p. 1088, Dec. 22, 1917.

cent years industry has found means of recovery of nitrogen products from these sources in increasing quantities on such a scale and at such prices as to afford strong competition to any natural nitrates that are now or may become available.

Production of ammonium sulphate, a by-product of the coke industry, has risen from less than 23,000 short tons in 1910 to nearly 188,000 short tons in 1929.[97] The nitrogen content of sulphate of ammonia is 20.56 per cent, whereas that of Chilean nitrate is 15.6 per cent.

In 1910 the United States produced no fixed nitrogen. In 1919 the production was only 276 short tons. By 1928 it had increased to 26,000 tons, and in 1929 it was 84,000 tons. Meanwhile the capacity for fixed nitrogen production had risen to about 138,000 tons. It is expected that with projected new installations this figure will soon be greatly increased. According to Brand,[98]

> Those in position to know estimate that by 1932 our capacity will be between 800 and 1,000 tons of pure nitrogen a day. As it takes 6.07 tons of Chilean nitrate to yield 1 ton of pure nitrogen, that rate of production could be equal to between 1,800,000 and 2,100,000 tons of sodium nitrate yearly.

As the United States in 1929, according to Bureau of Mines figures,[99] apparently consumed 431,200 short tons of nitrogen, national independence in this important commodity is evidently well within sight.

UNITED STATES GEOLOGICAL SURVEY PUBLICATIONS ON NITRATE

1912. Gale, H. S., Nitrate deposits: Bull. 523, 36 pp., 2 pls.

1914. Richards, R. W., Niter near Melrose, Mont.: Bull. 540, pp. 470–473.

1916. Mansfield, G. R., Nitrate deposits in southern Idaho and eastern Oregon: Bull. 620, pp. 19–44.

1919. Gale, H. S., Nitrates: Bull. 666–Z, 4 pp.

1922. Noble, L. F., Mansfield, G. R., and others, Nitrate deposits in the Amargosa region, southeastern California: Bull. 724, vii, 99 pp., 35 pls.

1924. Clarke, F. W., The data of geochemistry, 5th ed.: Bull. 770, pp. 254–260.

1929. Mansfield, G. R., Geology, geography, and mineral resources of part of southeastern Idaho: Prof. Paper 152, pp. 349–351.

1931. Noble, L. F., Nitrate deposits in southeastern California, with notes on deposits in southeastern Arizona and southwestern New Mexico: Bull. 820, v, 108 pp., 19 pls.

Mineral Resources of the United States for 1883, 1912, 1917, 1918, 1920, and 1922.

---

[97] Brand, C. J., The world war in nitrogen: Am. Fertilizer, vol. 74, No. 2, pp. 17–23, Jan. 17, 1931. Johnson, B. L., Nitrogen and its compounds: U. S. Bur. Mines Information Circ. 6385, January, 1931.

[98] Brand, C. J., op. cit., p. 23.

[99] Johnson, B. L., op. cit., p. 11.

INDEX

81298—32——8

O