DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 724

NITRATE DEPOSITS IN THE AMARGOSA REGION SOUTHEASTERN CALIFORNIA

BY

L. F. NOBLE, G. R. MANSFIELD, AND OTHERS

CANCELLED

OHIO STATE UNIVERSITY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

QE 75
B9
no. 724-727
Copy 2

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
35 CENTS PER COPY

OHIO STATE
UNIVERSITY

CONTENTS.

258084

ILLUSTRATIONS.

PREFACE.

By Hoyt S. Gale.

The subject of our nitrate supply was brought into exceptional prominence during the World War because of its vital relation to the production of explosives. It is well known that before the war the world as a whole was essentially dependent on Chile for its supply of nitrate salts, used in the manufacture of powder, as a fertilizer, and for many other industrial purposes. During the war the lack and uncertainty of shipping and the possibility of interference with our trade connection with Chile made it imperative to develop any possible sources of domestic nitrates.

The present work is an outgrowth of a general plan undertaken by the writer in 1911 to investigate and to give practical judgment concerning the many reported occurrences of nitrate salts in the United States. The publication of the bulletin on nitrate deposits[1] in 1912 was but a preliminary step in a plan that has since been followed consistently in many parts of the West.

The many accounts that have been published concerning nitrate deposits in our Western States have kept alive the general impression that this region may contain undeveloped deposits which, if properly mined, might yield this much-needed mineral in commercial quantities. Many of these accounts relate to deposits in remote or somewhat inaccessible parts of the southwestern desert country and have therefore been difficult to verify, so that they have passed unchallenged. The recent great shortage of nitrates revived nearly all these old rumors and inspired many new ones, and it stimulated a search which brought out practically all available evidence concerning deposits of this class.

Attention has been centered chiefly on several nitrate deposits along Amargosa River near the boundary between Inyo and San Bernardino counties, in southeastern California. This stream makes a broad sweep from a southerly course through Amargosa Valley at Zabriskie and Tecopa to the west and then to the north through South Death Valley into Death Valley, forming a large U, so that it crosses

[1] Gale, H. S., Nitrate deposits: U. S. Geol. Survey Bull. 523, 36 pp., 1912.

the east-west line between the two counties twice. The nitrate claims are distributed along the lower course of this river. Nitrate deposits resembling those of the Amargosa River region are said to have been found at other localities, and extravagant statements concerning the existence of vast deposits, in rock or in other forms, come from time to time from the Western States, mainly Oregon, California, Nevada, Arizona, New Mexico, and Texas.

The following report covers most of the so-called nitrate fields of the Amargosa region. As may be seen from the report, a systematic effort was made to find whether there is any substantial basis for the belief that commercially workable deposits of nitrate occur in these fields. The conclusions reached, however, have been entirely unfavorable; they indicate that the deposits are not commercially workable.

After the more promising fields in the Amargosa region had been studied brief examinations were made of other areas in the desert where nitrate was reported. As a result of this work nearly every reported deposit of nitrate in southeastern California had been investigated by the end of 1918. The conclusions reached were no less unfavorable than those which resulted from the more systematic work in the Amargosa region.

If the United States Geological Survey should be able to verify the reports of the occurrence of workable deposits of nitrates in the United States it would be performing a most pleasurable duty. It should overlook no clue to the existence of even possibly workable deposits. On the other hand, if the small or lean deposits in the United States are in fact not workable, this fact should be made known as conclusively as possible, in order to avoid waste of effort and of money on them. The Geological Survey has been studying these deposits for several years. Any further substantial evidence bearing on the deposits that may be brought to light should be promptly examined until there need be no further doubt as to the value or workability of any of the deposits. If the lands containing such deposits are not commercially mineral bearing the public should be informed of this fact, and the sincere promoters of enterprises designed to exploit the deposits ought to welcome a demonstration of the facts regarding their claims.

The details here presented in regard to cuts and pits in the clay hills containing nitrate are more valuable for what they show concerning the relations of the salts and soils in deposits of this type than for the data they give for the estimation of the content of nitrate salts in these particular deposits. The evidence presented to show the origin of the nitrate in these soils makes the estimates as to the possible value of the deposits more conclusive. The accumulation of nitrate salts at or near the surface in clay soils of different geologic ages and relations tends to show that the nitrate owes its preservation to peculiar surface conditions and that the mere fact of its presence does not imply some deep-seated source where it occurs in greater quantity. It is much more likely that the nitrate is formed at the surface in essentially the same way that nitrates are now being formed in fertile soils, and probably in many soils that are not fertile, all over the world. Consequently, the idea of exploring by deep drilling for a supposed source of the surface nitrate incrustations finds no warrant in the evidence that has been collected.

The United States Geological Survey's explorations for nitrates have been made under the direction of the writer. The field work in the present campaign was started under his personal direction but was carried out in detail by separate field parties which were individually in charge of Levi F. Noble, George R. Mansfield, Frank C. Calkins, and Theodore Chapin, and the report here presented is a compilation of the reports made by these geologists. Most of the chemical work was done under the direction of William B. Hicks in the laboratory of the Survey at Washington. The prospecting work, including the opening of all the deeper trenches and pits, was carried out by practical miners under the charge of David H. Walker, who worked in cooperation with the geologists engaged in the detailed examinations in the various parts of the region.

A report of the results of the investigation was promptly compiled and filed in the office of the Chief of Ordnance of the War Department. The matter was considered urgent, not because of a belief in the probable discovery of large or important deposits, but in order that the officials responsible for our Government's policy with regard to providing the supplies of nitrate essential for the prosecution of the war might have a true understanding of the nature of such deposits as exist in this country and might not place undue reliance on unfounded assertions concerning the existence of important deposits of nitrate here.

NITRATE DEPOSITS IN THE AMARGOSA REGION, SOUTHEASTERN CALIFORNIA.

By L. F. Noble, G. R. Mansfield, and others.

INTRODUCTION.

By Hoyt S. Gale and L. F. Noble.

DISTRIBUTION OF DEPOSITS.

Nitrates associated with other water-soluble salts in the covering soil layers of certain clay formations in the arid portions of the southwestern United States form a type of deposit to which much attention has been given but which has nevertheless been very imperfectly understood. These deposits are widely distributed, and although many of them are associated with shale or clay formations of Tertiary age, some are found in Quaternary beds. The nitrate deposits appear to be associated with certain peculiar physical conditions, such as climate and character of the soil, rather than with formations of any particular geologic period. The deposits themselves show certain strong analogies to the great nitrate deposits of Chile, and, on the other hand, there are many ways in which they differ. It is believed that a careful study of all the evidence will lead to results of practical and scientific value, even if the deposits in this country do not prove to be of commercial importance.

The present report sets forth the evidence in hand concerning only a part of the deposits of this class that have already been studied. It is the intention to follow this with other accounts by which the occurrences of this type may be more fully covered. This plan is to a certain extent insured of accomplishment by the lingering possibility that somewhere some of these deposits may prove to be of value.

The deposits in the Amargosa River valley are, so far as known, the most extensive and probably the richest of this type of occurrence yet recorded. They lie in a more or less related group, and thus their consideration may well be undertaken in a separate report.

The general distribution of the known nitrate-bearing clay deposits in the desert region of southeastern California is shown by the accompanying map (Pl. I). The areas discussed in the present report include the group lying southeast of Death Valley, in general those designated on the map with the smaller numbers, beginning with No. 1.

The names used in the index to this map are those used in the detailed descriptions in subsequent parts of this report. The order of numbering is that in which the first examinations of the campaign were undertaken and is otherwise without significance.

CHARACTER OF DEPOSITS.

The principal nitrate deposits of the Amargosa region are associated with beds of clay of Tertiary age. Most of these beds belong to a series of deposits which were laid down in nearly flat layers in lakes but which since their deposition have been very much deformed by faulting, folding, and igneous intrusion. These beds now crop out in more or less isolated light-colored hills, which are covered with a loose saline clay soil that is almost wholly barren of vegetation. Because the clay soil turns to mud during the infrequent desert rains, the hills are sometimes called "mud hills" by the prospectors. In some localities they are called "niter hills"; in others, "clay hills" or "sand hills."

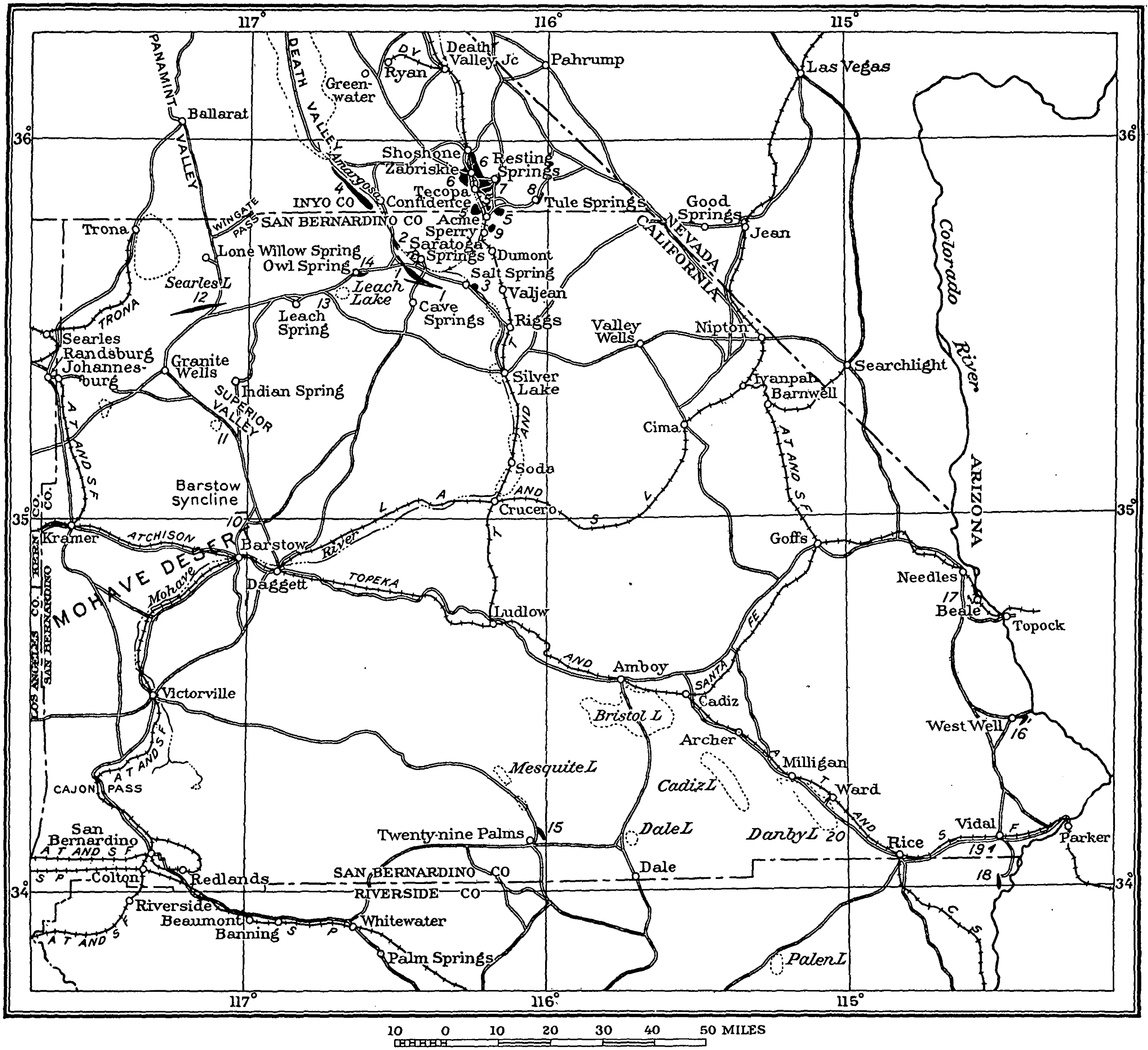
These clay or mud hill areas are among the strangest scenic features in the desert. Many of the hills have a peculiar shape which is difficult to describe but which, for want of a better comparison, may be likened to that of an elephant's back. (See Pl. II.) Their barren, rounded forms and pale, indefinite colors contrast so strikingly with the rugged forms and strong colors that prevail in the desert that they invariably arouse the curiosity of the observer.

Viewed from a distance none of the clay-hill areas appear to be much cut up by erosion, but viewed close at hand or in the early morning or late afternoon light the smoothness vanishes and each area is found to be eroded into an intricate system of deep gullies or washes, many of which are bounded by almost vertical cliffs. In places large tracts are carved into badlands. In general the flat or moderate slopes of all the hills are mantled with soil, whereas the cliffs along the washes and the steeper slopes in the badlands are bare outcrops of the bedrock strata. In many places, however, there is a soil mantle on the steeper slopes.

Numerous pits and trenches dug into the soil-mantled ground show that it is composed of the following layers:

Soil—soft, porous, usually less than 1 foot thick.

A more or less consolidated saline layer, usually less than 6 inches thick, which lies immediately below the loose soil. This layer is here called "caliche,"



INDEX MAP OF THE NITER FIELDS OF THE AMARGOSA DISTRICT.

For explanation of numbers see table on page 89.

THE SARATOGA NITER HILLS.

View southwestward from the top of hill No. 3.

a Spanish word applied to somewhat similar material in the Chilean nitrate fields.

Bedrock—stratified deposits of clay, sand, and gravel.

Of these three layers, the soil and caliche are simply blanket deposits, which lie parallel to the surface of the ground and are consequently independent of the stratification of the bedrock. The structure of the bedrock varies from place to place; as a rule the beds dip steeply and are folded and faulted, but in some places they are nearly horizontal and are practically undisturbed. The arrangement or position of the soil, caliche, and bedrock is shown diagrammatically in figure 1.

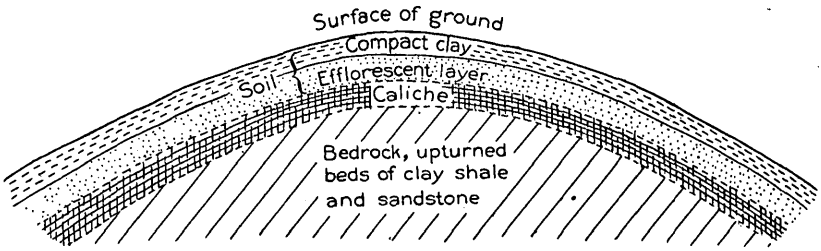


FIGURE 1.—Sketch showing arrangement of soil, caliche, and bedrock of the clay hills of the Amargosa region.

The soil for a depth of a few inches at the surface consists of compact clay whose surface is covered with innumerable little knobby corrugations formed by rain erosion. Underneath this clay crust the soil is loose and powdery and contains much soluble matter which appears as white, efflorescent salts—chiefly sulphates of sodium, calcium, and magnesium. In places this powdery layer is absent and the soil consists of compact clay alone. The surface crust of the soil carries practically no nitrate, and the underlying efflorescent layer carries very little. Perhaps the most striking feature of the soil is the practical absence of vegetation upon it. Whether this barrenness is due to the abundance of soluble salts in the lower part of the soil or to the peculiar physical character of the soil itself is not definitely known.

The caliche is essentially bedrock that has become disintegrated by weathering and then cemented with various salts. In places it is a well-defined layer, so compact and so thoroughly cemented that it forms a natural hardpan that is tougher and more difficult to penetrate with the drill than the bedrock beneath it. In places it is soft and flaky, grading imperceptibly into the soil above and into the bedrock below. It is rarely over 6 inches thick and in many places is entirely absent. The most abundant salt in the caliche and the one that may be said to characterize it is sodium chloride (common salt); sulphates, chiefly of sodium and calcium, are usually present, but the caliche is chiefly interesting because it contains sodium nitrate in much greater amounts than either the soil or the bedrock.

The bedrock strata consist largely of clay but include many beds of sand and gravel. Much of the clay is in massive beds, but some of it is rather thinly laminated shale. Nearly all the clay contains thin seams of gypsum, some of it contains crystals and seams of salt, and some of it contains crystals of celestite. At several places massive beds of rock salt and gypsum are interstratified with the clay. A great deal of the clay is believed to be fine volcanic ash, some of which is coarse enough to be classed as a sandstone. Most of the sand and gravel in the bedrock are sufficiently indurated to be classed as sandstone and conglomerate. Some of the sand is mixed with the clay, and some of it is in beds interstratified with the clay, but most of it is in thick sets of beds which in places contain a great deal of conglomerate. Most of the conglomerate is believed to have been deposited in alluvial fans and has been called "fanglomerate."[2] Some of it, particularly in places near areas of volcanic intrusion, is a volcanic breccia.

In the Saratoga, Round Mountain, Valley, Confidence, Owl Spring, Upper Canyon, and Lower Canyon areas the bedrock strata are steeply upturned, folded, and faulted. All these profoundly disturbed strata are of Tertiary age. Certain areas, however, which somewhat resemble the clay-hill areas just mentioned, are underlain by beds of clay and sand that lie in their original horizontal position and are probably Quaternary; among these are the Zabriskie, Resting Springs, and the Tule Springs areas. The Salt Springs nitrate deposits consist of horizontal lake beds of still more recent age than the others. All these areas of horizontal beds are carved into characteristic mesas and badlands, which are mantled with clay soil like that which covers the clay-hill areas of Tertiary strata. A caliche layer is found beneath the soil in some places, but it is much less widely distributed than the caliche in the Tertiary clay-hill areas and contains less nitrate.

Unconformities have been found in the Tertiary strata in some of the nitrate fields, so these strata probably comprise two or more series, each of which was upturned and eroded before the following series was laid down. Little is known of their exact age, because no fossils were found in them, but it is probable that they are deposits of the later rather than of the earlier half of Tertiary time.

Much saline material is evidently original in the bedrock, because the massive beds of rock salt and gypsum that are interstratified with the clays were evidently laid down at the same time that the clays were deposited. Most of the thin seams of gypsum found in

[2] Lawson, A. C., California Univ. Dept. Geology Bull., vol. 7, pp. 325–334, 1913.

the clays are secondary deposits—they were formed after the clays were laid down—for they cut the stratification. The regular lamination of the clays at many places is supposed to indicate deposition in still water, and the saline deposits suggest that this water was an evaporating saline lake. These facts afford ground for the supposition that nitrate might have been deposited with the sediments along with the other water-soluble salts, if it may be assumed that nitrate was among the other salts that accumulated in a saline lake of this character. Nitrate, however, is not found in this association elsewhere.

Some samples taken from the bedrock below the caliche gave a fairly strong reaction for nitrate, but this nitrate had evidently been carried downward in narrow cracks that probably do not extend very deep. Samples of the rock salt in outcrops and prospects gave no reaction for nitrate. Samples of the shales that are immediately associated with the bedded salt deposits also gave no significant reaction for nitrate. The samples of the shales were taken at places away from the surface or from the influence that might be assumed to govern the accumulation of nitrate in the caliche layer. The nitrate caliche bears no apparent relation to the part of the stratigraphic section that contains the salt, as good reactions for nitrate are obtained from caliche formed on deposits that are far removed from the influence of such salt deposits. In parts of these deposits that have been thoroughly prospected the unaltered bedrock strata have been exposed deep below the surface in long, continuous sections, and no evidence of nitrate-bearing layers in the bedrock could be found, though special search was made for them. The chances are thus strongly against the abundant occurrence of nitrate in the bedrock, as, if present, it would surely have been found.

Attention has therefore been directed chiefly to a study of the caliche. Numerous samples of soil, caliche, and bedrock have been carefully analyzed, so that there is now a more substantial basis than ever before for estimating the quantity of nitrate in these deposits and for determining whether the caliche is commercially workable.

GENERAL CONCLUSIONS AS TO VALUE.

Nitrate salts in extractable quantities have been found in the deposits described in this report, but considered in relation to the needs of the country, even for a very short period during the emergency of war, these deposits were not regarded as of immediate practical importance, because of the relatively high cost of any known method of collecting and extracting such nitrate in a commercial form, as compared with the cost of getting the nitrate from Chile.

It is considered extremely doubtful if the nitrate could be extracted from even the best of these California deposits at a cost sufficiently low to enable them to be worked at a profit in competition with nitrate from abroad or from other sources that can compete in the present markets.

The reasoning on which this conclusion is based can be briefly summarized. The record given appears emphatically pessimistic, but it is believed that each aspect has been reviewed carefully in the light of any possible modifications of policy, procedure, or treatment that might change this outlook. Some practical calculations given later, based on the most optimistic assumptions that it was thought possible to justify, do not alter the conclusion. In contrast with some more glowing accounts that have been issued the summary that now appears justified by the facts is as follows:

The ground in all the nitrate fields is rugged and broken, making transportation and mining somewhat difficult. The areas containing the higher-grade portions of nitrate-bearing caliche are small, only a few acres each at best, and these portions of the deposits are very irregular, pockety, or patchy. The caliche layer itself is rarely more than 4 or 5 inches thick, even in the best parts of the more favorable areas, and thus a large area would have to be worked over to obtain any great quantity of nitrate. The caliche underlies soil which would have to be removed in mining, and these two layers are in places exceedingly difficult to separate, the one grading almost imperceptibly into the other. A similar difficulty is involved in that the caliche has no distinct line of separation from the bedrock below.

The average nitrate value of the best material in the richer areas is low, few of the carefully taken samples obtained in the present investigation carrying more than 5.25 per cent of sodium nitrate. The total quantity of nitrate in the best of the areas studied is too small to justify the outlay of capital necessary for its commercial recovery.

The evidence on which this judgment is based is reviewed in detail in the subsequent parts of this report.

PREVIOUS WORK.

Serious interest in the nitrate fields of the Amargosa region was first awakened in 1892 by J. M. Forney, a mining engineer, who spent two months in examining the deposits of the Upper Canyon and Lower Canyon fields and made a report. Since that time a dozen or more examinations have been made in different parts of the region, and as many reports have appeared. Some of these discuss methods of mining and extracting the nitrate as well as its occurrence, others merely describe the deposits, and still others deal only with the chemical and mechanical problems of extraction.

The following is a brief review of the reports that discuss the nature, probable extent, quantity, and value of the nitrate. Those that deal solely with the chemical and mechanical problems of extraction are not cited, because they are based on unwarranted assumptions as to the quantity and value of the nitrate material. The review is believed to be a fairly complete summary of the information available when the present investigation was begun.

1892. Forney, J. M., The niter beds of the United States.—Report on the deposits of nitrate of soda found in the counties of Inyo and San Bernardino, State of California, Los Angeles, Vandercook.

This report is the result of a two months' examination in the Upper Canyon and Lower Canyon fields. The Lower Canyon field received the most attention, and the data gathered there are practically the basis for the conclusions reached. Forney recognized that the nitrate is in the so-called calichè layer, not in the overlying soil nor in the underlying clay strata (bedrock). The conclusion was reached that the caliche layer averages at least 6 inches in thickness and contains about 11 per cent of nitrate in these fields. Estimates made on this basis gave 97 tons of refined nitrate to the acre.

1902. Bailey, G. E., The saline deposits of California: California State Min. Bur. Bull. 24.

This report gives a rather full and very enthusiastic account of all the nitrate fields in the Amargosa region. The acreage located for nitrate in the several fields is stated as follows: Saratoga, 8,000 acres; Owl Spring, 6,000; Upper Canyon, 4,000; Lower Canyon, 3,000; Valley and Round Mountain, 3,000; Salt Springs, 3,000; Confidence, 2,500; Tecopa, 2,500. Samples of the nitrate-bearing caliche layer were taken from 104 separate claims in these fields, one sample to each 160-acre claim, and the average of all the chemical analyses is stated to be 9.54 per cent of sodium nitrate. The averages for the separate fields are as follows: Owl Spring, 17.2 per cent; Saratoga, 9.4 per cent; Upper Canyon, 8.98 per cent; Valley, 8.3 per cent; Lower Canyon, 4.77 per cent; Confidence, 1.7 per cent. The highest nitrate content reported was 67 per cent in a sample from the Owl Spring field. This field likewise showed the highest average analyses and was regarded as the most promising. The minimum thickness of the caliche layer in all fields is stated to be 6 inches, and the maximum 5 feet. The nitrate is considered to exist in large quantities in the bedrock as well as in the overlying caliche, and it is stated (see pp. 165 and 166) that the bedrock strata from 3 to 10 feet thick show from 13 to 45 per cent of nitrate. No details of the method of taking samples for analysis are given, but the analyses are prevailingly so high in comparison with those of the samples taken during the present investigation in the same fields that probably either they represent carefully selected and sorted material rather than an average nitrate content of the caliche in any one area, or, as is very likely to be the case, the analyses themselves are erroneous. The whole tenor of the report is such as to raise the highest expectations of the value of the nitrate fields. It has been widely read and used for reference by many parties subsequently exploiting the fields, and its influence in raising unjustified hopes has been far-reaching. Erroneous assertions by Forney and also by Bailey (see pp. 157 and 158) that the niter-bearing rocks are in undisturbed horizontal position may have led to the view held by some that rich nitrate beds at depth may be reached by drilling.

1907. Robbins, Frank (mining engineer), a report for the Pacific Nitrate Syndicate on the systematic prospecting and sampling of the claims of the company in the Upper Canyon and Lower Canyon fields.

A fair and evidently conscientious attempt to find a practical means of developing the property as a source of nitrate. A plan for the operation of these fields is worked out, showing estimated costs of production, and an estimate of 118,000 tons is given as the total possible production for this group of claims, which covers practically all the available niter-bearing ground. The claims are described as a group of hills composed of light-colored clay strata. The surface is a loose soil for 6 to 10 inches, called the "soft" layer, underneath which is a more consolidated layer, 4 to 6 inches thick, called the "hard" layer. This hard layer is the so-called caliche; it contains the most salts and shows the largest nitrate content. The loose-soil layer was found to contain some nitrate but not nearly so much as the caliche, and the original bedded clay below the caliche contains only traces. In sampling the ground long trenches were dug in what had been determined by preliminary tests to be the best ground. All the trenches were hundreds of feet in length, several running over 1,500 feet. Measurements of the "hard" and "soft" layers were taken at frequent intervals, and also samples, which were analyzed. More than 650 determinations for nitrates were made. From a summary of the results obtained by sampling and analysis from the field as a whole, it appears that the average thickness of both hard and soft layers, which according to Robbins would have to be worked together, is about 13 inches, of which the surface soft layer includes about 8½ inches and the underlying hard layer 4½ inches. The soft layer averaged 1.8 per cent of sodium nitrate and the hard layer, or caliche, 4.8 per cent; the mean of the two reduced for relative thicknesses was equal to 2.8 per cent of the whole. An area of 34 acres (Bully Hill), cited as conspicuously the best ground in the entire field both in thickness and in value, gives an average of 10.5 per cent for the caliche layer and 3.5 per cent for the soil layer, with an average of 6.5 per cent for the two together. These results are higher than those obtained from the same ground by the Survey party; otherwise the work seems to be in close accord with recent observations. The chief hope for successful development held out by the Robbins report is based on the expectation of finding other areas as rich as Bully Hill. In this connection it must be noted that some of the samples that gave the highest results were admittedly taken from selected portions of salt crusts or layers, and this may account in part for some of the higher tests reported from this area. It is significant, further, in judging the extent and value of the deposits that the report recommends that only 2,280 acres out of a total of 6,600 acres located by the company be retained—1,420 in the Upper Canyon and 860 in the Lower Canyon field. The remainder is regarded as worthless. It is indicated that a still further reduction of the estimate of workable ground might be made without greatly reducing the total value of the holdings.

1907. Olshausen, B. A. (chemical engineer), The prospects for a California nitrate industry (manuscript report).

A brief trip was made to the Saratoga, Valley, Confidence, and Owl Spring nitrate fields to relocate claims for the American Niter Co. An account is given of some sampling that was done by the company in these fields four years previously. Analyses were made of 50 samples taken at the time, one from each 160-acre claim, and the following is a summary of the results: Analyses of 29 samples from the Saratoga field averaged 19 per cent sodium nitrate, 7 from the Owl Spring field averaged 23.6 per cent, 11 from the Valley field averaged 20.3 per cent, and 3 from the Confidence field averaged 21.3 per cent. There is no information as to what the samples represented, but it is stated by Olshausen that the sampling was known to be unsystematic and unsatisfactory. It is indicated, further, that there is considerable doubt as to the reliability of the figures given, because the analyses were all made in the field and the original records were lost. Aside from the doubt cast by Olshausen upon the accuracy of the analyses, they are so consistently high, even in comparison with the high results given in the Bailey report for the same fields, that it is hardly conceivable that even if the analyses are accepted as correct the samples could represent anything but carefully selected or refined material.

1912. Free, E. E., Nitrate prospects in the Amargosa Valley, near Tecopa, Calif.: U. S. Dept. Agr. Bur. Soils Circ. 73.

This report is the result of a very brief reconnaissance in the Upper Canyon field near Morrison's Siding (Acme) and in the Lower Canyon field near Sperry. Sixteen samples were taken from the loose surface soil layer covering the clay hills, and the average of all the analyses showed 0.36 per cent of sodium nitrate. Three samples were taken at depths of 4 to 10 inches in what is described as the underlying stratified clay (bedrock). The analyses of these samples averaged 4.64 per cent of sodium nitrate, and one sample, taken from a depth of 10 inches, showed as high as 12.28 per cent. It was therefore suggested that the significant nitrate contents are in the underlying clay strata (bedrock), and the further exploitation of nitrates in the field was condemned unless exploration should reveal large quantities in the bedrock with a nitrate content as high as that of the richest sample. Without doubt, Free's rich sample from the "underlying clay" represents the so-called niter-bearing caliche layer and not the contents of an unaltered clay stratum in the bedrock.

1914. Drilling by the United States Geological Survey (unpublished notes).

In order to follow up the clue suggested by Free's report as to the possibility of a valuable nitrate content in the bedrock, a test by shallow drilling was made by a party of the United States Geological Survey in January, 1914, in the area in the Upper Canyon field (Bully Hill) where Free obtained the richest sample. Three holes were bored, to depths of 26, 18, and 14 feet. The first 2 feet of these test borings yielded nitrate contents of from 0.11 to 3.29 per cent; below that depth showings were obtained at intervals but in so small amounts as to seem lacking in economic significance. As the holes were not cased during the drilling, a small amount of nitrate-bearing dust probably fell into the lower part and may have been taken in the samples.

1914. Chestnut, John A. (mining engineer), Report on the nitrate beds located in the so-called Death Valley region of California, for the California Nitrate Development Co., San Francisco.

This is a report on holdings comprising 1,920 acres in the Saratoga field, 2,240 acres in the Owl Spring field, 2,720 acres in the Confidence field, 320 acres in the Valley field, and 1,440 acres in the Round Mountain field. A complete survey of all the claims was made, and over 1,000 samples of niter-bearing material were taken, from which some chemical determinations were made. No specific details in regard to the method of taking samples are given in the report, nor is there any list or tabulation of analyses. The exploration was conducted mainly in the surface soil and caliche layers by making numerous shallow trenches and pits. It is stated that large areas were shown that carried from 1 to 2 per cent of nitrate and that some large selected sections carried from 6 to 12 per cent. No tonnage estimates were made. Systematic drilling to depths of 50 feet was recommended to see whether the clay strata contain nitrates in valuable quantities.

1916. Farrell, J. R., A brief report to the California Nitrate Development Co., San Francisco, on the results of a cursory visit to the Owl Spring niter field, near Death Valley.

Four samples were taken at depths of 5 to 6 inches below the surface crusts in the Owl Spring field, and chemical analyses were made. The highest analysis showed 3.92 per cent of sodium nitrate. Farrell recognized that these samples show amounts insufficient to justify commercial exploitation but recommended underground exploration of the bedrock clays by drilling to see if they contain large beds of nitrate. He believed that a very considerable sum of money would be needed to do this work properly.

It may be seen that the records given in the above review are contradictory. First, there is a difference of opinion as to the character of the deposits. In some reports, notably that of Bailey, it is stated [3] that the nitrate exists in valuable quantities in the bedrock strata as well as in the overlying caliche. In other reports the commercially valuable amounts of nitrate are said to be confined to the soil and caliche layers, and in still others to the caliche alone. Second, there is a considerable difference in the values reported. Forney's report gives the average thickness of the caliche layer in the fields examined as 6 inches and the average nitrate content as 11 per cent. Bailey reports the average content of the caliche as 9.54 per cent in all fields together and states that the thickness of the caliche ranges from 6 inches to 5 feet. He gives the average nitrate content in one of the fields (Owl Spring) as high as 17.2 per cent. Robbins's estimate gives the average thickness of the caliche layer in the fields examined as 4½ inches and the average nitrate content as 4.8 per cent. In one selected area, Bully Hill, the average thickness of the caliche is given as 5.85 inches and the nitrate content as 10.5 per cent.

[3] Bailey, G. E., op. cit., pp. 146, 165.

PLAN OF PRESENT INVESTIGATION.

Because of the uncertainty regarding the nature of the nitrate deposits discussed in this report, the recognized fact that nitrate, locally in rich accumulations, had been found, and the contradictory nature of the reports that had been issued on the subject, it was considered that one of the first points to be determined was the form of these deposits. Certainly this is a fundamental necessity in order to estimate definitely the extent and value of the material. Consequently, during the first two months of the new work (particularly in the Saratoga field), while attention was being given chiefly to learning the character of the deposits, most of the sampling was done in long trenches dug deep enough to penetrate several feet into the bedrock beneath the caliche layer, and both bedrock and caliche were sampled with equal thoroughness. When, as a result of this work, it became fairly evident that the nitrate is concentrated in the caliche, the practice of digging deep trenches was largely abandoned. To make sure that no possible concentration of nitrate in the bedrock should be overlooked, one deep trench was made at the beginning of the work in each new area, but most of the sampling was done in lines of shallow pits dug only deep enough to insure penetration through the caliche. This change from trenches to pits greatly accelerated the work, for bedrock trenching is slow and expensive, whereas the pits can be dug rapidly and are relatively cheap.

The methods of prospecting and sampling are described and illustrated in the accounts of work in the several fields.

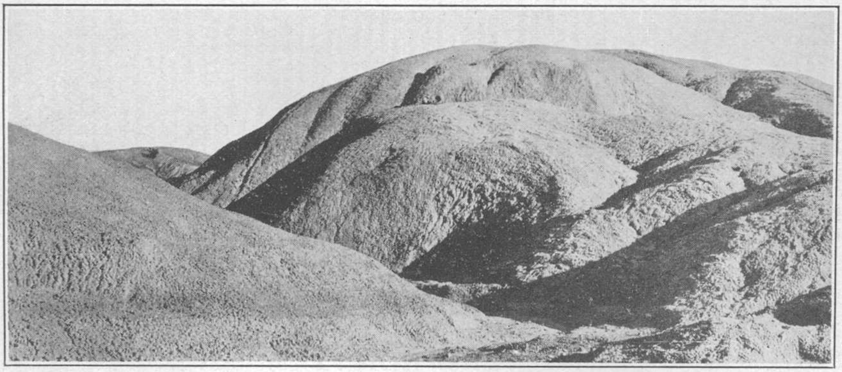
In the present investigation large portions of the Saratoga, Confidence, Zabriskie, Upper Canyon, and Lower Canyon fields were explored and prospected in the order named. Accounts of the results of this work, with tabulations, summaries, maps, and profiles, are given below. Preliminary scouting and testing in the Salt Springs, Resting Springs, and Tule Springs fields eliminated these fields at the start as a possible source of nitrate. The Owl Spring, Round Mountain, and Valley fields were visited during scouting trips, but were not explored in detail. Of these three only the Owl Spring field appeared to warrant much attention, because of the high average reported by Bailey and the fact that there are natural outcrops of rock salt in the section exposed there. An account of this field will be given in a later report. The location of all the above-named fields is shown on the index map (Pl. I).

The first step in the investigation was to determine in a preliminary way what ground contained nitrate. This was done by making numerous qualitative tests all over the area, using the "brown ring" reaction, which extensive practice and frequent comparison with the results of quantitive analyses had shown to be highly sensitive. For this testing a portable chemical outfit was carried by each geologist. (See Pl. III, *B*.)

The next step was to determine whether the nitrate was concentrated in places so as to form valuable deposits; and if so, whether these deposits are superficial layers near the surface of the ground or whether they extend underground into the bedrock. The following procedure was adopted, first at the west end of the Saratoga Hills and later in slightly modified form elsewhere. An area indicated as promising by the preliminary field nitrate test was laid out for a system of pits designed to cover the ground in a representative way. As the pits were dug every change in the character of the ground with depth was noted, and distinct layers were thus differentiated. All the material from each layer was taken out, carefully saved on canvas, weighed, and crushed. (See Pl. III, *C*.) It was then run through a small hand mill, and the finely ground product was divided down systematically until about 1 pound remained. (See Pl. IV.) This remaining pound was the final sample. It was sacked in duplicate bags and sent to the chemical laboratory of the Geological Survey for analysis.

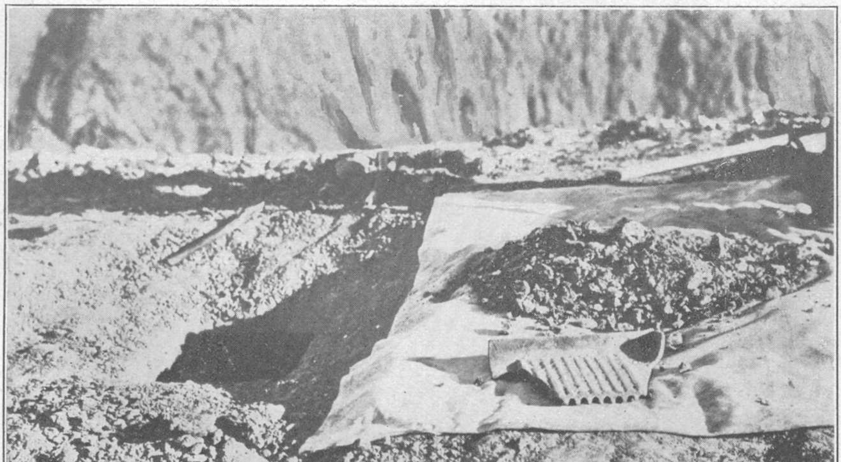
In each of the more promising fields the exploration was completed by the excavation of one or more deep trenches, thus revealing in a complete section not only the superficial layer, including soil and caliche, but a considerable thickness of the underlying bedrock, which, being available in freshly exposed sections, was carefully tested for signs of nitrate that might furnish clues to be followed by further exploration. The results of this work are discussed in detail in the following pages. Considerable difficulty was at first experienced in procuring quantitative chemical determinations of the nitrate in the samples collected. Some samples were sent to private commercial analysts. It soon became evident, however, that there was considerable disagreement in results obtained from different analysts, and it became necessary to investigate the matter.

In order to check the accuracy of the nitrate determinations on which this report is based, three typical samples from the field were carefully ground, mixed, and divided, and portions sent to two representative commercial chemists, designated L and P in the following table. Other portions were analyzed in the Geological Survey and in the Bureau of Chemistry of the United States Department of Agriculture.



A. WEST END OF HILL NO. 3, SARATOGA NITER HILLS, FROM THE WEST.

B. TESTING A SAMPLE OF NITRATE WITH PORTABLE FIELD OUTFIT.



C. PIT TEST AT WEST END OF SARATOGA NITER HILLS.

A. POUNDING MATERIAL BEFORE GRINDING IN MILL.

B. DIVIDING MATERIAL AFTER IT HAS BEEN GROUND.

SAMPLING OPERATIONS.

Percentage of nitrate (NO_3) in samples of caliche from Amargosa field.

Sample No.	United States Geological Survey.		Bureau of Chemistry. Method not stated.	L. Lunge's nitrometer method.	P. Gunning method modified to include nitrate (based on total nitrogen?).
	Iodometric method.	Ferrous sulphate titration.			
1	0.60	0.69	0.84	0.75	2.17
2	3.69	3.68	3.95	3.73	5.75
3	9.31	8.50	9.12	8.53	9.34

The iodometric determinations are probably the most nearly accurate. No. 1 is an average of three determinations—0.59, 0.59, and 0.63. No. 2 is an average of two determinations—3.71 and 3.67. No. 3 is an average of three determinations—9.39, 9.22, and 9.31. The ferrous sulphate determination is a little too high on the low-grade material and too low on the high-grade material. The results seem to show in a general way the degree of accuracy of the ordinary analysis for nitrate, although many analyses made by a commercial analytical firm gave results much more divergent than any of these.

The method of determining nitrates adopted for most of the testing during the present work is that in general use in the Chilean nitrate fileds. It is an adaptation of the sulphuric acid and ferrous sulphate test for nitrates, often referred to as the brown-ring test, which is made quantitative by a simple titration device. The results were constantly checked, and comparison with determinations made by standard methods of analysis shows that this method is very satisfactory when used with proper precaution. The determinations of sodium nitrate in the sample as delivered at the laboratory are probably correct within 0.1, at most 0.2 or 0.3 per cent.

The selection of material that would be considered available in mining was also given careful consideration. Among ill-defined layers or zones, some of which gave strong nitrate reaction, it was always a question as to what should be considered representative minable material, such as would be taken out on an average in the general course of mining operations. The possible methods of scraping with implements without much selection and of a system of hand sorting by the miner were also considered.

HAND SORTING AND DEEP DRILLING.

Operations suggested but not tried extensively are hand sorting and deep drilling.

Hand sorting of the richer portions of the caliche, such as is employed in practical mining in Chile, has been suggested as a feasible method of working these deposits. It was therefore desirable to determine how the hand-picked samples would compare in nitrate content with the fixed standard established by the field parties in sampling to show the average nitrate content of the caliche layer. The value of the material collected might be so raised by hand sorting that certain richer areas could be worked on a small scale. This plan was tried in four representative areas after the main investigation had been completed.

A sample of a particularly well defined bed of moderately soft caliche, the "Amphitheater type," was taken at the head of Amphitheater Canyon, in the Saratoga field. This sample, which was rich in soluble salts and gave a strong reaction for nitrate, was obtained by crushing and quartering a pile that included all the richer-looking lumps thrown out in digging a prospect trench across the side of a ridge. This method of sorting is based on an ability to recognize nitrate salts, in certain forms at least, gained as a result of experience in handling a field test outfit. It corresponds in a general way to the method of sorting used in the Chilean fields. The sample obtained by this method carried 4.88 per cent of sodium nitrate. This result may be compared with that obtained by the original sampling represented by sample No. S–81, spur cut No. 3, Amphitheater Canyon, considered on page 47 of this report, which gave an average of 4.41 per cent of sodium nitrate for the defined caliche layer in a 10-foot trench. This result indicates that the material included in the original sample of caliche carried almost as high a percentage of nitrate as the hand-sorted sample, showing that in this locality hand sorting did not much increase the value of the product.

The second test was made on Bully Hill, in the Upper Canyon field, in caliche of the soft, flaky "Bully Hill type." An average sample of a 10-foot strip, including the whole caliche layer and corresponding to original sample 0202 (see Pl. XXX), carried 6.88 per cent of sodium nitrate. The original sample obtained at this place contained 8.55 per cent of sodium nitrate, but the two determinations are not strictly comparable, as the original sample consisted of cuttings from two narrow channels 10 feet apart, whereas the test sample was an average sample taken throughout a 10-foot strip. In the test sample the more thoroughly cemented material in the lower part of the strip was taken, because, in actual mining, the soft flaky material in the upper part of the strip would have to be removed with scrapers, layer by layer, and much of it would be mixed with soil or wasted. The test therefore gave an idea of how much nitrate the more compact part of the caliche would carry, if sorted from the softer material, but it was not strictly a sorting test of the whole caliche layer. It is exceedingly doubtful whether hand sorting could be profitably applied to the softer part of the caliche layer.

The third test was made at cut No. 3, at the west end of the Saratoga field, where the caliche is of the very hard, salty "Saratoga type." (See Pl. XI, p. 44.) The original caliche samples in this cut were taken in 2-foot strips, and each sample represented an average of the first foot of hard material beneath the surface soil. Those at the ends of the cut represent caliche overlying greenish sandstone. All those between the ends of the cut represent caliche overlying brown salty shale. Those over the shale were poor in nitrate, but those over the greenish sandstone were much richer, the one at the east end of the cut carrying 6.53 per cent and the one at the west end 3.06 per cent. The sorting test was made between the 165 and 192 foot marks, at the west end of the cut, in the caliche represented by original sample S-68, which carried 3.06 per cent of sodium nitrate. By selecting pieces of only the hardest material in this strip, material which is relatively heavy, thoroughly cemented, and characterized by numerous tiny veins of transparent salts, a hand-sorted sample was obtained which carried 11.10 per cent of sodium nitrate—nearly four times as much as the original sample. Material of this character, however, does not appear to form over half of the caliche layer and in places may not form over a quarter of it.

The fourth test was made at the "green hill lens" in the Confidence field (see Pl. XIV, *B*, and p. 57), where the caliche is of the hard "blister type." The original sample, 48 pounds, collected in this locality from eleven of the blisters by taking only pieces easily detached by a pick, carried 15.63 per cent of sodium nitrate, which was the highest percentage obtained in the Amargosa region during the nitrate investigation. The sorting test was made by taking two samples from this locality, each from the caliche of a blister selected at random. As in the third test the hardest and heaviest material was selected, material characterized by numerous small veins of transparent salts. One of these samples carried 22.18 per cent of sodium nitrate, the other 22.21 per cent.

All determinations of samples taken in the hand-sorting tests were made in the laboratory of the Geological Survey.

The results of the first and second tests, made in localities where the caliche is moderately soft or flaky, can not be considered encouraging, but those of the third and fourth tests, made in localities where the caliche is hard and salty, indicate that further sorting tests, in connection with a systematic search for areas of the richer caliche of the hard type, might conceivably reveal areas that could be worked on a small scale. The sharp variation of the caliche in nitrate content with change in character of the underlying rock—low content over salty brown shale and higher content over greenish sandstone, as shown in the part of the Saratoga field where the third test was made; high content of the blister caliche over green shale and low content of the caliche over adjacent brown shale, as shown in the Confidence field—is a feature which should receive attention in any further study of the origin of the nitrate.

It has been repeatedly urged that exploration by boring should be undertaken in the areas where nitrate efflorescences or caliche crusts appear at the surface, the argument being based on the hypothesis that small amounts of the soluble salt at the surface may have been derived from larger bedded deposits buried at depth. The idea is perhaps not beyond the limits of possibility, but up to the present time at least there seems to be little evidence to favor its acceptance. The indications as to possible origin, accumulation, and preservation of the nitrate seem to point to it as purely superficial. Deeply buried deposits of the very soluble nitrate salts have never been found, and nitrate is not known to be associated with interstratified deposits of rock salt or other salines below the surface. Explorations by deep boring would be interesting and of course might yield results that could not be anticipated, but such work could hardly be recommended in the present circumstances as either practical or economical.

NITRATE FIELDS IN AMARGOSA REGION.

The areas in which nitrate has been discovered—the so-called nitrate fields—in the Amargosa region are listed below in succession down Amargosa River from the towns of Shoshone and Zabriskie to the low basin ("sink") of Death Valley. (See Pl. I.)

Zabriskie.—Extending 7 to 8 miles along Amargosa Valley between Shoshone and Tecopa, stations on the line of the Tonopah & Tidewater Railroad, and running back several miles west of the river opposite Tecopa and Zabriskie.

Resting Springs.—Extending 1 mile west and 2 or 3 miles northeast of Resting Springs, which are 5 miles northeast of Tecopa.

Tule Springs.—Extending about 3 miles northeast from the vicinity of Tule Springs, which lie about 10 miles S. 78° E. in a direct line from Tecopa but 12 miles or more by the usual road. It is about 4 miles northeast of the old Tecopa smelter, a well-known landmark of the region.

Upper Canyon.—Extending about 2 miles northwest, north, and northeast of Acme siding on the Tonopah & Tidewater Railroad (5 miles south of Tecopa), in and about the narrow portion of Amargosa Valley known as Amargosa Canyon.

Lower Canyon (Sperry).—About a mile northeast and east of Sperry, on the Tonopah & Tidewater Railroad, not far from the point where Amargosa River leaves the canyon.

Salt Spring.—Extending a mile or more east of Salt Spring, near the south end of South Death Valley. The nearest railroad point is Valjean, on the Tonopah & Tidewater Railroad, about 8 miles east of this field.

Saratoga.—Extending 9 miles in a northwesterly direction along the west side of South Death Valley, at the base of the Avawatz Mountains. This field lies directly opposite Saratoga Springs, which are on the east side of the valley, about 3 miles from the nearest part of the field. The nearest railroad point is

Dumont, on the Tonopah & Tidewater Railroad, about 14 miles east of Saratoga Springs.

Round Mountain.—About 2 miles northwest of the northwest end of the Saratoga field and practically a part of it.

Valley.—In the bottom of South Death Valley along the bed of Amargosa River, about 5 miles northwest of the Round Mountain field and about 10 miles from Saratoga Springs.

Confidence.—Extending about 10 miles northwestward along the west side of South Death Valley, beginning at a point near the old Confidence mill, the ruins of which are about 20 miles by road northwest of Saratoga Springs. The Confidence field is about 34 miles from Dumont, on the Tonopah & Tidewater Railroad, by way of Saratoga, or about 27 miles from Zabriskie or Shoshone by a road over the summit of the Black Mountains.

Owl Spring.—This field is usually included in the Amargosa region, although it lies some distance from Amargosa River. It is situated about Owl Spring, near the head of Owl Spring Wash, a large dry valley which enters South Death Valley from the west, opposite Saratoga Springs. Owl Spring is about 10 miles due west of the northwest end of the Saratoga field and about 16 miles from Saratoga Springs by road. The field is thus about 30 miles west of Dumont, on the Tonopah & Tidewater Railroad, the nearest railroad point.

Dumont and Valjean, though they are the railroad points nearest to some of the South Death Valley fields, are not connected with these fields by passable roads. The nearest available supply point at present is Silver Lake, on the Tonopah & Tidewater Railroad, 32 miles southeast of Saratoga Springs by road, and the nearest accessible railroad point is Riggs, about 25 miles southeast of Saratoga by road. The Confidence field is best reached from Zabriskie or Shoshone.

Large parts of all these fields were explored in the course of the present investigation. The Zabriskie, Upper Canyon, Lower Canyon, and Confidence fields and the Saratoga Hills area of the Saratoga field were prospected most thoroughly. The less promising Resting Springs, Tule Springs, Salt Springs, Round Mountain, Valley, and Owl Spring fields were reviewed by general inspection during scouting trips. The Salt Basin and Cave Spring Wash areas of the Saratoga field and the extreme northwest end of the Confidence field were not explored.

NITRATE DEPOSITS REPORTED ELSEWHERE IN SOUTHEASTERN CALIFORNIA.

Outside the Amargosa district the following nitrate fields in southeastern California have been reported (see index map, Pl. I):

Pilot.—At the south end of the Slate Range, about 7 miles southeast of the south end of Searles Lake. The name is derived from Pilot Knob, a prominent peak about 12 miles due south of the field. The nearest railway point is Spangler, on the Trona Railroad, about 8 to 10 miles west of the field.

Twenty-nine Palms.—Near Twenty-nine Palms Springs, which are about 35 miles (48 miles by road) northeast of Whitewater, a station on the main line of the Southern Pacific Railroad.

Along Colorado River.—In the Beale or Topock area, 6 miles southeast of Needles; the West Well area, about 28 miles southeast of Needles (33 miles by road); and the Vivet Eye area, in the Riverside Mountains, 6 miles south of Vidal.

Leach Lake.—In the playa beds of a dry lake 4 miles southwest of Owl Spring.

Danby Lake.—In the playa beds of a dry lake just west of Ward and Milligan, stations on the Cadiz-Parker line of the Atchison, Topeka & Santa Fe Railway.

Kingston Range.—In seams in limestone 3 miles east of Horse Spring, about 23 miles southeast of Tecopa.

Carrizo Creek.—West of Imperial Valley, in the extreme southern portion of the State, in clay-hill areas.

East of Salton Sea.—In T. 10 S., R. 14 E. San Bernardino meridian.

All these localities, except the one in Kingston Range, the one on Carrizo Creek, and the one east of the Salton Sea, were visited and examined after the investigations in the Amargosa region were completed. An account of these examinations will be given in a later report.

In the course of work subsequent to that in the Amargosa region, nitrate-bearing ground was found and tested in several localities where it had not hitherto been reported, as follows (see index map, Pl. I):

In the Strontium Hills, about 9 miles north of Barstow, in the so-called Barstow syncline.

In the bed of a dry lake in Superior Valley, about 23 miles north of Barstow.

About 2 miles southwest of Vidal.

The index map (Pl. I) shows the location of all areas in the desert region of southeastern California which were examined for nitrate in 1918. A tabulation on page 89 shows the prevailing character of the ground in each area.

SOUTH DEATH VALLEY.

By L. F. Noble.

GENERAL FEATURES.

The valley of Amargosa River above Death Valley consists of a long open basin that is really the southward extension of Death Valley and is here referred to as South Death Valley, and above this basin a canyon and valley course along which several of the so-called nitrate fields are situated. The Death Valley portion of this region is less accessible than that higher along the course of the Amargosa, which is traversed by the railroad that passes by way of Tecopa and Silver Lake. The South Death Valley region may naturally be discussed as a broader unit in which conditions of access, transportation, climate, water supply, and character of the country are much alike throughout. The other nitrate fields higher up in the valley are discussed more or less individually following the discussion of South Death Valley.

The features of South Death Valley and the lower part of Amargosa Valley are not greatly unlike those of the many other desert valleys in southeastern California. The region is somewhat less populous, less traveled, and possibly generally less well known than most of the so-called desert region. The mountains consist of barren rocky slopes rising abruptly in many rugged scarps from the broad, low alluvial slopes and detritus-filled valleys. The ranges in general follow a north-south parallel alinement such as is characteristic of the mountain system of the Great Basin, and many of the intermountain valleys are long north-south flat-bottomed troughs, with some irregular transverse valley connections.

A few conspicuous features mark the South Death Valley and Amargosa region in an unusual way. Perhaps the most striking is the utter barrenness of the rock mountain walls and the distinctness with which the dull reds, browns, and other characteristic colors of these rocks show even at great distances in the clear air. The gorge of Amargosa River below Tecopa is one of the weird features of this desolate region, being carved in fantastic forms through peculiarly varied volcanic-flow rocks, conglomeratic breccias, and the so-called lake-bed sediments. Huge piles of loose drifted sand hundreds of feet high lie in several corners of the desert, where they are heaped and preserved by peculiar eddies of the prevailing air currents.

The nitrate-bearing clays may also be classed among the unusual elements in the landscape. Appearing at intervals in a narrow belt along the southwest margin of the valley are areas of curiously rounded light-colored clay hills whose surface is practically barren of vegetation and which are carved from steeply upturned beds of clay shales and sandstones of Tertiary age. These areas of upturned strata are the so-called nitrate fields. In the South Death Valley district the southeasternmost area extends northwestward 9 miles from the vicinity of Sheep Creek, a small canyon in the north face of the Avawatz Mountains, to Owl Spring Wash and is known as the Saratoga field. The next outcrop of the strata on the northwest appears in Round Mountain, a small hill in the middle of Owl Spring Wash, about 2 miles northwest of the Saratoga field. This small area is the Round Mountain field. Three miles northwest of Round Mountain the strata are exposed for a mile along Amargosa River, whose saline waters are forced to the surface at this point apparently by the bedrock dam formed by the strata. This outcrop is the Valley field. Five miles northwest of the Valley field the strata reappear in a long range of low hills, which extends 10 miles southwestward along the valley border. This area is the Confidence field. None of the areas are more than a mile wide, and at most places they are less than half a mile wide.

WATER.

There is no potable water in any of the nitrate fields of South Death Valley, so that a prospecting party must either camp on the ground to be explored and haul water from the nearest spring or must camp at a spring and make trips to the ground.

Three springs near the Saratoga field can be reached by road. The largest of these, Saratoga Springs, lies on the opposite side of the valley, 3 miles northeast of the nearest point in the field. The springs come out at the edge of the valley floor along the steep western face of one of the belted ridges of the Ibex Hills and appear to rise along a fault. They yield an abundant flow of warm water (85°), which tastes decidedly salty but apparently is not unsafe to drink, for the Survey party exploring the Saratoga field used it for two months without ill effects. One of the springs rises in a pool 35 feet wide and 4 or 5 feet deep. All of them overflow northward into small lakes which are surrounded with a growth of tules. Saratoga Springs form one of the best-known watering places in the region and are the only springs of potable water on the floor of South Death Valley. The other two springs are high above the floor of the valley. One, a small spring known as Denning Spring, is about 5 miles southwest of the central part of the Saratoga field, at an elevation of about 2,000 feet in Denning Spring Wash, a dry stream course that crosses the field a mile west of Cave Spring Wash. Denning Spring may be reached by a road up Cave Spring Wash or by a road up Denning Spring Wash. The other spring, Cave Spring, is about 7 miles south of the central part of the field, in Cave Spring Wash at an elevation of about 3,700 feet, and is reached by the road up Cave Spring Wash. The water is in small caverns in a bed of conglomerate or breccia and is cold and good, but the supply is small. The Geological Survey party that explored the Saratoga field established camp at Saratoga Springs and made trips to the field from that point.

The only springs near the Confidence field are Rhodes Spring and Bradberry Well, both about 8 miles northeast of Confidence, in the Black Mountains, 1,800 feet above the floor of South Death Valley. These springs are on opposite sides of a broad valley occupied by the channels of Rhodes Wash. Bradbury Well, on the south side of the valley a few hundred feet from the Confidence-Zabriskie road, is a covered well dug in disintegrated granite. Rhodes Spring, on the north side of the valley 1½ miles from the road, is a small seep which issues along a contact between horizontal beds of conglomerate and upturned beds of quartzite. The Survey party that explored the Confidence field established camp near Confidence and hauled water from these two springs to the camp.

The Saratoga Springs are the only ones in the region that could yield a supply of water large enough to use in a plant for the extraction of nitrates on a commercial scale. Probably fresh water could be reached by drilling wells in the lower slopes of some of the larger alluvial fans in South Death Valley, and an adequate supply could be obtained by pumping. Favorable situations for such wells are in the fans at the mouths of Owl Spring Wash, Cave Spring Wash, and Rhodes Wash. Wells dug in the valley floor would be likely to yield salt water, because the underflow of the Amargosa, wherever it comes to the surface, is a heavy brine. A well dug in the valley floor some years ago at Confidence yielded brine.

ROADS.

The roads by which South Death Valley is reached are poor and are very little traveled, most of them being simply beaten tracks that follow the easiest route across the country. All those here described, unless otherwise indicated, are passable by automobile. In general, stretches of fairly good road alternate with stretches that are very rough and sandy, so that on long trips the average speed of a car will not usually exceed 12 miles an hour. Owing to torrential local thunderstorms or "cloudbursts," one of which is pretty sure to visit some part of the region every summer, the condition of a road from year to year is uncertain, and no account of it is of permanent value. However, a car can usually be gotten over a washed-out stretch with a little work, if a pick and shovel are carried, and a track once beaten and traveled will remain until the next storm.

The Geological Survey has placed signs at the intersections of all the main traveled roads in this part of the desert as far north as the Inyo County line. These signs point the way from place to place, give distances, and indicate the location of springs, so that the traveler who has had experience on desert roads is in little danger of losing his way or of having difficulty in finding water.

Three roads enter South Death Valley in the vicinity of Saratoga Springs, coming from the west, south, and southeast and meeting on the southwest side of the valley opposite Saratoga. The road from the west comes down Owl Spring Wash and leads from Johannesburg, Randsburg, and Barstow. The distance from Saratoga to Johannesburg by this road is 83 miles; to Barstow (by way of Indian Spring), 85 miles. The road from the south comes down Cave Spring Wash and leads from Barstow. Saratoga is 76 miles from Barstow by this road. The road from the southeast comes from Silver Lake, following down the old channel of Mohave River into South Death Valley. The distance from Saratoga to Silver Lake by this road is 32 miles.

The Geological Survey party that explored the Saratoga field brought supplies from Silver Lake over this road.

Formerly two roads ran north and northeast from Saratoga to Tecopa and Zabriskie, stations on the Tonopah & Tidewater Railroad in Amargosa Valley. The road to Tecopa followed the main channel of Amargosa River east of Saratoga and ascended the canyon of the river to Acme, whence a road leads to Tecopa by way of the China ranch. The road to Zabriskie ran due north from Saratoga and crossed the Ibex Hills at a low divide northeast of the Ibex mine. Both roads have been impassable by automobile for several years, and the only way to reach Amargosa Valley at present is by way of Confidence and a road over the Amargosa Range described below.

From Saratoga a road runs down the valley to Confidence, following the southwest side of the valley west of Round Mountain and the Valley nitrate field. The distance from Saratoga to Confidence by this road is 20 miles.

From Confidence a road runs north to the mouth of the canyon of Rhodes Wash, 3 miles from Confidence, ascends the canyon, and at a point 5 miles from Confidence intersects a well-graded road that connects Zabriskie and Shoshone in the Amargosa Valley with the sink of Death Valley and is known locally as the Carbonate caterpillar road. The distance from Confidence to Zabriskie by this road is 27 miles. To reach Zabriskie or Shoshone from the intersection the traveler turns northeast up Rhodes Wash on the caterpillar road and crosses the divide between Amargosa and South Death valleys at an elevation of 3,300 feet. To reach the sink of Death Valley he turns southwest on the caterpillar road, leaves Rhodes Wash, ascends to the summit of a low pass or col, and descends westward into South Death Valley down a long alluvial slope, passing McCarty's mill, 7 miles northwest of Confidence, and coming into Death Valley proper near the mouth of Wingate Wash.

Formerly a road ran northwestward from Confidence down the channels of the Amargosa to the sink of Death Valley. This road is washed out and is impassable by automobile for several miles just southeast of McCarty's mill but is passable for several miles below Confidence.

A light car can reach the Saratoga and Confidence fields in many places from the road along the valley by running up one of the numerous washes that lead down to the valley from the niter hills, because the sandy channels of these washes are so well cemented by salts washed from the hills that they will support the car.

CLIMATE.

During July and August systematic work in the nitrate fields would be very difficult, if not impossible, because of the intense heat.

The average maximum temperatures of these months may exceed 115°, and temperatures of 120° or higher are not uncommon. Most days in June and September also are likely to be very hot, but the climate during the remainder of the year is mild and favorable for work. An occasional gale of cold wind in winter may last several days, fill the air with sand and dust, and make working disagreeable. More rarely a rain may turn the surface of the clay hills to mud and make walking impossible for a day or two. Probably the average yearly rainfall in South Death Valley does not exceed 3 inches, and the evaporation is as high as in any other part of the desert, if not higher.

VEGETATION.

The vegetation of South Death Valley is scanty. The only trees are a few mesquites that grow along the channels of Amargosa River. Palo verde, ironwood, and similar trees, which grow rather abundantly in dry washes farther south in the desert and afford a meager but welcome shade, are entirely absent in this region. The alluvial slopes bordering the valley, as elsewhere in the desert, are covered everywhere with a scattered growth of creosote bush (*Covillea*). In the gravelly washes and on the rocky slopes of the hills the most characteristic bush is the desert holly (*Atriplex hymenelytra*). Along the salt-crusted flats bordering the river channels "pickle weed" (*Allenrolfea*) and other similar plants grow abundantly, and the moister ground is covered with salt grass. Rushes and yerba mansa (Spanish for mild weed; *Anemopsis californica*) grow about Saratoga Springs. Fuel is very scarce. The best is dead mesquite, which may be dug out of small sand dunes in places along the Amargosa. In most places the only fuel obtainable consists of the roots of desert bushes, which may be dug out of the sand.

GEOLOGY AND TOPOGRAPHY.

From a point opposite the mouth of Wingate Wash, a few miles south of the salt flat in Death Valley proper, South Death Valley extends southeastward about 30 miles to a point opposite the north face of the Avawatz Mountains. This part of the valley is not more than 5 miles wide at most places and is nearly straight. Opposite the Avawatz Mountains it widens into a broad and rather shapeless depression, which opens northward into the narrow canyon of Amargosa River and southward into a long trough occupied by a chain of dry lakes along the lower course of Mohave River. In this report the name South Death Valley is applied to the straight and relatively narrow part of the valley, which extends from Wingate Wash to the Avawatz Mountains and through which Amargosa

River descends to the sink of Death Valley. The river crosses the 200-foot contour near Saratoga Springs at the south end of the valley, the sea-level contour near Confidence, 15 miles northwest of Saratoga, and the contour 200 feet below sea level near the mouth of Wingate Pass.

The floor of the valley is a plain from 1 to 2 miles wide, which is for the most part a dreary waste of saline clay soil covered at intervals by blown sand. It is occupied by shifting channels of Amargosa River and because of the gentle grade of the river appears nearly lėvel to the eye. The channels are dry except in a stretch a few miles long opposite and below Saratoga Springs. In this stretch the water comes to the surface in a few places, but is heavily charged with salts and is wholly unfit to drink. Opposite Saratoga much of the valley floor is moist or even boggy and is covered with a growth of salt grass. Owing to the rapid evaporation in this dry region the moist ground is crusted with salts.

South Death Valley is bordered by ranges of bare, rocky mountains which form a southeastward extension of higher ranges that border Death Valley. The mountains northeast of the valley are a part of the Amargosa Range and have various local names: Opposite Confidence they are known as the Black Mountains; farther southeast, opposite Saratoga, as the Ibex Hills. The mountains southwest of the valley, opposite Confidence, are the Owl Mountains, an extension of the Panamint Range, and opposite Saratoga, the Avawatz Mountains, which are separated from the Owl Mountains by a wide valley known as Owl Spring Wash.

Practically all the rocks in the slopes of the mountains facing the valley are pre-Tertiary crystalline and metamorphic rocks—granites, gneisses, schists, basic intrusive rocks, and more or less metamorphosed sediments. The lower slopes of the Black Mountains, near Confidence, are composed of gneisses and quartz schists that are probably of pre-Cambrian age. Higher up in the range large areas of Tertiary volcanic rocks overlie gneisses, schists, and partly metamorphosed sediments. The Ibex Hills, near Saratoga, are parallel ridges of upturned sedimentary beds which strike north and dip steeply east. They are the first of a series of "belted" ranges, so called because of the conspicuous banding of the strata, which the traveler encounters in crossing the region from west to east between South Death Valley and Pahrump Valley. The rocks in the Ibex Hills are marbles, quartzites, and slates which have been metamorphosed from limestones, sandstones, and shales without obliterating the original bedded structure. Their age is unknown, but is believed to be Algonkian or early Paleozoic. The Owl Mountains consist chiefly of massive granite upon which lie flows of black lava. Most of the rocks in the north face of the Avawatz Mountains are granitic rocks and metamorphosed sediments.

All these mountains are extremely rugged, and their bare rocky slopes are scored by deep canyons, each of which opens on an alluvial fan. Along the margins of the valley, except in the vicinity of Saratoga Springs, the fans unite in a wide sloping plain of alluvial waste which buries the lower slopes of the mountains and sweeps down to the valley floor. In places this alluvial plain is 2 miles wide and rises more than 1,000 feet between the valley floor and the base of the mountains.

The most precipitous slopes in the region are those of the Black Mountains, along the northeast margin of the valley northwest of Confidence. Here in places the mountains rise more than 5,000 feet above the valley in a distance of 2 miles and are so intricately dissected that, when viewed from a distance in the late afternoon light, the corrugations on their slopes resemble the innumerable wrinkles on a withered apple. Some of the largest alluvial fans in the valley lie at the mouths of the canyons in this steep face of the range. Higher up in the mountains the topography is much less rugged than along the valley border, and the canyons open upward into wide alluvium-filled valleys which extend back almost to the crest of the range.

The Ibex Hills, unlike the Black Mountains, do not face the valley in a precipitous slope. They consist rather of parallel ridges which extend southward and intersect the trend of the valley, which is southeast. These ridges descend toward the valley between wide sloping embayments of alluvium, and their rocky slopes project into the valley floor in rocky promontories. In places beyond the ends of the promontories low rocky hills stand like islands above the valley floor.

The Owl Mountains, along the southwest side of the valley, rise rather abruptly and, like the Black Mountains, are steeper along the valley margin than in their higher portions, but they are not so high as the Black Mountains and are less precipitous.

The Avawatz Mountains, to the south, rise very steeply from the valley in a bold escarpment to their crest, which lies at an elevation of 6,000 feet or more, but they slope southward much more gently from their crest.

The topographic features just described—steep slopes at most places along the valley margin and gentler slopes in the higher portions of the bordering mountains—suggest that South Death Valley owes its origin to faulting. Apparently the Death Valley trough is a long, narrow block of the earth's crust that has been depressed along one or more faults, but the structure is complex, because the mountains bordering the valley are themselves crustal blocks that have been elevated, tilted, and rotated in various directions, and the movements have not taken place in a single period of time. Thus in the vicinity of Saratoga each of the belted ridges of the Ibex Hills that descends to the valley is evidently a fault block that has been elevated along its western face, but all the ridges appear to be tilted southward as far as a fault along which the steep north face of the Avawatz Mountains, south of the valley, is elevated. Here the valley appears to have been determined by both tilting and faulting. Northwest of Confidence, where the slopes are steep on both sides of the valley, it appears to have been determined by two faults, one along each margin, and is thus a fault trough or "graben."

The only large valley entering South Death Valley is a wide alluvium-filled embayment which enters from the west about 5 miles below Saratoga Springs and is occupied by the channels of Owl Spring Wash. This Owl Spring embayment is one of a chain of depressions separated by low divides which form a well-defined trough extending far to the west. The Owl Spring nitrate field lies along the channels of Owl Spring Wash near Owl Spring, which is at an elevation of 1,800 feet, about 14 miles west of Saratoga. Just west of Owl Spring a low divide separates the Owl Spring embayment from a depression which contains Leach "Dry Lake." West of Leach Lake is another low divide, near Leach Point, beyond which the trough continues westward across the south end of Panamint Valley, past the south end of the Slate Range, along which lies the Pilot nitrate field, and across the south end of the valley of Searles Lake. The origin of the trough is not known, but it appears to be associated with a line of faulting which trends west, almost at right angles to the prevailing north-northwest trends of Death, Panamint, Searles, and Owens valleys, and apparently marks the southern limit of these north-northwest structural features over a wide area west of Death Valley. One of the old routes of travel into Death Valley follows this trough, coming into it just north of Granite Wells from Barstow and Randsburg, passing Leach Spring and Owl Spring, and descending Owl Spring Wash to South Death Valley.

A long but rather steep and narrow valley known as Cave Spring Wash enters South Death Valley from the south, coming out of the Avawatz Mountains at a point about 4 miles south of Saratoga Springs and 6 miles southeast of the mouth of Owl Spring Wash. Cave Spring lies near the head of Cave Spring Wash, 9 miles due south of Saratoga, at an elevation of about 3,700 feet. Another old route of travel into Death Valley crosses the Avawatz Mountains near Cave Spring and descends Cave Spring Wash to South Death Valley.

Along the northeast side of South Death Valley a number of deep canyons near Confidence extend well back into the Black Mountains.

One of these, Rhodes Wash, is important because it is followed by the only road into South Death Valley passable by automobile from stations in Amargosa Valley on the Tonapah & Tidewater Railroad and because two springs of good water, Rhodes Spring and Bradbury Well, lie near the road.

SARATOGA FIELD.

By L. F. Noble.

FIELD WORK.

The Saratoga nitrate field was the first to be investigated. The work was begun December 1, 1917, by a party consisting of one geologist and two other men, which was expanded December 26 by the addition of four geologists and seven other men. The work was continued until January 21, 1918, when the party moved on to the Confidence district.

LOCATION AND EXTENT.

The Saratoga field comprises two long, narrow, roughly parallel belts of saline and gypsiferous shales and sandstones reported to be nitrate bearing. The longer of these belts lies nearer to the valley and extends from Owl Spring Wash southeastward about 9 miles along the base of the Avawatz Mountains to Sheep Creek. Midway between Owl Spring Wash and Sheep Creek it is crossed by the channels of Cave Spring Wash, which enter South Death Valley on a great alluvial fan. This fan buries the strata for about half a mile and divides the belt into two parts. The area west of Cave Spring Wash is 4 miles long and three-quarters of a mile wide at the widest place, and is known as the Saratoga Hills. The area east of Cave Spring Wash is 5 miles long and less than a quarter of a mile wide. It may be called the Salt Basin area, from Salt Basin, a rugged badland amphitheater 1 mile east of Cave Spring Wash, where the strata are particularly well exposed.

The other belt extends northwestward at a slight angle from the southeast end of the Salt Basin area and runs nearly parallel with it and half a mile south of it as far as Denning Spring Wash. It is, like the Salt Basin area, a strip about 5 miles long and not over a quarter of a mile wide. It may be called the Cave Spring Wash area.

SALT, GYPSUM, AND CELESTITE DEPOSITS.

The Salt Basin and Cave Spring Wash areas and a part of the east end of the Saratoga Hills have been prospected extensively by the Avawatz Salt & Gypsum Co., and deposits of rock salt, gypsum and celestite have been found in many places. Some of the largest excavations in the deposits are in Salt Basin, where the company's camp is situated. In this locality the salt is in a solid bed interstratified with reddish or brownish clay shale, adjacent to which are beds containing celestite and large amounts of gypsum. The company's claims cover practically all the Saratoga field except the Saratoga Hills, and its ground has been mapped and the deposits described in a manuscript geologic report prepared under the direction of Harry R. Johnson. The celestite deposits have been described by Phalen.[4]

SARATOGA HILLS.

PREVIOUS WORK.

In the search for nitrate the Saratoga Hills have always been considered the most promising part of the Saratoga field. Since the report by Bailey appeared, in 1902, they have been prospected many times, and thousands of feet of shallow trenches in the surface soil remain as testimony to the extent of the work. The most thorough exploration was carried on by the California Nitrate Development Co. (See p. 14.) The Saratoga Hills area differs little in general character from other parts of the field, but owing to its greater width it contains larger outcrops and more beds of the supposed niter-bearing strata than the other areas. For these reasons the Geological Survey undertook the exploration of the Saratoga Hills first.

THE STRATA.

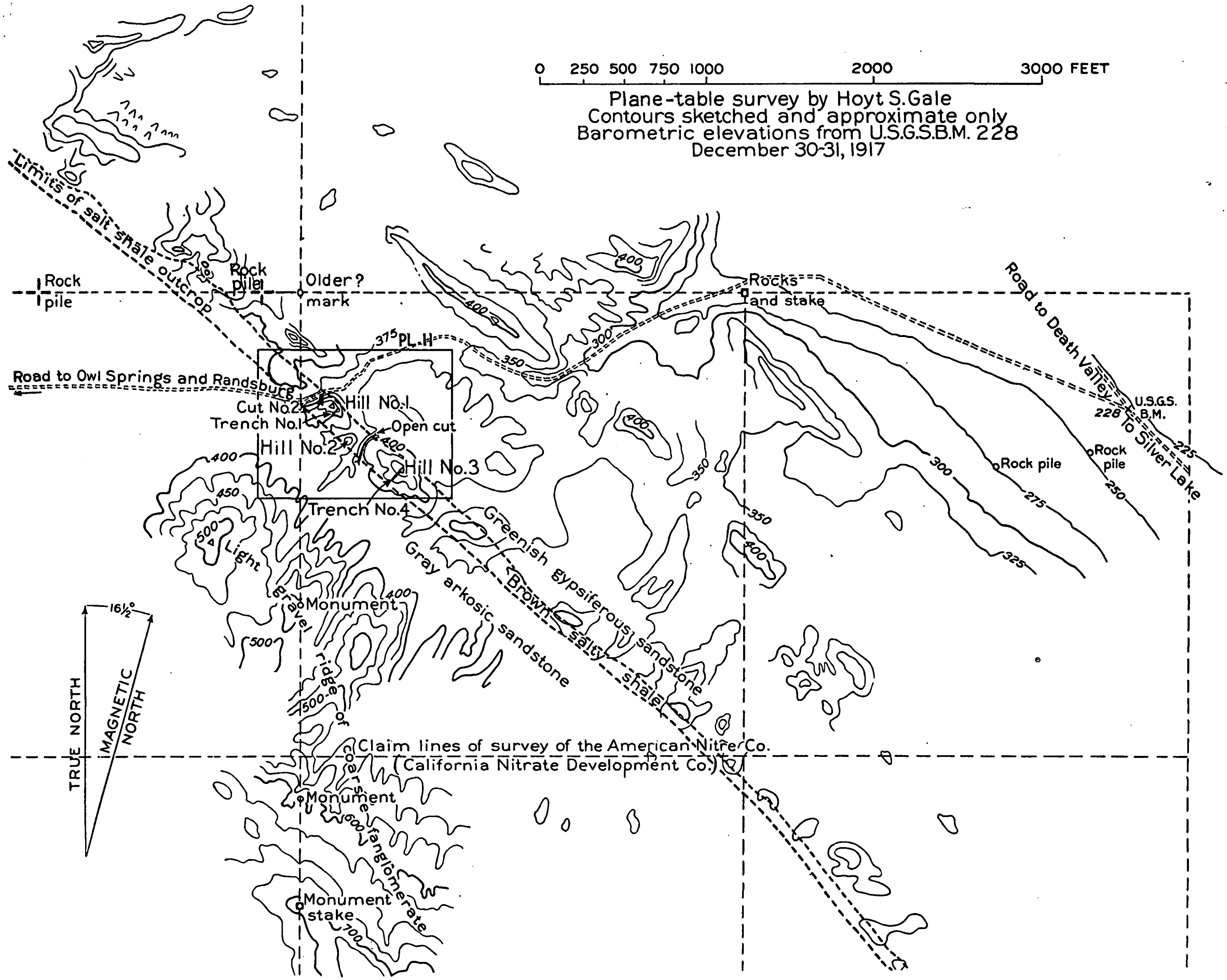
STRUCTURE.

The strata that underlie the Saratoga Hills are steeply upturned and are folded and faulted along an axis which trends southeastward parallel with the axis of South Death Valley. In most places they strike southeast and dip steeply southwest, but in some places they dip steeply northeast or are vertical. Some beds are intensely folded, and some of the folds are overturned. The more resistant strata are eroded into long lines of curiously rounded hills, the so-called niter hills, which are covered with a sterile clay soil that is essentially barren of vegetation. (See Pl. II, p. 6.)

In the Saratoga Hills the relation of these strata to the older crystalline and metamorphic rocks of the mountains bordering South Death Valley is difficult to determine, because their contacts with the older rocks are concealed in most places beneath younger formations. Along the base of the hills, toward the valley, they are buried under fans of alluvial waste, whereas on the west, toward the mountains, they disappear under a high gravelly ridge composed of tilted

---

[4] Phalen, W. C., Celestite deposits in California and Arizona: U. S. Geol. Survey Bull. 540, pp. 526–531, 1913.



GENERAL MAP OF THE WEST END OF THE SARATOGA NITER HILLS.

beds of coarse fanglomerate. Southeast of the Saratoga Hills, however, in the Salt Basin and Cave Spring Wash areas, their contacts with the older rocks are exposed. Here the strata are inset in the older rocks, by faulting, in long, irregular parallel strips in a fault zone that trends southeast along the margin of the valley—a "graben" structure which somewhat resembles that in the San Andreas rift zone in southwestern California. The Saratoga Hills, Round Mountain, and Valley areas lie along the southwest margin of the valley, directly in line with this fault zone, and their axes of structure trend parallel with it. The structural axes in the Confidence field likewise trend southeast, and the strata seem to be faulted against the older rocks southwest of the valley. Apparently, therefore, the strata of all the nitrate fields in South Death Valley lie in the zone of a fault along the southwest margin of the valley and have been faulted down between the older rocks during one of the movements by which the Death Valley trough was formed.

BELT OF GREENISH GYPSIFEROUS SANDSTONE.

The Saratoga Hills comprise roughly three parallel belts of outcrop (see Pl. V) contrasted in character of bedrock and in the color of soil, each of which runs, with some interruptions, the length of the field. The soil in the belt on the valley side is marked by creamy tints and is underlain by a formation that consists chiefly of fine-grained greenish-gray sandstone and contains large quantities of gypsum. Part of the gypsum is interbedded with the sandstone, and part of it is in veins that cut across the bedding. The sandstone is at least 900 feet thick. In places it passes downward into buff conglomeratic sandstone, which near the base consists almost wholly of granitic fragments and in one exposure appears to rest on granite.

BELT OF BROWN SALTY SHALE.

The formation underneath the soil in the middle belt is about 300 feet thick and consists of beds of very salty reddish-brown shale which include, in the southeastern part of the Saratoga Hills, a solid bed of rock salt at least 10 feet thick. The shale contains a considerable amount of gypsum in small veins that cut the bedding. The middle portion of the shale is the most saline and contains the bed of rock salt. This salt bed extends from Amphitheater Canyon, in the middle of the Saratoga Hills area, southeastward to Salt Basin, where the salt has been mined by the Avawatz Salt & Gypsum Co. It was not found in the shale northwest of Amphitheater Canyon. The salty shale is more resistant to erosion than the other rocks in the Saratoga Hills, so that its outcrop is marked by the highest and most conspicuous line of hills. The soil, in contrast with that in the other belts, is marked by dark colors—brown or reddish brown.

BELT OF GRAY ARKOSIC SANDSTONE.

The rocks in the third belt, which lies highest along the valley border, are chiefly beds of fine arkosic sandstone whose prevailing color is gray, with greenish, brownish, or yellowish tints. Some of the beds are separated by thin layers of clay, and some of them contain lenses of angular granitic pebbles. In places, near the base of the formation, there are beds of gypsum. The arkosic sandstone is overlain, with apparent unconformity, by beds of coarse fanglomerate in the high gravelly ridge west of the Saratoga Hills, so that its thickness can not be determined, but at least 800 feet of it is exposed. In the southeastern part of the Saratoga Hills the arkosic sandstone is eroded into rugged badland amphitheaters, one of the largest of which lies at the head of Amphitheater Canyon. (See Pl. VI, *A*.) The soil in this belt is marked by pale greenish, yellowish, or reddish tints.

AGE AND CORRELATION.

The upturned strata just described appear to have been laid down under conditions much like those that exist in the region at the present day—the gypsiferous and saline clays and sands in playas or evaporating lakes; the coarser sands and the gravels in alluvial slopes which at times spread out and buried the playas. There is no evidence that any of them were deposited beneath the sea. These strata in the Saratoga Hills are but one of many similar series of terrestrial deposits found in the Mohave Desert and the Death Valley region which are known to have been laid down in Tertiary time but whose approximate horizon in the Tertiary has been determined by fossil evidence only in a few places. No fossils were found in the strata in the Saratoga field, although no systematic search was made for them, so it is impossible to assign the strata definitely to any period in the Tertiary or to correlate them with other deposits in the general region. In lithology and in structure they resemble the strata in the Confidence and Owl Spring fields very closely, are practically continuous with them, and without doubt are the same series. In degree of disturbance and to some extent in lithology they resemble the upturned strata in the Upper Canyon and Lower Canyon nitrate fields of Amargosa Valley, the Siebert Lake beds of Death Valley and the Amargosa Range, the strata of the Pilot nitrate field, southeast of Searles Lake, the beds of Red Rock Canyon, which Merriam has designated "Ricardo formation," and the beds of the Barstow syncline to which Merriam has applied the name "Barstow formation," but they contain much less volcanic ash than the strata in these other areas and no lava. The strata of Red Rock Canyon and the Barstow syncline have been searched for fossils by parties working under the direction of J. C.

Merriam, and collections of mammal remains have been obtained which, according to Merriam,[5] fix the age of the strata in Red Rock Canyon as approximately lower Pliocene and the age of those in the Barstow syncline as approximately upper Miocene. According to Bailey,[6] the head of a *Palaeotherium* was found in the strata of the Upper Canyon field, and upon this evidence the strata in that field and, indeed, those in all the nitrate fields were considered to be Eocene. It was not stated where the specimen is stored or who determined it. Merriam, however, in a letter to the writer states: "*Palaeotherium* is an Old World genus not known in America, but it resembles in a superficial way a number of our early middle Tertiary horses. There are, for example, species in the upper Miocene which might be mistaken for *Palaeotherium*." Inasmuch as the upturned strata of the Saratoga field resemble in a rather general way the Pliocene beds of Red Rock Canyon and the Miocene beds of the Barstow syncline, and inasmuch as practically all Tertiary rocks in the region older than the middle Miocene are lavas,[7] it would seem more probable that the strata in the Saratoga field are late Miocene or Pliocene than that they are early Tertiary.

The beds of coarse fanglomerate that overlie the upturned strata of the Saratoga Hills are moderately disturbed and are considerably older than the alluvial fans of the region. They may be either early Quaternary or late Tertiary. Similar fanglomerates overlie the upturned strata of the Confidence field in a high gravel ridge and apparently also overlie the upturned strata of the Upper Canyon field in places.

DISTRIBUTION OF NITER-BEARING GROUND DETERMINED BY PRELIMINARY QUALITATIVE TESTS.

It was found that field tests for nitrate showing results varying all the way from weak to strong could be obtained nearly everywhere just beneath the surface soil in the ground within the three parallel belts of rock marked by the sterile clay soil, but that the gravelly channels of the washes cutting through the hills, the gravel slopes covering parts of the hills, and the older rocks (granite, quartzite, and limestone) bordering the area were totally barren of nitrate. The niter-bearing ground was thus shown to coincide with the outcrop of the upturned Tertiary strata, an area roughly 4 miles long and from one-fourth to three-fourths of a mile wide.

[5] Merriam, J. C., Tertiary mammalian faunas of the Mohave Desert: California Univ. Dept. Geol. Bull., vol. 11, p. 454, 1919.

[6] Bailey, G. E., The saline deposits of California: California State Min. Bur. Bull. 24, p. 172, 1902.

[7] Ball, S. H., A geologic reconnaisance in southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, p. 33, 1907.

TESTS AT WEST END OF SARATOGA HILLS.

PRELIMINARY PIT TESTS.

LOCATION.

An area of about 5 acres at the west end of the Saratoga Hills, in the salty shale belt, where a number of preliminary field tests had shown high nitrate content, was selected as representative of the field, to be tested by shallow pits. Thirteen square pits were sunk in this area, distributed at irregular intervals of about 100 feet (fig. 2). The pits were from 1 to 3 feet in diameter and were sunk to

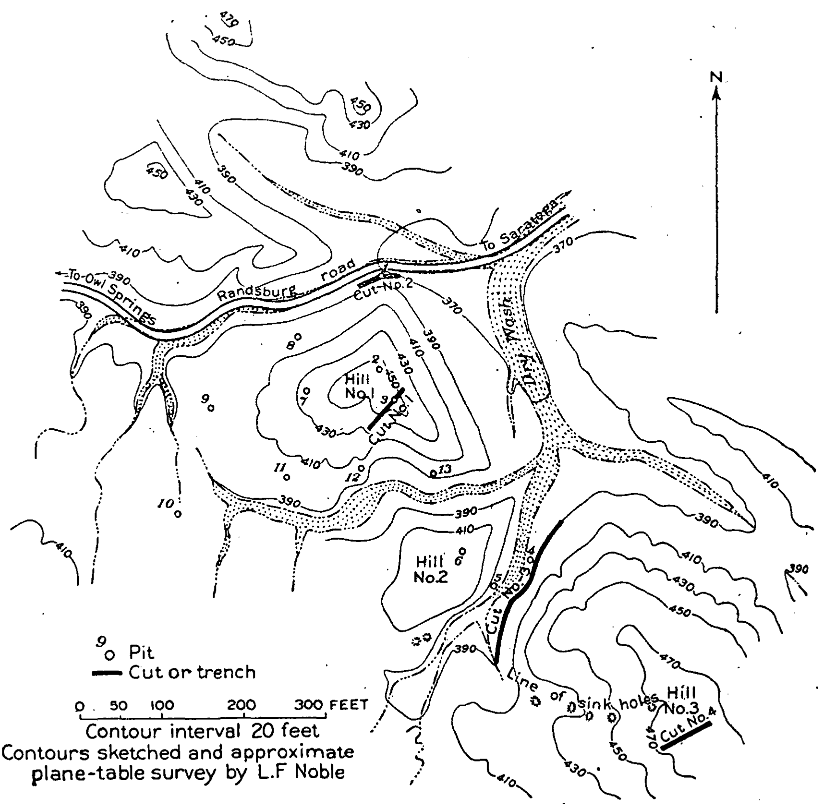


FIGURE 2.—Detailed map of the west end of the Saratoga niter hills, showing location of pits.

depths averaging 18 inches. The complete record of the results of these pit tests is given in the tables and summary on pages 40–46.

CROSS SECTION OF DEPOSIT.

The pits revealed the following cross section of the niter-bearing ground (see fig. 1, p. 7):

1. Loose surface soil, averaging 6.5 inches in depth. This soil for a depth of a few inches at the surface of the ground consists of compact clay whose surface is covered with innumerable little knobby corrugations. (See Pl. III, *A*, p. 16.) Underneath this clay crust the soil is loose and powdery and contains much soluble matter, which appears as white efflorescent salts more or less mixed with brown powdery clay. Because the salts in this layer of the soil are largely sulphates (chiefly of sodium, magnesium, and calcium), it may be called the "sulphate layer." In places this sulphate layer is absent and the soil consists of compact clay alone.
2. A cemented layer, or "caliche," averaging 8.3 inches in thickness. This caliche is essentially the weathered upper portion of the bedrock which has been recemented by various salts, chief of which is common salt, or sodium chloride. In this locality it is very hard and compact in the upper portion but becomes less dense in texture downward, so that it grades imperceptibly into the bedrock, and the boundary between the two is indistinct.
3. Bedrock, consisting of steeply tilted beds of salty brown shale.

NITRATE CONTENT.

Analyses of the samples (see pp. 40–41) taken from this ground, layer by layer, showed that—

1. The surface soil as a whole is practically barren of nitrate, showing an average of only 0.07 per cent for the thirteen pits.

2. The caliche averages 1.94 per cent of nitrate for the thirteen pits, and some layers within it show amounts as high as 6.35 per cent, 6.74 per cent, and 10.96 per cent. The nitrate in the caliche is very irregularly distributed, ranging from 0.32 per cent in one pit to 4.99 per cent in another.

3. The bedrock to a depth of 5.4 inches below the caliche contains an average of only 0.35 per cent of nitrate.

FURTHER TESTS.

Although the pit tests showed with some certainty that the nitrate is concentrated in the caliche and that the soil and bedrock are relatively barren, the fact that the bedrock contains small amounts of nitrate made further exploration of it imperative.

Long trenches were therefore dug to depths of 5 to 9 feet across the places where the samples highest in nitrate had been obtained in the pit tests. Four of these excavations were made, ranging in length from 42 to 192 feet; all were laid out at right angles to the strike of the steeply dipping beds, so that every foot of every stratum in the salty shale belt was exposed for sampling. Two samples were taken in each trench, one in bedrock along the bottom of the trench, the other in the caliche layer. The samples in bedrock represent sections of equal length in a continuous strip 6 inches wide; the caliche samples represent sections of equal length in a continuous strip whose width is approximately the thickness of the caliche. Finally, three pits that showed either a high nitrate content in the caliche or an increase of nitrate with depth and that had not been followed up by trenches were dug deeper to make sure that no clue had been overlooked. A record of the results of this work, with profiles and illustrations, is given in detail in the table and summary on pages 40–46.

CONCLUSIONS.

The conclusions regarding the salty shale belt deduced from the above tests may be stated as follows:

1. The nitrate is concentrated in the caliche.
2. The nitrate is irregularly distributed in the caliche, some samples showing twice as much nitrate as others a few feet away.
3. The richer spots are of small extent, generally not over a few feet in length.
4. The average nitrate content of the caliche is low, averaging only 1.73 per cent for all pits and trenches in the area tested.
5. Although the bedrock strata contain nitrate as far down as explorations were carried (to a depth of 10 feet), the amounts are very small and decrease with depth. There is no evidence of marked concentration of nitrate in any stratum.

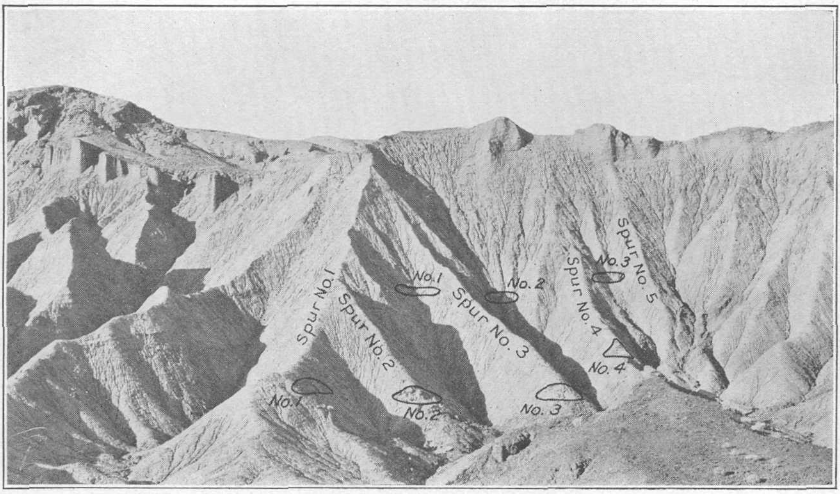
TESTS IN AMPHITHEATER CANYON.

Work in the belt of salty shale was therefore abandoned, except that it was decided to make an excavation across the belt in Amphitheater Canyon, 1½ miles southeast of the locality of the previous work, because there is a bed of rock salt in the shale in Amphitheater Canyon which is not known to be present in the west end of the Saratoga Hills. This was done in order to determine whether there might not have been a concentration of nitrate accompanying the deposition of the salt.

The belts of greenish gypsiferous sandstone and of gray arkosic sandstone adjacent to the outcrop of salty shale were also explored in like manner. Amphitheater Canyon was chosen for this work because the gypsiferous sandstone and the arkosic sandstone are exposed there much better and in wider outcrops across the strike than in the west end of the Saratoga Hills.

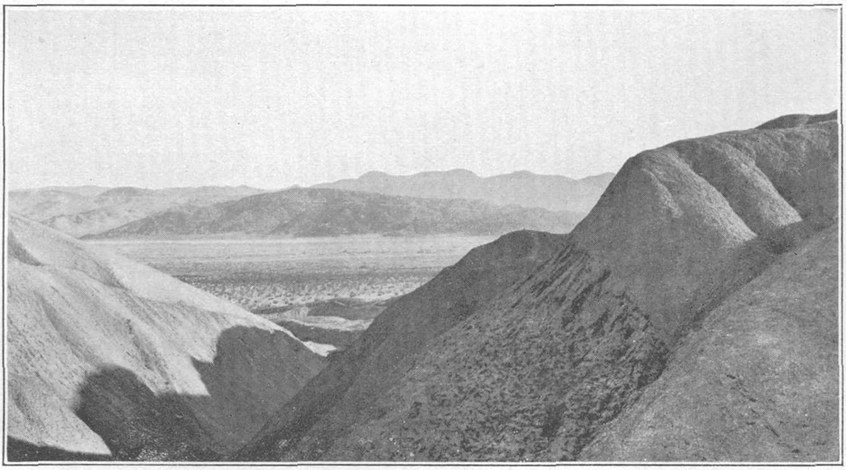
BELT OF GRAY ARKOSIC SANDSTONE.

Seven trenches were made in the belt of gray arkosic sandstone in the badland amphitheater near the head of the canyon, where preliminary field tests had shown good results. These trenches ranged from 6 to 12 feet in length and from 4 to 6 feet in depth and were sampled in the manner already described. Four of the trenches were on spurs of ridges, and three were in ravines. All were on steep



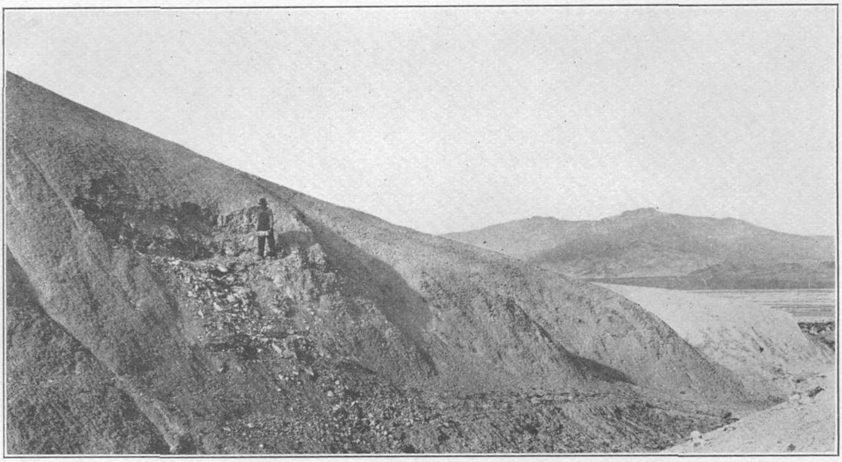
A. HEAD OF AMPHITHEATER CANYON.

Showing location of spur and ravine cuts.



B. VIEW FROM AMPHITHEATER CANYON ACROSS SOUTH DEATH VALLEY.

Showing characteristic outcrop of salt caliche marking bed of rock salt.



A. MOUTH OF AMPHITHEATER CANYON.

Showing cut in gypsiferous sandstones.

B. VIEW ALONG TRENCH A, CONFIDENCE HILLS.

slopes. (See Pl. VI, *A*.) A record of the results of this work is given in detail in the tables and summary on pages 47–49.

The average nitrate content of the caliche in the samples taken (2.12 per cent) proved to be higher than in the salty shale belt, but the nitrate is very unevenly distributed, varying from an average of 4.41 per cent in one cut to 0.03 per cent in another. The caliche on the spurs of the ridges averages about 3.16 per cent, whereas that in the heads of the ravines averages 0.36 per cent. The bedrock and soil in all the trenches were shown to be nearly barren of nitrate.

The caliche in this amphitheater is associated with beds of rather coarse sandstone, not with beds of clay, and it lies on very steep slopes.

BELT OF GREENISH GYPSIFEROUS SANDSTONE.

Because of the disappointing results in the belt of arkosic sandstone, and because the field tests had indicated that no more promising results could be expected in the belt of gypsiferous sandstone, only

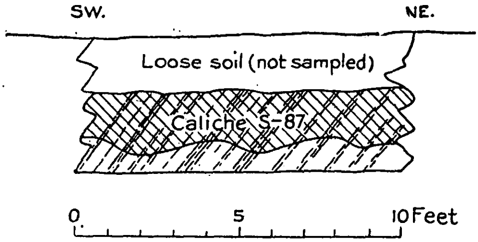


FIGURE 3.—Profile cut in gypsiferous sandstone at mouth of Amphitheater Canyon.

one excavation was made in that belt. This was a trench 10 feet long and 4 feet deep near the mouth of Amphitheater Canyon, in a locality where a good field test had been obtained. (See fig. 3 and Pl. VII, *A*.)

The caliche in this trench averaged only 1.62 per cent in sodium nitrate, and the bedrock beneath it gave only a weak reaction for nitrate with the field testing outfit.

BELT OF BROWN SALTY SHALE.

Finally, a trench was made across the outcrop of the bed of rock salt in the salty shale belt in Amphitheater Canyon. This trench was 125 feet long and 6 feet deep. It traversed a solid bed of rock salt 10 feet thick and beds of salt mixed with clay on either side of it. Neither the salt bed, the beds of salt mixed with clay, nor the overlying firmly cemented salt and caliche showed a trace of nitrate. Plate VI, *B*, shows a characteristic outcrop of salt caliche marking a bed of rock salt.

RESULTS OF TESTS IN DETAIL.

TESTS AT WEST END OF SARATOGA HILLS.

Pit tests in belt of brown salty shale.

[Area covered by pit tests about 5 acres. Pits irregularly distributed at distances of about 100 feet apart. See fig. 2 and Pl. III.]

No. of pit.	Layer.	Thickness of layer removed. (inches).	Nitrate as $NaNO_3$ (per cent).	Total thickness (inches).	Average content of nitrate as $NaNO_3$ (per cent).
1	Loose soil	4 8	0.00 .37	12	0.25
	Caliche	3 4	1.38 1.15	7	1.25
	Bedrock	4	.25	4	.25
2	Loose soil	1 3	.03 .01	4	.015
	Caliche	5	.32	5	.32
	Bedrock	7	.04	7	.04
3	Loose soil	4	.00	4	.00
	Caliche	4 7	1.93 6.74	11	4.99
	Bedrock	Not reached.	....	....	....
4	Loose soil	None.	....	....	....
	Caliche	1 4	10.96 1.77	5	3.60
	Bedrock	2 0.5	.26 .00	2.5	.20
5	Loose soil	4	.00	4	.00
	Caliche	5 5	1.04 2.77	10	1.95
	Bedrock	3 6	.82 .59	9	.66
6	Loose soil	3 4	.00 .00	7	.00
	Caliche	3 4	1.12 .66	7	.86
	Bedrock	4 1	.36 .07	5	.30
7	Loose soil	6	Trace.	6	Trace.
	Caliche	6	1.03	6	1.03
	Bedrock	6	.29	6	.29
8	Loose soil	5	.11	5	.11
	Caliche	7	3.62	7	3.62
	Bedrock	4	.92	4	.92
9	Loose soil	7 5	.11 .11	12	.11
	Caliche	5 7	1.07 1.60	12	1.38
	Bedrock	Not reached.	....	....	....
10	Loose soil	7	.04	7	.04
	Caliche	7	.89	7	.89
	Bedrock	7	.12	7	.12
11	Loose soil	7	.01	7	.01
	Caliche	7 4	.41 .81	11	.55
	Bedrock	Not reached.	....	....	....
12	Loose soil	4	.01	4	.01
	Caliche	8	.43	8	.43
	Bedrock	5	.43	5	.43
13	Loose soil	6	Trace.	6	Trace.
	Caliche	7 5	.75 6.33	12	3.07
	Bedrock	Not reached.	....	....	....

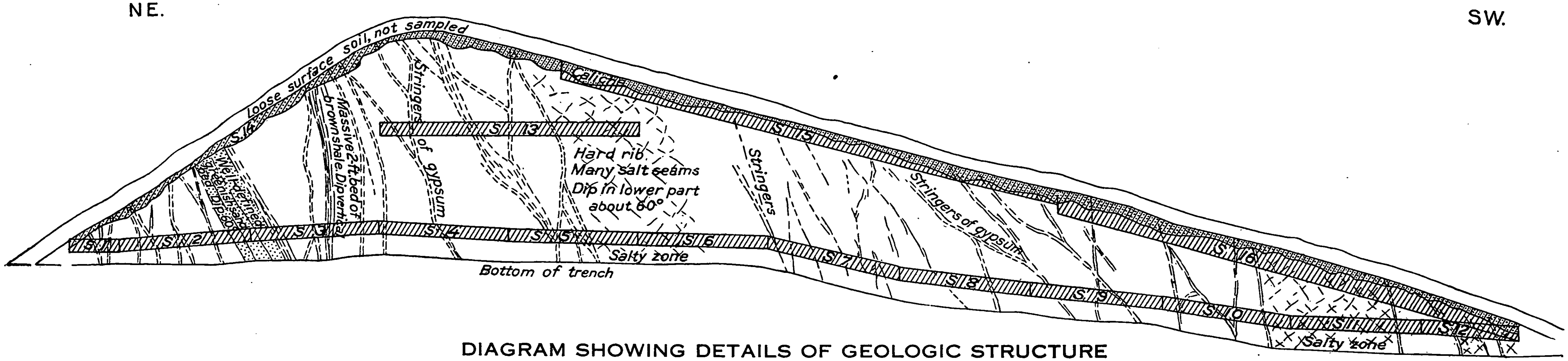


DIAGRAM SHOWING DETAILS OF GEOLOGIC STRUCTURE

The shaded blocks show position from which samples were taken.
The general dip of the beds is westerly, steep to about 60°, but the strata show crumpling and distortion

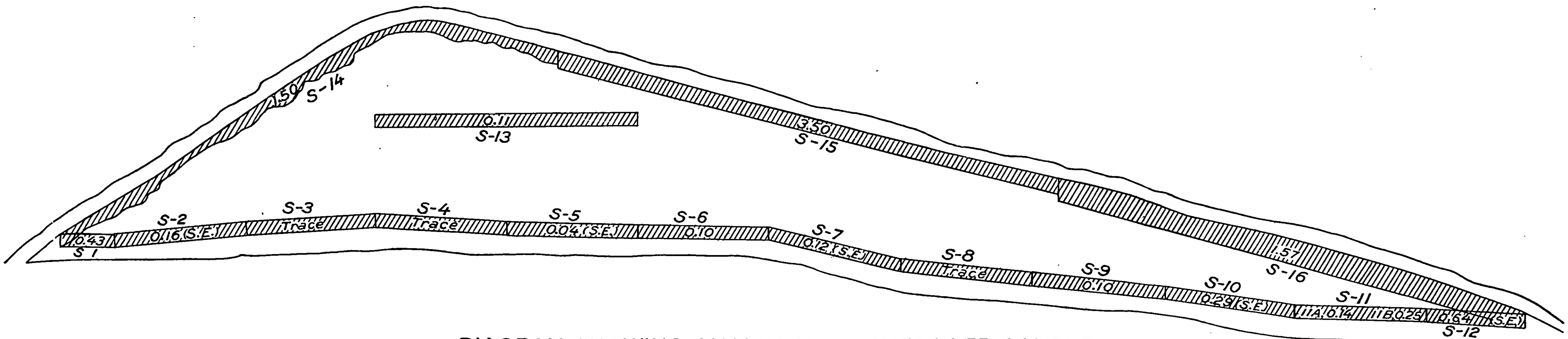


DIAGRAM SHOWING ANALYSES OF AVERAGED SAMPLES

Analyses in terms of sodium nitrate ($NaNO_3$) contained in the carefully averaged sample as received at laboratory are shown here. Analyses by private analysts are marked S. E.

0 5 10 15 Feet

PROFILE OF TRENCH NO. 1, ON TOP OF HILL NO. 1, WEST END OF SARATOGA NITER HILLS.

Summary.

No. of pit.	Soil.		Caliche.		Bedrock.	
	Thickness (inches).	Nitrate as $NaNO_3$ (per cent).	Thickness (inches).	Nitrate as $NaNO_3$ (per cent).	Thickness penetrated (inches).	Nitrate as $NaNO_3$ (per cent).
1	12	0.25	7	1.25	4	0.25
2	4	1.01	5	.32	7	.04
3	4	.00	11	4.99	....	....
4	0	....	5	3.60	2.5	.20
5	4	.00	10	1.95	9	.66
6	7	.00	7	.86	5	.30
7	6	.00	6	1.03	6	.29
8	5	.11	7	3.62	4	.92
9	12	.11	12	1.38	....	....
10	7	.04	7	.89	7	.12
11	7	.01	11	.55	....	....
12	4	.01	8	.43	5	.43
13	6	.00	12	3.07	....	....
Average	6.5	[a] .07	8.3	[a] 1.94	5.4	[a] .35

[a] Obtained by multiplying thicknesses by assays and dividing the sum of these products by the sum of the thicknesses.

Further work done from clues afforded by the pit tests.

Clue.	How followed up.
Samples with the highest nitrate content in the caliche layer:	
Lower 7 inches of caliche in pit No. 3, 6.74 per cent	Deep trench (No. 1) through site of pit.
1-inch crust of caliche on steep hillside in pit No. 4, 10.96 per cent.	Long trench (No. 3) along hillside through site of pit.
Lower 5 inches of caliche in pit No. 13, 6.33 per cent	Pit dug deeper.
Nitrate content increasing with depth in pit No. 9	Do.
Nitrate content increasing with depth in pit No. 11	Do.

Pit No. 9, which showed a higher nitrate content (1.60 per cent) in the lower part of the caliche than in the upper part (1.07 per cent), was deepened 2 feet 4 inches below the base of the caliche layer. A sample from the bedrock at the bottom of the deepened pit (4 feet 5 inches below the surface of the ground) assayed 0.47 per cent of $NaNO_3$.

Pit No. 11, which showed a higher nitrate content (0.81 per cent) in the lower part of the caliche than in the upper part (0.41 per cent), was deepened 1 foot 3 inches below the base of the caliche. A sample taken from the bedrock at the bottom of the pit (2 feet 9 inches below the surface of the ground) assayed 0.44 per cent of $NaNO_3$.

Pit No. 13, which showed a nitrate content of 6.33 per cent in the lower part of the caliche, was deepened 1 foot 8 inches below the base of the caliche. A sample from the bedrock at the bottom of the deepened pit showed only a trace of $NaNO_3$.

In each of these pits the nitrate content of the bedrock beneath the caliche was found to decrease rapidly with depth, indicating that the nitrate is concentrated in the caliche.

Trench No. 1, 57 feet long and 9 feet deep, was dug at the top of hill No. 1 (see Pl. VIII) to explore bedrock beneath pit No. 3, to expose for sampling a section across the strike of the steeply dipping beds of salty shale in order to find out whether any of the beds contain valuable quantities of nitrate, and to expose a long continuous section of the soil and caliche for sampling and study.

Sample No.	Material.	Description.	Depth (feet)	Nitrate as $NaNO_3$ (per cent).
Not sampled	Loose soil	Average depth about 8 inches		Tested and found practically barren.
S-14	Caliche	Represents a strip about 19 feet long, 6 inches thick—the upper and in this locality more thoroughly cemented half of the caliche.		1.50
S-15	do	Represents a strip 19 feet long, 6 inches thick—the upper and in this locality more thoroughly cemented half of the caliche.		3.50
S-16	do	Represents a strip about 19 feet long, 12 inches thick, which includes all material between the loose soil and the unaltered bedrock and thus represents the entire caliche layer. The lower part of the caliche grades into unaltered bedrock, and the boundary between caliche and bedrock is indefinite.		1.57
S-13	Bedrock	Represents a strip 10 feet long across steeply dipping beds of brown salty gypsiferous shale 5 feet below surface of ground.		.11
S-1	do	Each of these samples represents a strip 4 to 5 feet long across steeply dipping beds of brown salty gypsiferous shale 1 foot above bottom of the trench. The depths below the surface, in feet, are indicated at the right:	0-2	.43
S-2	do		2-5	.01
S-3	do		5-8	Trace.
S-4	do		8	Trace.
S-5	do		8	Trace.
S-6	do		8-6	.13
S-7	do		6-5	.12
S-8	do		5-4	Trace.
S-9	do		4	.14
S-10	do		4-3	.21
S-11	do		3-2	.34
S-12	do		2-0	.45

The results obtained in this trench may be summarized as follows:

The loose surface soil is practically barren of nitrate.

Two samples, representing a strip 38 feet long of the upper, more thoroughly cemented half of the caliche layer, average 2.50 per cent of sodium nitrate.

One sample, representing an adjacent strip 19 feet long including the entire caliche layer, carries 1.57 per cent of sodium nitrate. The lower part of the caliche represented by this sample is a transition zone between caliche and unaltered bedrock.

The nitrate content of the bedrock below the caliche decreases with depth, and only a few hundredths of 1 per cent is present at depths of 8 feet. There is no significant concentration of nitrate in any stratum in the bedrock.

The nitrate is concentrated in the caliche and is apparently more abundant in the upper, more thoroughly cemented half of the caliche than in the lower, less thoroughly cemented half.

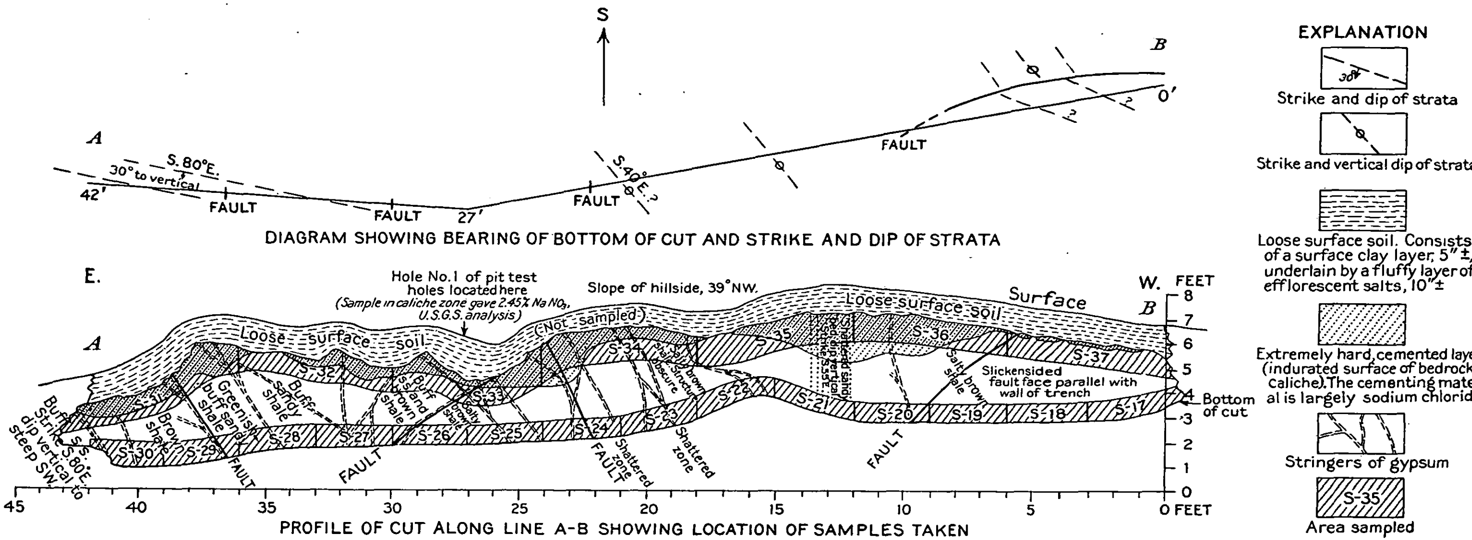
The nitrate is unevenly distributed in the caliche from place to place, one sample (S-15) showing over twice as much as an adjacent sample (S-14).

More complete analyses of some of the samples described in the foregoing section are as follows:

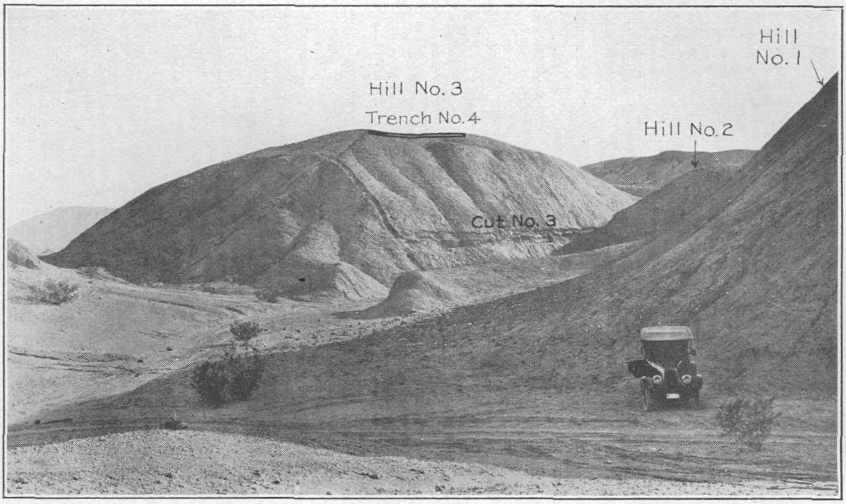
Analyses of samples from summit trench, hill No. 1, Saratoga Hills.

[W. B. Hicks, analyst.]

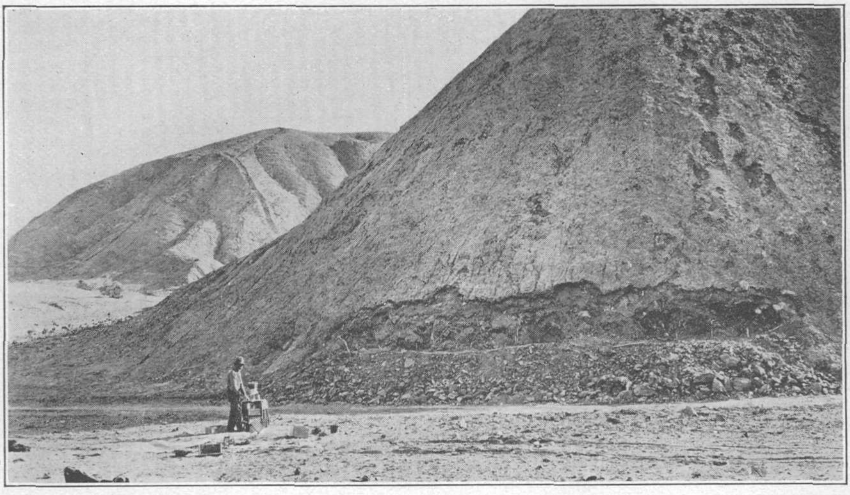
No.	Na.	K.	Ca.	NO_3.	Cl.	CO_3.	SO_4.	Total salts at 180° C.
S-1	Much.	Trace.	Much.	0.31	1.38	Trace.	4.63	10.07
S-2	Much.	Trace.	Much.	.01	1.76	Trace.	3.36	7.85
S-5	Much.	Trace.	Much.	Trace.	4.53	Trace.	4.00	13.44
S-10	Much.	Trace.	Much.	.15	4.05	Trace.	3.77	12.69
S-12	Much.	Trace.	Much.	.33	7.66	Trace.	3.92	19 33



PROFILE OF TRENCH NO. 2, AT NORTHWEST BASE OF HILL NO. 1, ON RANDSBURG-SARATOGA ROAD.



A. HILL NO. 3 FROM NORTHWEST END OF SARATOGA NITER HILLS.



B. TRENCH NO. 2, AT NORTHWEST BASE OF HILL NO. 1, WEST END OF SARATOGA NITER HILLS.

The foregoing results are equivalent to the following calculated constituents:

No.	$NaNO_3$.	NaCl.	$CaSO_4$.	Total by summation.
S-1	0.43	2.28	6.56	9.27
S-2	.01	2.90	4.76	7.67
S-5	....	7.47	5.67	13.14
S-10	.21	6.68	5.34	12.23
S-12	.45	12.63	5.56	18.64

Trench No. 2, 42 feet long and 4 feet deep, was dug at the northwest base of hill No. 1 (see Pls. IX; X, *B*) to expose for sampling a continuous section of soil, caliche, and bedrock in steeply dipping beds of salty shale and gypsiferous shale and sandstone in a fault zone to see if the bedrock contains valuable nitrate. The loose soil was about 1 foot deep. It was tested and found practically barren, so no samples of it were taken. Seven samples of caliche were taken, each representing a strip 6 feet long and including all material in the first 10 inches beneath the base of the soil. Fourteen samples of bedrock were taken, each representing a strip 3 feet long and 4 feet below the surface of the ground. The nitrate content of the caliche and bedrock, as indicated by the analyses of these samples, is given in the following table:

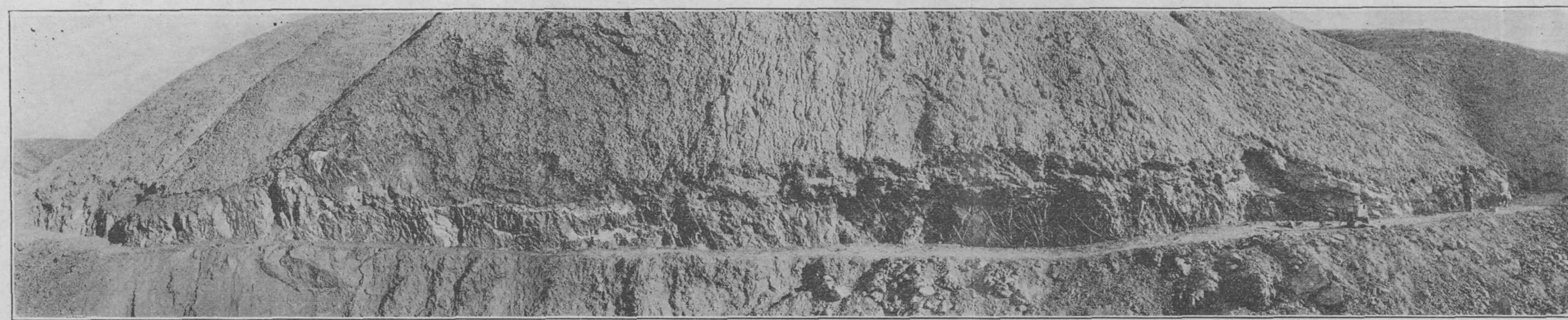
No. of sample.	Material.	Nitrate as $NaNO_3$ (percent).	No. of sample.	Material.	Nitrate as $NaNO_3$ (percent).
S-31	Caliche	0.92	S-20	Bedrock	0.21
S-32	do	1.19	S-21	do	.20
S-33	do	.48	S-22	do	.19
S-34	do	.55	S-23	do	Trace.
S-55	do	.27	S-24	do	....
S-36	do	1.01	S-25	do	.27
S-37	do	3.72	S-26	do	.27
			S-27	do	.27
Average		1.16	S-28	do	.23
			S-29	do	.22
S-17	Bedrock	.33	S-30	do	.23
S-18	do	.22			
S-19	do	.18	Average		[a].20

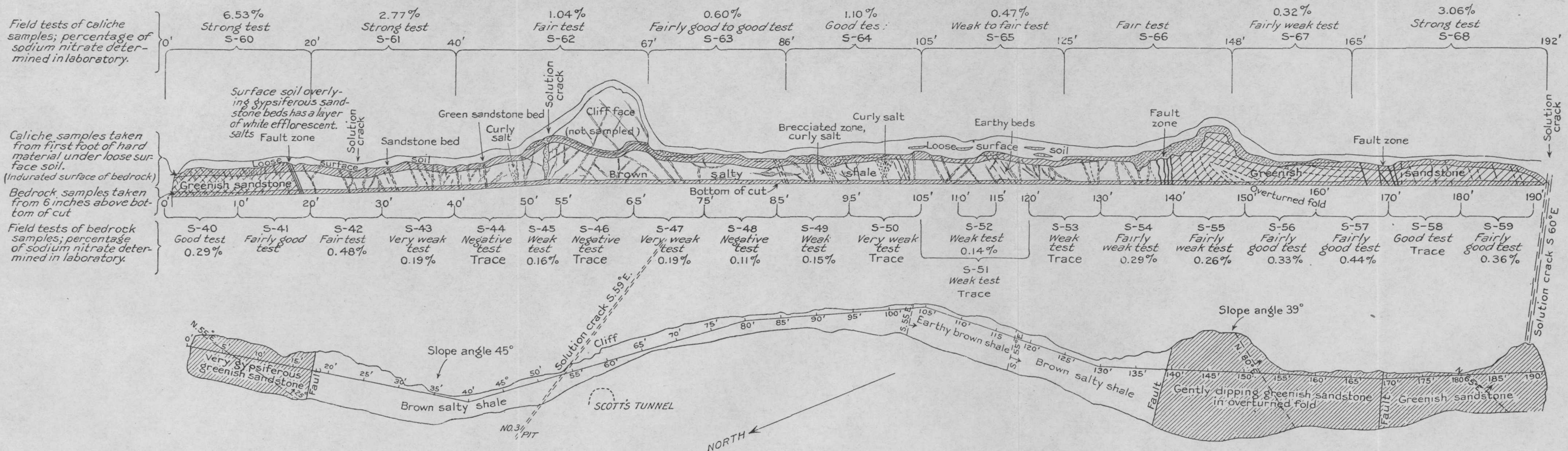
[a] Average of 13 samples.

Trench No. 3, 192 feet long and 5 to 12 feet deep, was dug on the west slope of hill No. 3 (see Pls. X, *A*; XI) to expose for sampling a continuous section of soil, caliche, and bedrock across the belt of salty brown shale, from greenish gypsiferous sandstone on one side of the belt to greenish micaceous sandstone on the other, being dug across the strike of the steeply dipping beds in order to afford a maximum chance of encountering concentrations of nitrate, if they exist in the beds, to obtain, by traversing different kinds of rock, evidence as to whether a change in kind of rock marks any change in the nitrate content of the overlying caliche layer, and to explore bedrock in the vicinity of pit No. 4, which showed a nitrate content of 10.96 per cent in a part of the caliche layer.

Sample No.	Weight of sample (pounds).	Material.	Description.	Nitrate as $NaNO_3$ (per cent).
Not sampled.	....	Loose soil.........	Average depth about 18 inches..............	Tested and found practically barren.
S-60.........	20	Caliche overlying greenish gypsiferous sandstone.	This and each of the following caliche samples represents a strip about 20 feet long and 12 inches thick. It includes all material between the loose soil and the unaltered bedrock and thus represents the entire caliche layer. The lower part of the caliche grades into unaltered bedrock, and the boundary between caliche and bedrock is indefinite.	6.53
S-61.........	21	Caliche overlying brown salty shale.	See sample S-60............................	2.77
S-62.........	28	.....do...........	In vicinity of test pit No. 4, in which a part of the caliche carried 10.96 per cent sodium nitrate. See sample S-60.	1.04
S-63.........	20	.....do...........	See sample S-60............................	.60
S-64.........	20	.....do...........	.....do....................................	1.10
S-65.........	20	.....do...........	.....do....................................	.47
S-66.........	20	Caliche overlying fault zone between brown shale and greenish sandstone.	.....do....................................	
S-67.........	20	Caliche overlying interbedded brown shale and greenish sandstone.	.....do....................................	.32
S-68.........	20	Caliche overlying greenish micaceous sandstone.	Hand-sorting test made here (p. 19). See sample S-60.	3.06
S-40.........	10	Bedrock..........	Greenish gypsiferous sandstone. This and each of the following bedrock samples represents a strip about 10 feet long, 6 inches above the bottom of the cut and about 4 feet below the surface of the ground.	29
S-41.........	11	.....do...........	Greenish gypsiferous sandstone in fault zone, gypsum in beds.	....
S-42.........	10	.....do...........	Brown salty gypsiferous shale...............	.48
S-43.........	10	.....do...........	.....do....................................	.19
S-44.........	11	.....do...........	Brown very salty gypsiferous shale..........	Trace.
S-45.........	10	.....do...........	Brown very salty gypsiferous shale (vicinity of test pit No. 4).	.16
S-46.........	10	.....do...........	Brown very salty gypsiferous shale cut by network of gypsum stringers.	Trace.
S-47.........	10	.....do...........	Brown salty gypsiferous shale like S-46, with greenish spots.	.19
S-48.........	12	.....do...........	.....do....................................	.11
S-49.........	12	.....do...........	.....do....................................	.15
S-50.........	10	.....do...........	Brown very salty gypsiferous shale, much curly salt along veins.	Trace.
S-51.........	10	.....do...........	Earthy beds of brown shale alternating with salty beds.	Trace.
S-52.........	11½	.....do...........	Earthy beds only, in middle of strip represented by sample S-51.	.14
S-53.........	10	.....do...........	Brown gypsiferous shale....................	Trace.
S-54.........	10	.....do...........	Brown gypsiferous shale in fault zone, with much salt along veins and in films.	.29
S-55.........	21	.....do...........	Interbedded greenish sandstone and brown shale in overturned fold; some salty shale in center of fold: broken zone of salty brown sandstone in fault cracks.	.26
S-56.........	21	.....do...........	Nearly horizontal beds of greenish sandstone and brown shale.	.33
S-57.........	21	.....do...........	Same as Sample S-56, in fault zone..........	.44
S-58.........	21	.....do...........	Greenish micaceous sandstone in fault zone, strike N. 65° E., dip 80° SW.	Trace.
S-59.........	21	.....do...........	Steeply dipping beds of greenish micaceous sandstone, with some thin beds of brown shale; little salt or gypsum.	.36

The results obtained in trench No. 3 may be summarized as follows: The loose surface soil is practically barren of nitrate.





TRENCH NO. 3, ON WEST SLOPE OF HILL NO. 3, WEST END OF SARATOGA NITER HILLS.

Eight samples, representing 172 feet of the caliche exposed in the cut, average 1.99 per cent of sodium nitrate. The lower part of the caliche represented by these samples is a transition zone between caliche and unaltered bedrock.

Nineteen samples, representing 180 feet of bedrock at a depth of 4 feet, average 0.17 per cent of sodium nitrate.

The nitrate is concentrated in the caliche and is very irregularly distributed.

The nitrate content of the caliche is higher (6.53 per cent) above the gypsiferous sandstone at the north end of the cut than at any point over the adjacent brown salty shale. It is also higher (3.06 per cent) over the greenish micaceous sandstone at the south end of the cut than at any point over the salty shale.

There is no significant concentration of nitrate in any stratum in the bedrock.

Trench No. 4, 60 feet long and 2 to 3 feet deep, was dug at the top of hill No. 3 (see Pl. X, *A*, and fig. 4) for further exploration of the soil, caliche, and bedrock in the belt of brown salty shale.

Sample No.	Material.	Description.	Nitrate as $NaNO_3$ (per cent).
Not sampled	Loose soil	Average depth about 12 inches	Tested and found practically barren.
S-69	Caliche	Each of these caliche samples represents a strip about 20 feet long, 12 inches thick. It includes all material between the loose soil and the unaltered bedrock, and thus represents the entire caliche layer. The lower part of the caliche grades into unaltered bedrock, and the boundary between caliche and bedrock is indefinite.	3.48
S-70	do		1.10
S-71	do		1.27
S-72	Bedrock	Represents a strip 20 feet long, 3 feet beneath surface of ground, directly under caliche sample S-71. Rock is brown salty gypsiferous shale.	03

The results obtained in trench No. 4 may be summarized as follows:

The loose surface soil is practically barren of nitrate.

Three samples representing the 60 feet of the caliche exposed in the trench average 1.95 per cent of sodium nitrate. The lower part of the caliche represented by the samples is a transition zone between caliche and unaltered bedrock.

One sample, representing 20 feet of bedrock at a depth of 3 feet, carries 0.03 per cent of sodium nitrate. The bedrock is thus practically barren of nitrate.

The nitrate is concentrated in the caliche and is unevenly distributed.

Summary of caliche analyses from trenches and test pits at west end of Saratoga Hills.

Opening.	Total length of strips from which analyses are available (feet).	Average content of nitrate as $NaNO_3$ (per cent).
Trench No. 1	[a] 38	2.50
	19	1.57
Trench No. 2	42	1.16
Trench No. 3	172	1.99
Trench No. 4	60	1.95
Thirteen pits		1.94

[a] Upper, more indurated half of caliche layer.

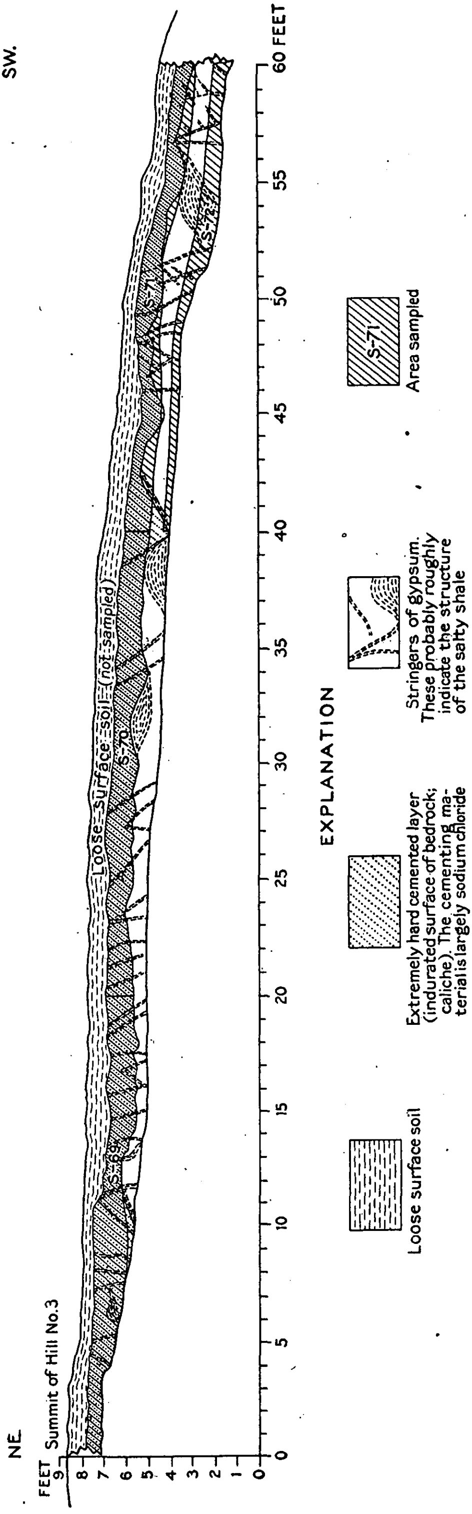


FIGURE 4.—Profile of trench No. 4, hill No. 3, Saratoga niter hills.

TESTS IN AMPHITHEATER CANYON.

Seven cuts were made in the belt of gray arkosic sandstone in Amphitheater Canyon, to expose for sampling sections of caliche and bedrock on steep badland slopes in a locality where preliminary tests had shown high nitrate content. (See Pl. VI, *A*, and fig. 5.)

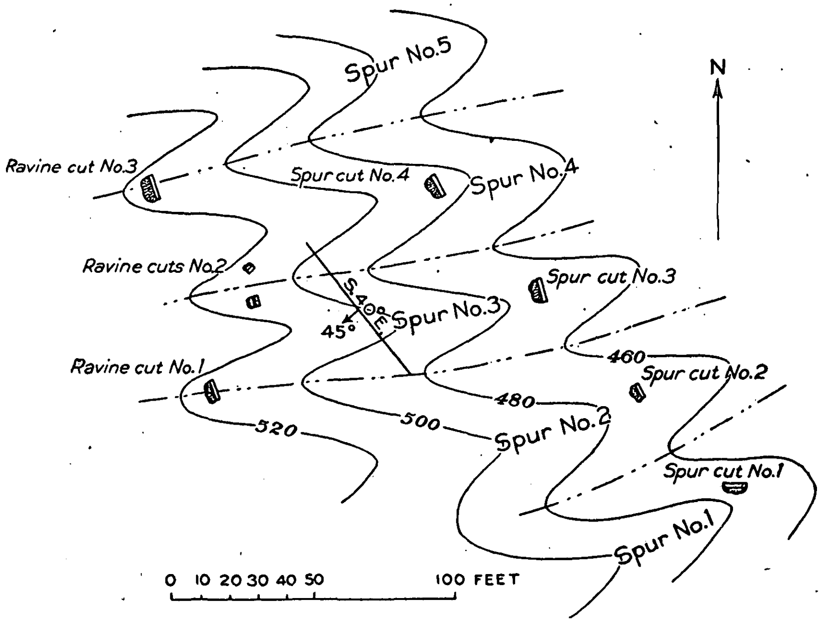


FIGURE 5.—Sketch map showing location of spur and ravine cuts in badland amphitheater at head of Amphitheater Canyon.

Cut.	Sample No.	Material.	Description.	$NaNO_3$ (per cent).
Spur cut No. 1, 12 feet long, 4 feet deep.	Not sampled	Loose soil...	Depth about 1 foot..................	Tested and found practically barren.
	S-75.........	Caliche......	Represents strip 12 feet long, 8 inches thick. (Hand-sorting test made here. See p. 18.)	3.39.
	S-77.........	Bedrock.....	Represents strip 6 feet long, 6 inches wide, 2 feet below base of caliche.	0.03.[a]
Spur cut No. 2, 7 feet long, 5 feet deep.	Not sampled	Loose soil...	Depth about 1 foot..................	Tested and found practically barren.
	S-79.........	Caliche......	Represents strip 7 feet long, 8 inches thick.	3.81.
	S-78.........	Bedrock.....	Represents strip 3 feet long, 6 inches wide, 2 feet below base of caliche.	0.03.[a]
Spur cut No. 3, 12 feet long, 5 feet deep.	Not sampled	Loose soil...	Depth about 1 foot..................	Tested and found practically barren.
	S-81.........	Caliche......	Represents strip 10 feet long, 6 inches thick.	4.41.
	S-80.........	Bedrock.....	Represents strip 5 feet long, 6 inches wide, 3 feet below base of caliche.	0.07.[a]
Spur cut No. 4, 11 feet long, 5 feet deep.	Not sampled	Loose soil...	Depth about 1 foot..................	Tested and found practically barren.
	S-82.........	Caliche......	Represents strip 10 feet long, 6 inches thick.	1.18.[a]

[a] Analyses by Smith, Emery & Co., Los Angeles.

Cut.	Sample No.	Material.	Description.	$NaNO_3$ (per cent).
	Not sampled	Bedrock.....	2 feet below base of caliche..........	Tested and found practically barren.
Ravine cut No. 1, 11 feet long, 4 feet deep.	.....do.......	Loose soil...	Depth about 1 foot..................	Do.
	S-83.........	Caliche zone.	Caliche lacking. Sample represents strip 10 feet long at horizon where caliche would normally be found.	0.03.[a]
Ravine cut No. 2, 6 feet long, 5 feet deep.	Not sampled	Loose soil...	Depth about 1 foot..................	Tested and found practically barren.
	S-84.........	Caliche......	Represents strip 3 feet long, 6 inches thick.	1.27.[a]
	Not sampled	Bedrock.....	1 foot below base of caliche..........	Tested and found practically barren.
Ravine cut No. 3, 11 feet long, 6 feet deep.	.....do.......	Loose soil...	Depth about 1 foot..................	Do.
	S-85.........	Caliche......	Represents strip 10 feet long, 8 inches thick.	0.42.[a]
	Not sampled	Bedrock.....	2 feet below base of caliche..........	Tested and found practically barren.

[a] Analysis by Smith, Emery & Co., Los Angeles.

The results obtained in the belt of gray arkosic sandstone are summarized below.

The soil and bedrock are practically barren of nitrate.

The nitrate is concentrated in the caliche, where the average content, obtained by multiplying the lengths by assays and dividing the sum of the products by the sum of the lengths, is as follows: For spurs, 3.16 per cent; for ravines, 0.36 per cent; for all samples, 2.12 per cent.

From the above table it is evident that the nitrate is very unevenly distributed in the caliche and that the caliche in the apexes of ravines carries much less nitrate than it does on the spurs. In places in the apexes of ravines caliche is entirely absent. Probably one-third of the outcrop of the arkosic sandstone in Amphitheater Canyon is in ravines.

A sample representing a 10-foot strip of caliche in spur cut No. 3 and carrying 4.41 per cent of sodium nitrate is the richest sample obtained in Amphitheater Canyon.

The average nitrate content of the caliche on the arkosic sandstone in Amphitheater Canyon is higher than in the caliche on the brown salty shale at the west end of the Saratoga Hills, and the results of the exploration indicate that it may be possible to find areas of 5 to 10 acres on the arkosic sandstone that will average over 4 per cent of sodium nitrate and smaller areas that will average over 6 per cent. However, the total area of outcrop of the arkosic sandstone does not exceed 400 acres in the Saratoga Hills, and the richer patches of caliche in this area are too small and their distribution too spotty to warrant a campaign of systematic sampling for estimating tonnage and value.

A cut 125 feet long and 6 feet deep was made in the belt of brown salty shale on the east side of Amphitheater Canyon, to explore a bed of rock salt in the shale and ascertain whether the salt contains nitrate. The cut traversed a 10-foot bed of solid rock salt and beds of salt mixed with clay on either side of the salt bed. (See Pl. VI, *B*.) The cut crossed these steeply dipping beds at right angles to their strike. Numerous tests made in this cut in the rock salt, in the beds of mixed clay and salt, and in the heavily cemented salt caliche above all the beds failed to show even a trace of nitrate. Consequently no samples were taken in the cut.

A test pit sunk in the brown salty shale at a point 50 feet north of the cut showed the following results:

Material.	Thickness of layer removed (inches).	Percentage of nitrate as $NaNO_3$.
Soil	4	0.00
Caliche	4	.62
Do	4	.32
Bedrock	5	.01

Two test pits sunk in the brown salty shale on opposite sides of Denning Spring Wash, 1½ miles southeast of Amphitheater Canyon, showed practically the same results as the pit mentioned above. Samples were taken from them, but were not analyzed because the material gave poor reactions for nitrate.

Numerous field tests made in the bed of rock salt in Salt Basin, 2½ miles southeast of Amphitheater Canyon, failed to show a trace of nitrate in the salt.

The caliche in the belt of brown salty shale appears to be poorer in nitrate in and southeast of Amphitheater Canyon than it is in the west end of the Saratoga Hills. Evidently the bed of rock salt is entirely barren of nitrate.

A cut 10 feet long and 4 feet deep was made in the belt of greenish gypsiferous sandstone near the mouth of Amphitheater Canyon (see Pl. VII, *A*) to explore caliche and bedrock in a locality underlain by beds of greenish, very gypsiferous sandstone, where a strong reaction for nitrate had been obtained in a preliminary field test.

Sample No.	Material.	Description.	Percentage of nitrate as $NaNO_3$.
Not sampled	Loose soil	Depth about 18 inches	Tested and found practically barren.
S-87	Caliche	Represents strip 10 feet long, 12 inches thick, which includes all material between the loose soil and the unaltered bedrock and thus represents the entire caliche layer. The lower part of the caliche grades into unaltered bedrock, and the boundary between caliche and bedrock is indefinite.	1.62.
Not sampled	Bedrock	Strip 6 inches below base of caliche	Tested and found practically barren.

The soil and bedrock are practically barren of nitrate and the nitrate is concentrated in the caliche. This one cut can not be considered a fair test of the belt of gypsiferous sandstone. However, a considerable number of preliminary field tests indicated that the belt is no more promising, on the whole, than the belt of arkosic sandstone and that any areas of caliche that will average over 4 per cent sodium nitrate are likely to be only a few acres in extent. The total area of gypsiferous sandstone on which these richer patches of caliche might be found does not exceed 600 acres in the Saratoga Hills, so it was not thought advisable to continue sampling in the belt at present, although the belt is the most accessible of the three because it lies lowest along the valley border and nearest the road.

Summary of all samples from the Saratoga Hills.

	Soil.		Caliche.		Bedrock.	
	Number of samples taken.	Average content of nitrate as $NaNO_3$ (per cent).	Number of samples taken.	Average content of nitrate as $NaNO_3$ (per cent).	Number of samples taken.	Average content of nitrate as $NaNO_3$ (per cent).
West end of Saratoga Hills.						
Belt of salty shales:						
Pit tests	16	0.07	21	1.94	12	0.35
Pits dug deeper					3	.30
Trenches and cuts			a 22	1.73	b 48	.22
Amphitheater Canyon.						
Belt of greenish sandstone: Spur and ravine cuts			7	2.12	3	.04
Belt of salty shales: Pit tests	1	.00	2	.47	1	.01
Belt of gypsiferous sandstone: Cut			1	1.62		
	17	c .066	d 53	c 1.82	e 67	c .24

	Total number of samples taken in Saratoga field.	Number of analyses available to date.	Average content of nitrate as $NaNO_3$ for all analyses available. (per cent).	Highest content of nitrate as $NaNO_3$ in any sample (per cent).	Lowest content of nitrate as $NaNO_3$ in any sample (per cent).
Soil	17	17	c 0.06	0.37	0.00
Caliche	53	52	c 1.82	10.96	.03
Bedrock (2 to 9 feet)	67	55	c .24	.92	.00
	137	124			

a 21 analyses.
b 36 analyses.
c These figures are simply averages of the total number of samples taken; they do not express averages of the ground as a whole, because, as is evident from the table, the greater number of samples came from the salty shale belt, where the caliche is lower in nitrate than in the belt of greenish sandstones. Out of fifty samples for which analyses are available in the caliche only four show a nitrate content of more than 5 per cent (10.96, 6.74, 6.53, and 6.33 per cent).
d 52 analyses.
e 55 analyses.

CONCLUSIONS ON THE SARATOGA FIELD.

CONDITIONS REQUISITE FOR EXPLOITATION.

It was evident that unless (1) valuable deposits of nitrate could be discovered in the bedrock strata, or unless (2) a fairly continuous deposit of caliche (3) averaging more than 5 per cent in nitrate content could be found over all the Saratoga Hills area, this portion of the Saratoga niter field, shown by preliminary testing to be less than 1,200 acres in extent, is too small to be worth consideration as a source of nitrate even under war conditions.

ACTUAL CONDITIONS.

1. The existence of valuable deposits of nitrate in the bedrock is exceedingly unlikely. An exploration of the various types of rock in the area by pits and trenches to depths of 4 to 10 feet revealed

only small amounts of nitrate, the largest amount shown in any sample being less than one-tenth of the average amount contained in the caliche.

2. The areas of caliche are discontinuous and patchy.

3. The average nitrate content of the caliche is low in all samples taken, an average of the samples in the salty shale belt showing only 1.73 per cent and in the arkosic sandstone belt only 2.12 per cent, and there is no promise of a higher average in the belt of gypsiferous sandstones. Although a few single samples running over 5 per cent were obtained, they came from richer spots of less than an acre each, and the distribution of these richer spots was shown to be very irregular.

UNTESTED AREAS.

Although there yet remains untested a part of the Saratoga field as large as the Saratoga Hills, if not larger, the Saratoga Hills area is not only fairly typical of the whole field but has always been considered the most promising part of it. This fact and the disappointing results above outlined have caused the abandonment of intensive work in this field. The untested areas may be examined later by a small scouting party after the more promising portions of other fields have been explored.

CONFIDENCE FIELD.

By F. C. Calkins.

INTRODUCTION.

The old Confidence mill is in South Death Valley about 15 miles from the entrance to Death Valley proper. The name of the old mill may conveniently be applied to the neighboring group of clay and gravel hills in which the nitrate is found, as well as to the field itself. The Confidence Hills were explored from a camp pitched about half a mile northwest (down the valley) from the mill. (See Pl. XII.)

This range of hills extends from a point nearly opposite the mill northwestward along the southwest side of the Amargosa channel. Its length is probably at least 10 miles, and its greatest breadth about 1 mile. The exploration, however, extended only from the southeast end of the range to a canyon about 4 miles distant, which cuts completely through the group of hills and will be referred to as Through Canyon. No prospecting was done southwest of the crest of the range, for it was decided that a study of the northeast flank of the southeast half of the range gave sufficient data for appraising the effect of geologic and topographic conditions upon the distribution of nitrate salt in this field.

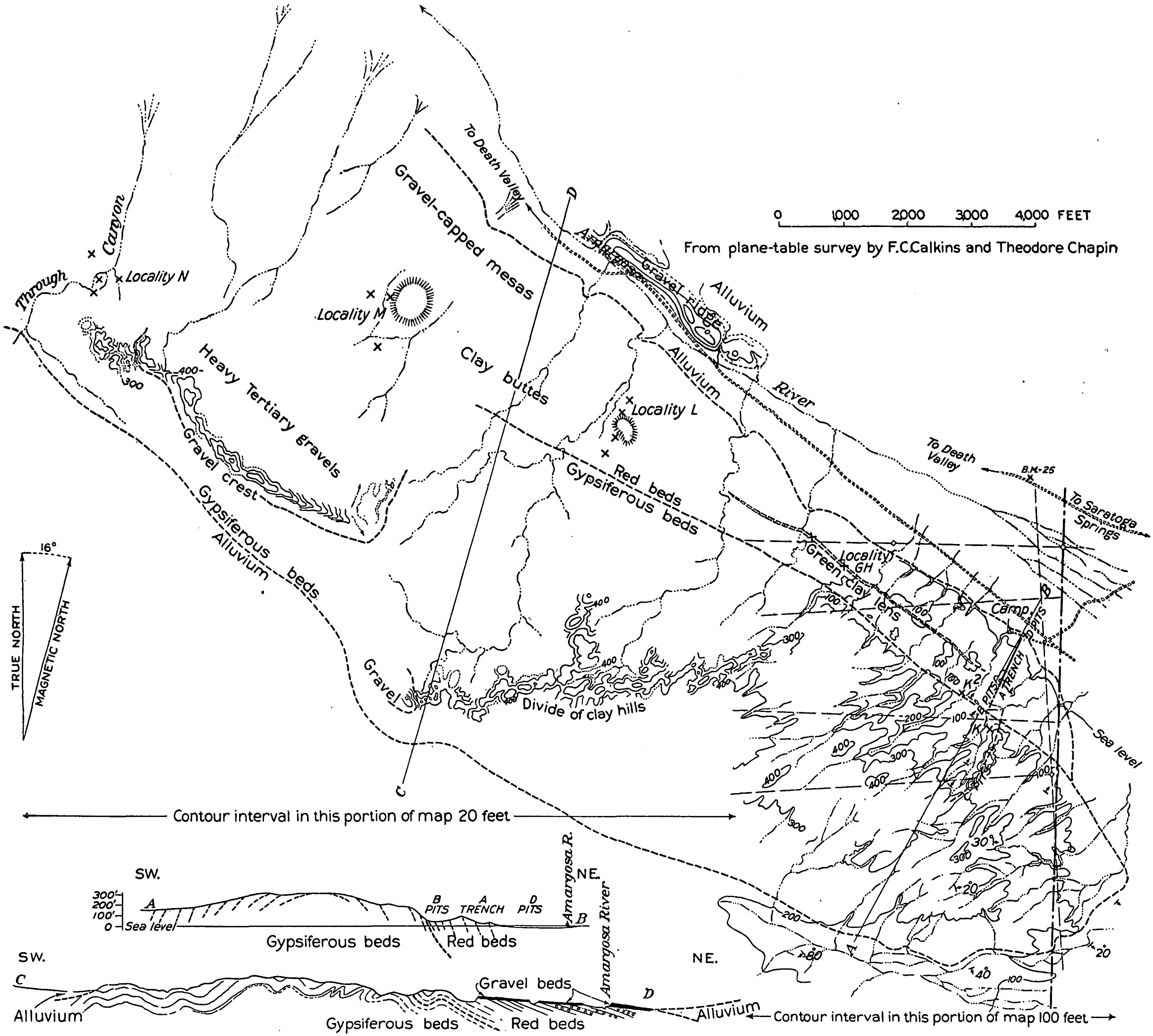
GEOLOGY AND TOPOGRAPHY.

The greater part of the Confidence Hills is carved from a series of beds that consist mainly of clay and that may be grouped into two formations. The older formation is made up chiefly of clays that show many tints of red, green, drab, and buff, but it contains also an abundance of gypsum in beds, nodules, and veins. The younger formation, whose bedding is parallel to that of the older, is nearly free from gypsum and is predominantly reddish. It consists mainly of clay, but contains, especially in its upper part, a good deal of conglomerate and sand, and some volcanic ash. The only conspicuous exception to the dominant red color is shown in a lenticular stratum of green clay, about a mile long and about 50 feet in maximum thickness, the southeast end of which is near the camp site. The clay formations are overlain unconformably by gravelly deposits which are of no economic importance, for the areas occupied by them contain no nitrate that could conceivably be worked.

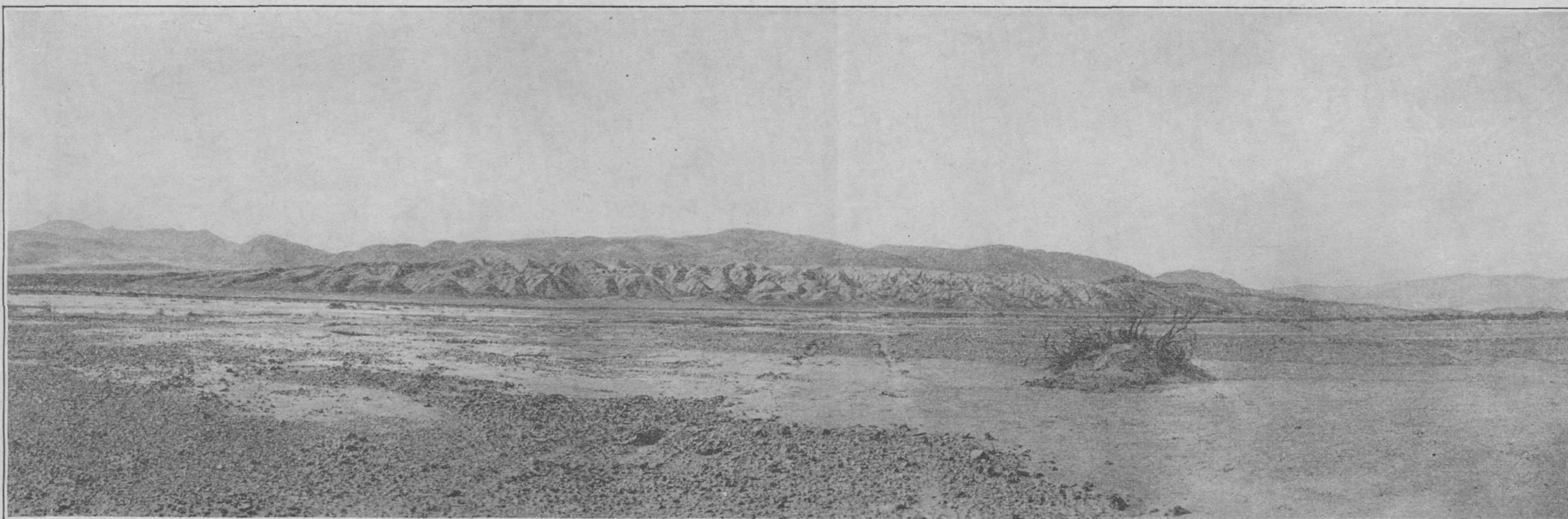
The structure of the hills may be sufficiently understood from the two diagrammatic cross sections in Plate XII. The beds have been arched up along the crest of the range, and in most of the area explored the lower beds are exposed along the crest and the upper beds along the flanks. In the vicinity of the camp site, and especially southeastward from it (see Pl. XVI), the structure is simple, the cross section of the strata being like an arch. Farther north it is more complex. The clay beds here are compressed into several folds that die out southeastward, and the clays are partly overlain by gravels that are completely stripped away to the southeast. (See Pl. XIII, *B*.)

The topography is closely related to the geology, the form of the hills, as well as their structure, being simplest at the southeast end of the range. Near the camp site the main body of the clay hills is flanked on the northeast by strike ridges, which disappear beneath the alluvium a short distance farther east and give way half a mile to the west to irregular hills and isolated buttes, flanked on the northeast by dissected gravel-capped mesas. The main clay ridge disappears about a mile from Through Canyon beneath a mass of old gravel, which forms a higher crest. (See Pl. XIII, *B*.) The northwestern part of the hills explored is, in short, both more diversified and more rugged in topography than the southeastern part and presents less extensive areas having gentle slope and underlain by clay beds. (See Pl. XIV, *A*.)

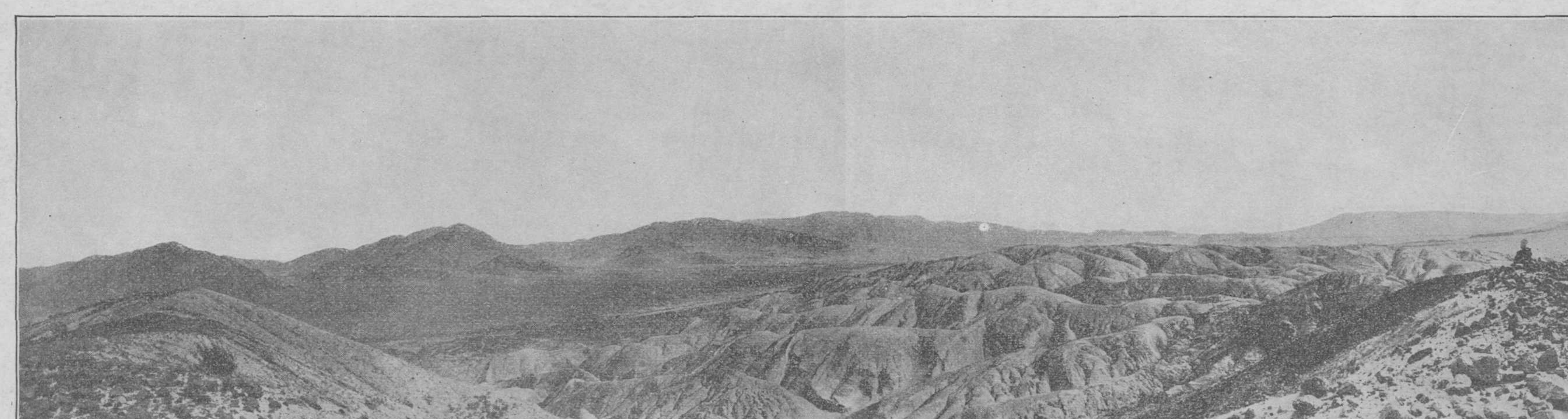
Some of the main topographic and geologic features of the Confidence Hills are shown in the incomplete sketch map that forms Plate XII), and a view embracing the part of the range which was examined is shown in Plate XIII, *A*.



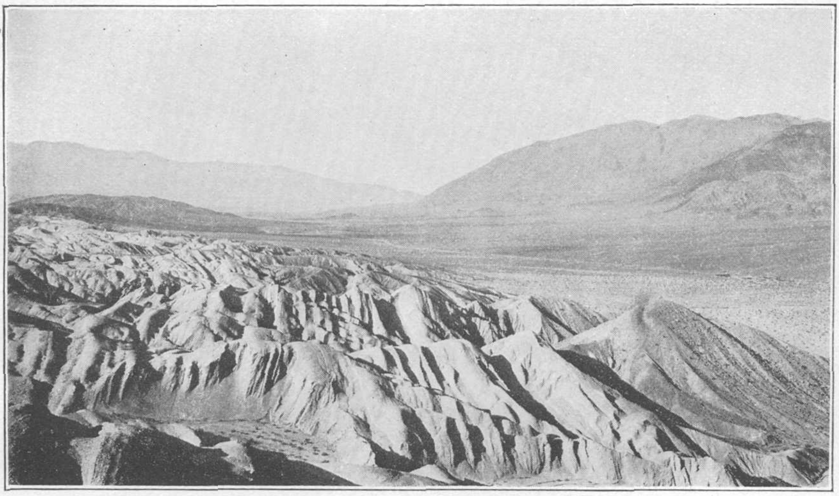
SKETCH MAP AND SECTIONS OF CONFIDENCE FIELD.



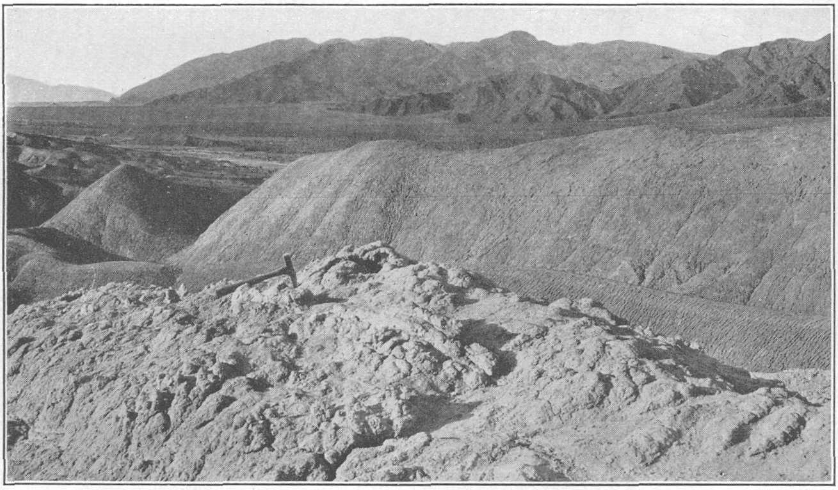
A. GENERAL VIEW OF CONFIDENCE HILLS.



B. VIEW SOUTHEASTWARD ALONG CREST OF CONFIDENCE HILLS.



A. VIEW NORTHWESTWARD ACROSS THROUGH CANYON.



B "BLISTER CALICHE" ON GREEN HILL.

KINDS OF CALICHE PRESENT.

In the Confidence field, as in the Saratoga field, the most abundant sort of caliche is hard and compact and contains a large proportion of sodium chloride. The nitrate in it can rarely be seen or tasted. Most of the caliche of this type is covered with soil to the depth of nearly a foot.

A caliche of similar composition but largely barren of soil is conspicuous on the lower parts of some canyon walls and of the banks of some stream channels.

A soft nitrate caliche of the same type as that found in Amphitheater Canyon, in the Saratoga field, showing nitrate and salt in white or pearly crusts on the walls of cracks, was found only in one locality.

The most unusual type of caliche in the Confidence field has been found in this field only, where it always lies on fine green clay. It takes the form of hollow domes or blisters, about a yard in average breadth and only thinly covered with soil, and may be distinguished as "blister caliche." (See Pl. XIV, *B*.) The caliche substance itself is somewhat like that of the Amphitheater type, being softer than the common salt caliche and containing in places enough nitrate to be tasted. A sample of this caliche is the richest that was taken in the entire Amargosa region, but the quantity of it present in the Confidence field is so small that it can not be developed there as a commercial source of nitrate.

GENERAL SEQUENCE AND RESULTS OF PROSPECTING OPERATIONS.

The exploration of the Confidence field attained the scope of a fairly thorough reconnaissance and led to a decidedly unfavorable opinion as to the possibility of finding nitrate there in any quantity that could be considered commercial. The grounds for this conclusion and the reasons for not carrying the exploration further may be shown by a brief narrative account of the prospecting operations.

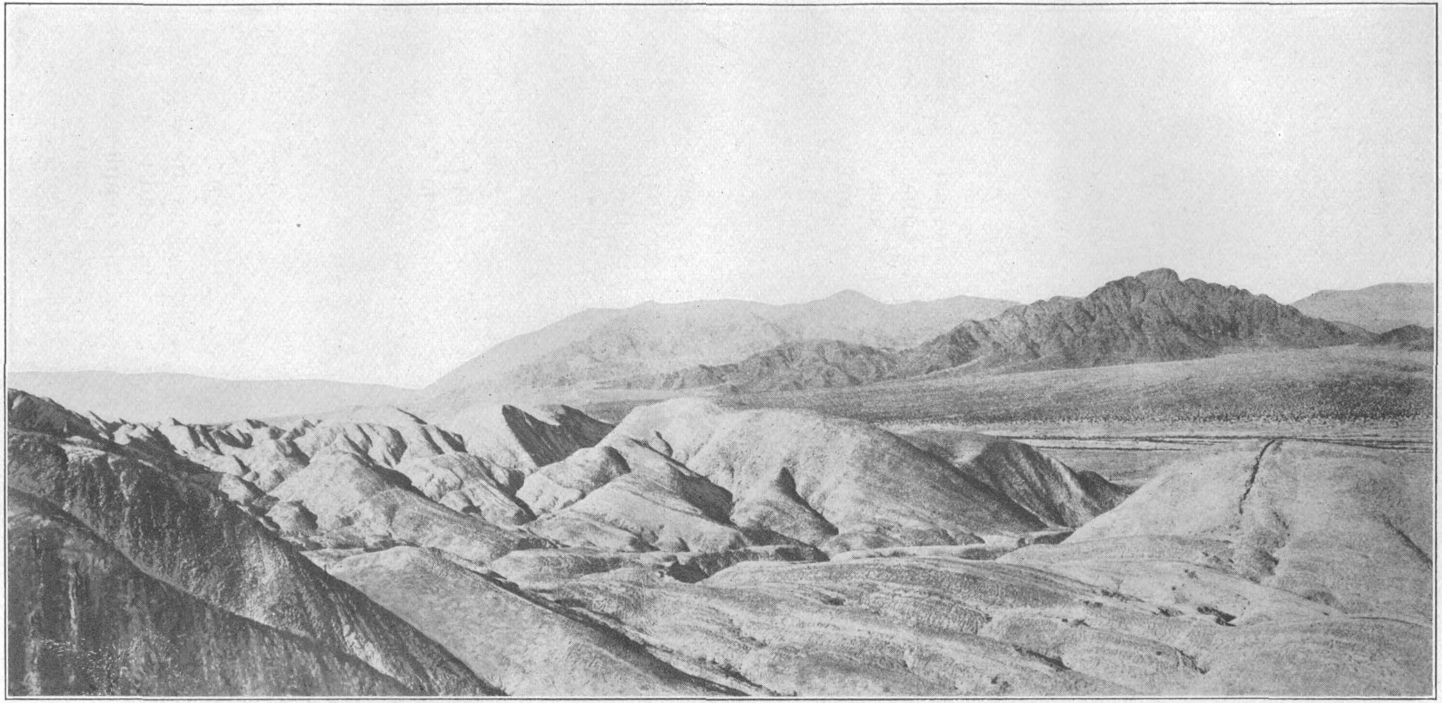
At the time when work was first undertaken in the field it was still thought possible that nitrate might form a considerable part of some of the bedrock strata. A number of pits were made, therefore, that penetrated through caliche and well into the underlying bedrock; and at many places chips were taken from the bedrock where it was exposed without a cover of soil or caliche. It was invariably found that the bedrock gave either no reaction for nitrate or only a very feeble one, while the caliche gave some reaction almost everywhere and a strong reaction at some points. This independent evidence from the Confidence field soon received confirmation from the work done in the Saratoga Hills, which was proceeding at the same time, and it became apparent that the immediate object of the quest should be caliche that was rich, extensive, and thick enough to be workable at a profit.

Two sorts of material were first investigated with some hope that they might be unusually rich. The first of these was the green clay lens in the upper clay formation. Strong tests were obtained from the surface of this green clay, but a trench cut partly across the lens exposed only a thin layer of caliche, which gave weak tests and of which, therefore, no samples were saved; and the bedrock, as usual, proved to be virtually barren.

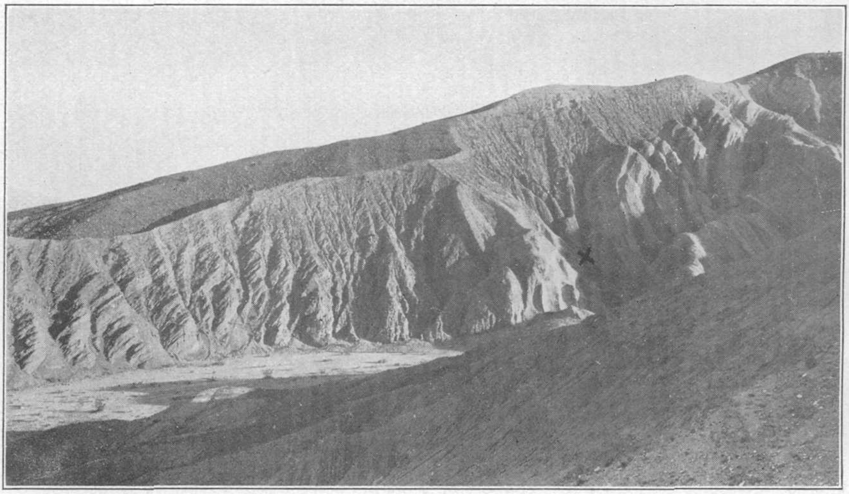
The second material tested was a hard salty caliche, not wholly covered with soil, that was common on the lower slopes of the canyon walls. This caliche, which was penetrated in several places, was everywhere found to be thin and poor, and no samples of it were kept for analysis.

It now seemed probable that if any commerical deposit were to be found it would be likely to occur on the rather gentle slopes that prevailed in the southeastern part of the area. Observation had indicated that the caliche would be more continuous and thicker on these slopes than on the more rugged slopes to the northwest, and it was determined to gain a quantitative idea of its average thickness and tenor along some representative section. The site for the necessary prospecting operations was chosen at a spot indicated on Plate XII (p. 52) by the letters A, B, and C. At this place it seemed possible to obtain within a shorter distance than anywhere else an idea of the effects of topography and of the composition of the bedrock upon the thickness and tenor of the caliche. Structurally the beds form the half of a simple anticline. They have a steep dip along a great part of the section, and the entire thickness of the red clay formation, which preliminary results in the Saratoga Hills had indicated to be relatively favorable, is fully exposed. The barren gravel deposits are wholly absent from this section. The locality presents a variety of gentle and moderate slopes but no cliffs.

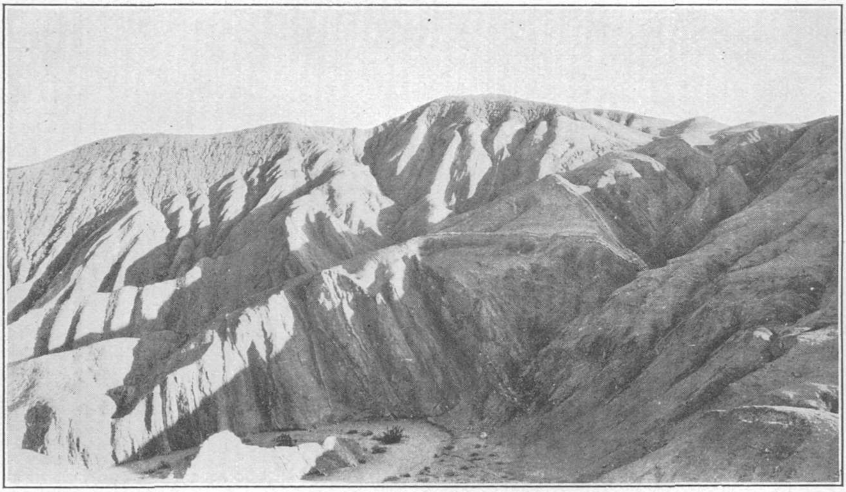
A trench was dug from the foothills next to the river channel southwestward across the strike of the beds and the trend of the ridges. (See Pl. VII, *B*, p. 39.) After it had been extended for several hundred feet the continuous trench was abandoned in favor of a line of pits, the first placed at regular intervals of 20 feet, and the later ones at longer, unequal intervals, which was continued to the summit of the range. (See Pl. XVI.) The trench and the pits were made sufficiently deep at all points to insure the complete penetration of the caliche and a thorough exposure of the bedrock. They reveal a nearly continuous layer of caliche of the hard salty type that is commonest in the Saratoga field. A few pits also were sunk in the valley



LINE OF PITS B AND END OF TRENCH A, CONFIDENCE FIELD.



A.



B.

SOUTHEAST SIDE OF THROUGH CANYON.

alluvium at the foot of the hills, and in them also caliche was found. (See Pl. XV.)

Each of the samples taken along the trench represented, as a rule, a length of 15 feet, though a few represented as much as 20 feet or as little as 10 feet. A single sample was taken from each of the pits. The samples that were quartered down and preserved for analysis represented caliche alone; a few field tests were made on soil and bedrock, but, as these tests gave negative or nearly negative results, no quantitative analyses of material other than caliche were considered necessary.

The results of this prospecting operation were not at any stage encouraging. The thickness of the caliche varied through the range that is common to the region as a whole and averaged about 5¾ inches. So few of the reactions obtained in the field tests were strong that it is reasonably certain that the nitrate content would average much less than 5 per cent; the analyses of 23 of the better samples gave an average of only 1.34 per cent of sodium nitrate.

In the meanwhile news had come from the Saratoga Hills of the discovery of particularly rich caliche, of a novel type, on the rather steep sides of the so-called Amphitheater Canyon. Some further prospecting in the northwestern part of the Confidence field, where slopes of similar character are common, had already been planned, but it was undertaken the more hopefully because of this discovery. Three localities were chosen for prospecting; their approximate situation is indicated on the map (Pl. XII, p. 52) by the letters L, M, and N.

At locality L three trenches were cut on the side of a small butte of red clay, six pits were dug on a sloping terrace, and two niches were made in clay slopes on the side of a gravel-capped mesa. The results obtained in this group of prospects were very meager. The caliche, which, where found, was of the hard salty type, was, however, generally thin and commonly absent, and field tests indicated that it was poor in nitrate. Five samples from this group of prospects were taken for analysis, and these were found to contain only from 0.22 to 0.55 per cent of sodium nitrate.

Locality M is marked by an isolated red-clay butte that is larger than the one at locality L. The butte is surrounded by gravel wash, which is partly encircled by steep to moderate slopes carved from reddish clay. A trench (M 1, M 2) was cut along the north side of the butte, and another (M 3) on a moderate slope across the wash to the north. Three niches were also cut at the bases of neighboring precipitous slopes. The four samples from this group of prospects that were assayed contain, on the average, 1.46 per cent of sodium nitrate, and are thus a little richer than those from the trench and pits near camp, but the caliche at locality L is thinner and less continuous than that in the eastern part of the range.

The northwesternmost locality, designated N, is at Through Canyon. At this locality also are shown the best exposures of some layers of impure manganese oxide, which are interbedded with steeply tilted clays. The manganese oxide was sampled in several places but is probably not commercially valuable. The nitrate prospects here are interesting because they reveal two or three different sorts of caliche.

A trench (N 8 and 9; see Pl. XVII, *A*) extending for about 40 feet across the strike of some red beds was the only prospect in the Confidence Hills that showed caliche of the Amphitheater type. The amount of this sort of caliche here present was very small, but a thin caliche of the hard salty type extended along most of the trench. Two samples were taken from this trench; that from the portion which revealed the Amphitheater type of caliche contained 1.40 per cent of sodium nitrate, and that from the other portion only 0.45 per cent.

Another pit made in the same red stratum about 100 feet farther north showed no caliche of any sort. Two others made in the same stratum a short distance northwest of Through Canyon (these prospects were the most distant from camp that were made) penetrated a hard salty caliche of ordinary thickness, two samples of which contained 0.84 and 1.32 per cent of sodium nitrate.

An irregular line of pits was made along the crest of a spur immediately south of Through Canyon (N 7, 10, 11, 12, 13, 14, 17, 18, 20; see Pl. XVII, *B*). Most of these revealed common hard salty caliche in varying but usually small thickness. On some olive-green beds near the brow of the spur, however, the caliche is in places arched up into hollow domes, and a small piece of material from the roof of one of these domes gave a vigorous reaction for nitrate. The large samples of this "blister caliche," though it proved to be the richest from this group of prospects, contained only 1.99 per cent of sodium nitrate, and the other samples from the same spur averaged less than 1 per cent. The Through Canyon locality is therefore entirely unpromising.

It was still thought barely possible, from considerations which, not having been confirmed, need not be detailed here, that the caliche lying on the steep sides of the canyons might be especially rich. Two trenches (K 1 and K 2) were therefore made at different levels on the sides of the canyon that drains through camp. Trench K 1, the higher one, was 47 feet long. The caliche exposed by it is vesicular and uneven in thickness; its average thickness is estimated to be 6 inches. The Survey's analysis gives the nitrate content as only 0.77

per cent. Trench K 2 was 46 feet long; it exposed caliche of the same type as that in K 2 but somewhat thicker. The nitrate percentage, however, is still less, namely, 0.22 per cent.

Experience at the Through Canyon locality suggested the advisability of specially prospecting the caliche blisters (see Pl. XIV, *B*, p. 52) on the green-clay lens near camp (Green Hill lens). A large sample (48 pounds) was therefore collected by a miner, with pick and shovel, from eleven of these blisters, the intervening caliche being disregarded. Although no further sorting was done than that involved in the miner's choice of easily detached pieces, the sample proved to be the richest taken in the entire Amargosa region, the content of sodium nitrate being reported by the Geological Survey laboratory as 15.63 per cent.

Material so rich as this could undoubtedly be worked at a profit, if it covered a large acreage almost continuously. Unfortunately, this is not the case in the Confidence Hills. Very little of the blister caliche is found except on the Green Hill lens. The total area of this lens is less than 5 acres, and that of the blisters, which occur only on finest green clay, is certainly less than 1 acre and probably less than half an acre. The amount of sodium nitrate derivable from the blister caliche in the Confidence Hills could hardly exceed 100 tons.

RESULTS OF TESTS IN DETAIL.

All the analyses of samples from the Confidence field with one exception were made by the United States Geological Survey.

Locality A, B, C.—Trench 800 feet long and 39 pits along a northeast-southwest line near camp. Total length of section explored, 2,750 feet. (For details see sections, Pl. XV, in pocket.) The samples all represent hard caliche, 5.76 inches in average thickness. Number of samples taken, 88; number analyzed, 23. Highest percentage of $NaNO_3$ in samples analyzed, 3.91; average, 1.34. (As the samples analyzed were selected from those giving the better field tests, the average percentage for all would be less than 1.34.)

Locality K.—Two trenches, each about 47 feet long, on steep sides of canyons near the camp site. One sample from each trench, K 1 and K 2, representing porous salty caliche 6 or 7 inches in average thickness. $NaNO_3$ in sample K 1, 0.77 per cent; in sample K 2, 0.21 per cent.

Locality G, H.—Hill carved from green clay, about half a mile west of camp Three trenches about 50 feet in total length showed only a thin layer of caliche. giving weak to fair field tests, no samples of which were saved. Only one sample (G, H 1), taken from 11 "blisters" of caliche. Its weight was 48 pounds, and it contained 15.63 per cent of $NaNO_3$.

Locality L.—Trenches aggregating about 60 feet in length on side of small red butte about 1½ miles northwest of camp, and eight pits in its vicinity. Samples all represent hard salty caliche, averaging not over 2 inches in thickness, with adhering bedrock. Bedrock reddish, more or less sandy clays.

No. of sample.	Source.	Nitrate as $NaNO_3$ (per cent).
L 1	Side-hill trench, 12 feet long	0.55
L 2	Side-hill trench, 40 feet long	.21
L 3	Pits on side of mesa north of butte	.25
L 6	Trench, south side of butte; thin, discontinuous caliche	.33
L 7	Second pit in row on bench southwest of butte. Most of these pits show no caliche	.22
	Average	.31

Locality M.—Near large red butte about 2 miles southwest of camp; trench about 35 feet long on northwest side of butte, another about 30 feet long across wash north of it, and several other pits in the vicinity. Caliche 2 feet in maximum thickness but averages less than 4 inches. Bedrock reddish, more or less sandy clays.

No. of sample.	Source and character of material.	Nitrate as $NaNO_3$ (per cent).
M 1	Thick caliche, northern part of trench on butte	1.30
M 2	Thin caliche, southern part of trench on butte	2.16
M 3	Upper 4 feet of trench north of butte (lower part shows little or no caliche)	1.37
M 4	Two niches near base of bluff, southwest of butte; caliche very thin	1.00
	Average	1.46

Locality N.—Near Through Canyon, about 3½ miles northwest of camp. Trench N 8 and 9, about 30 feet long, and nine pits, all except two, N 15 and 16, southeast of the canyon. Caliche of several varieties, averaging less than 5 inches thick. Samples N 1–6 represent manganese ore of very low grade.

No. of sample.	Source and character of material.	Nitrate as $NaNO_3$ (per cent).
N 7	Blister caliche, pit on spur southeast of canyon	1.99
N 8	Soft niter caliche with adherent bedrock, southern part of trench	1.40
N 9	Thin hard salty caliche, northern part of same trench as N 8	.45
N 10	Caliche, hard and salty, from floor of a "blister" on spur southeast of canyon	.62
N 11	Hard salty caliche, pit on spur southeast of canyon	.56
N 12	do	.49
N 13	Gypsiferous clay, seamed with salt, spur southeast of canyon	1.07
N 14	Blister caliche, pit on spur southeast of canyon	[a] 1.92
N 15	Hard salty caliche, pit northwest of canyon	.84
N 16	do	1.32
N 17	Highest pit on spur southeast of canyon; red shale seamed with salt	1.69
	Average	1.05

[a] Analysis by Smith, Emery & Co., Los Angeles. Check samples by Geological Survey gave 1.48.

SUMMARY.

The Confidence field 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.

Of three or four varieties of caliche found in this field, the most abundant is of the hard salty Saratoga type. Of the 42 specimens of such caliche analyzed, in part selected as giving good field tests, the richest contains less than 4 per cent of sodium nitrate, and the average content is less than 1.03 per cent.

A sample of the Amphitheater types of caliche, which was found only at one place, gave but 1.40 per cent of sodium nitrate; and all specimens of the barren caliche on the sides of gulches gave such weak tests that none were analyzed.

The richest sample taken in the Confidence Hills (15.63 per cent of sodium nitrate) was of the "blister" type. The only other sample of such caliche (a less typical one) contained but 1.99 per cent of nitrate. Caliche of this kind is rare and of extremely spotty distribution, and the largest quantity that could probably be gathered in the entire field, even by careful hand work, is less than 100 tons.

It is clear, therefore, that the most abundant sort of caliche in the Confidence field is too poor, and that the richest is too scarce, to be exploited commercially.

MIDDLE AMARGOSA REGION.

GENERAL FEATURES.

By G. R. Mansfield.

Much that has been said on preceding pages about the geography and geology of South Death Valley applies with equal force to the middle Amargosa region, which, as here described, includes the valley of Amargosa River between Shoshone and Sperry, stations on the Tonopah & Tidewater Railroad, with contributory territory. In this region are included the Zabriskie, Resting Springs, Tule Springs, Upper Canyon, and Lower Canyon nitrate fields. The usual topographic features are the naked or partly waste-covered rocky mountain ridges and the broad alluviated valleys, with generally north-south trend, bordered by stony alluvial fans that stretch far up into the ridges and are cut by dry washes with steep or vertical sides.

The main tributary valleys are (1) the broad amphitheater which heads against the Ibex and Calico hills and drains eastward into Amargosa River about 1½ miles north of Tecopa, on the Tonopah & Tidewater Railroad; (2) Chicago Valley, which is parallel with Amargosa Valley on the east but is separated from it by a rocky ridge that tapers out about 5 miles northeast of Tecopa; and (3) an unnamed valley east of Chicago Valley, separated from it by the Nopah Range, which is crossed by Willow Creek, an affluent of Amargosa River, about 8 miles southeast of Tecopa. The old Tecopa smelter is at this point. Willow Creek drains the unnamed valley, and this valley is separated by a low divide from Pahrump Valley, which farther north lies east of the Nopah Range.

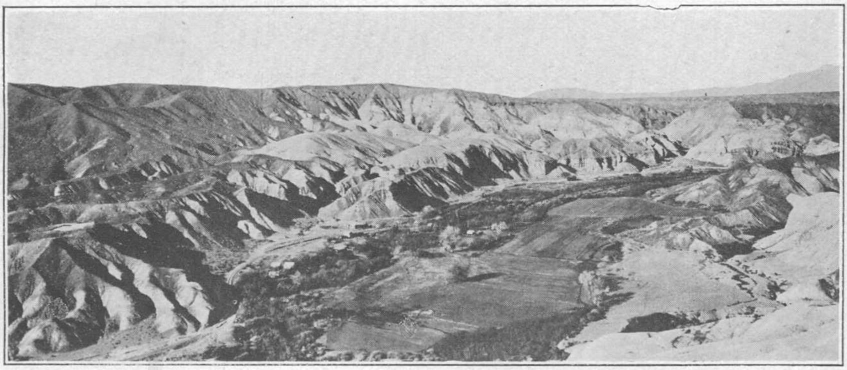
All the streams of the region are practically dry except Amargosa River, which maintains an intermittent flow of very saline water. The lower mile of Willow Creek is supplied by springs at the Morrison (China) ranch and has a fairly continuous flow of small volume but of fresh water. At Shoshone and at Tecopa warm springs, nearly fresh, supply water for railroad purposes and for settlements along the railroad. Water also emerges from mine tunnels along the railroad about a mile south of Tecopa. Aside from the springs along the railroad the more important springs of the region are (1) at the China ranch (Pl. XVIII, *A*), about 1 mile north of Acme station; (2) Tule Springs, about 3 miles northeast of the Tecopa smelter on the road from China ranch to Pahrump Valley, of small volume and largely overgrown; (3) Resting Springs, at the foot of Chicago Valley, about 5 miles northeast of Tecopa on one of the roads to Pahrump Valley, abundant flow of cool, fresh water; (4) Yeoman Spring, at the foot of the rocky ridge about 5 miles southeast of Shoshone and about an equal distance northeast of Zabriskie, from which it may be reached by road, strong flow of water, practically fresh but warm.

Like the mountains adjacent to South Death Valley the rocky ridges of the middle Amargosa region are composed of ancient bedded rocks with banded appearance, associated with igneous rocks, some of which are ancient and some probably Tertiary.

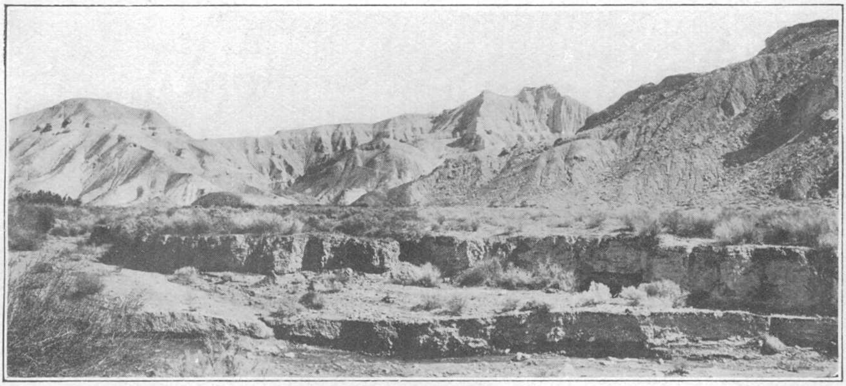
Between Tecopa and Shoshone Amargosa Valley is relatively broad and is occupied by light-colored clays, practically horizontal, that have been considerably dissected, forming in the districts more or less removed from Amargosa River the butte and mesa topography more fully described below, but nearer the river reduced to broad flats and lower rounded hills. The old shore line of the lake in which the clays were deposited is still fairly distinct along the mountain sides. The less dissected surfaces of the clays are strewn with dark bouldery gravel.

South of Tecopa the valley is constricted by rock ledges and by great stony alluvial fans through which Amargosa River has cut a steep-sided gorge, now somewhat widened. The gravel composing the fans stands in nearly vertical cliffs having but little accumulation of waste at their bases. The structure of the gravel, which here and there includes beds of light-colored volcanic débris, is clearly disclosed, as shown in Plate XVIII, *C*. About 2 miles north of Acme the valley widens.

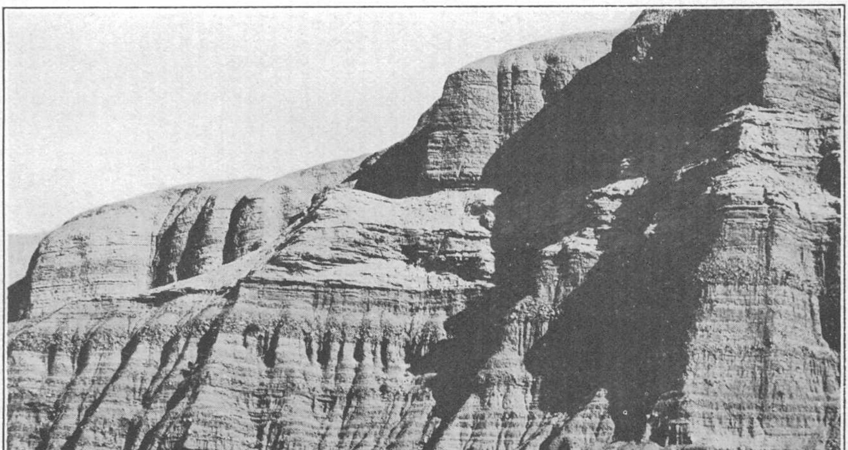
The south sides of the great fans are irregularly cut away, exposing the tilted light-colored clays, which form the "niter hills" of the Upper Canyon field. Both the nitrate-bearing clays and the gravels are extensively and intricately dissected. The contrast in appearance between the black stony gravels and the almost dazzling light-colored clays is very striking. Plate XIX, *B*, gives a general view of the Upper Canyon field from a high clay hill on its west side. Plate XIX, *A*, gives a view of the Upper Canyon field from a high



A. CHINA RANCH FROM THE SOUTH.



B. GRAVEL ESCARPMENT AND "NITER HILLS" ALONG WILLOW CREEK ABOVE CHINA RANCH.

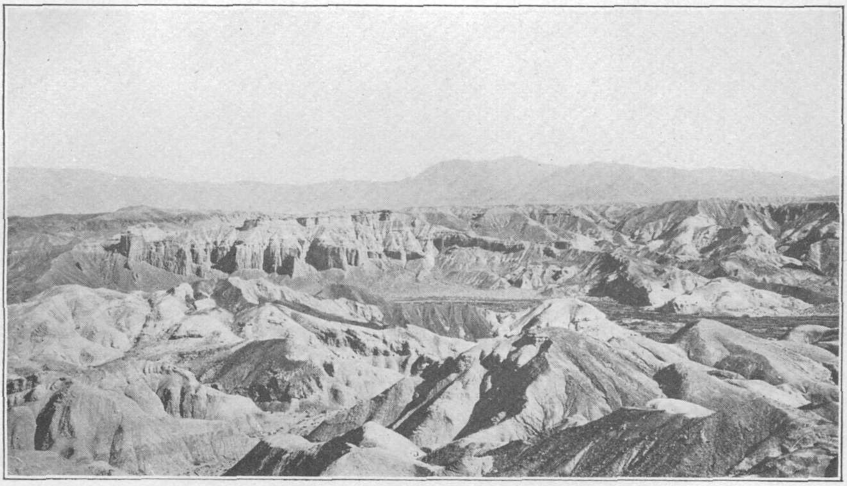


C. GRAVEL CLIFFS ALONG AMARGOSA RIVER ABOUT 2 MILES ABOVE ACME STATION.

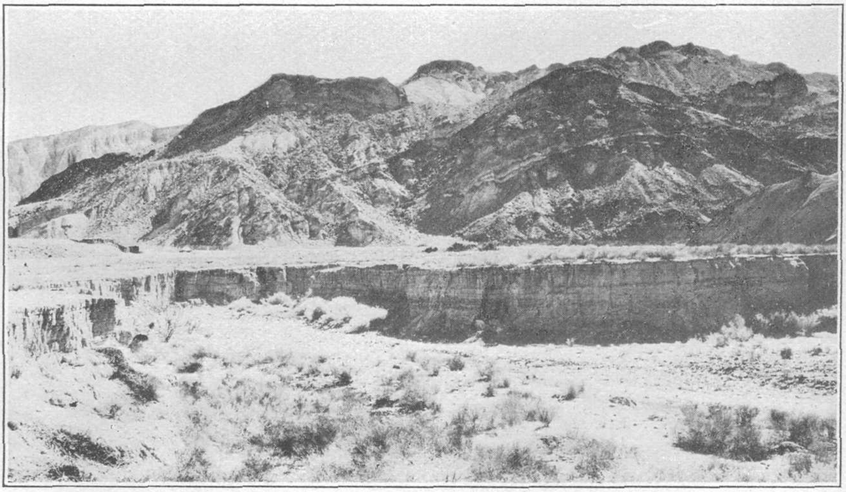
A. UPPER CANYON NITRATE FIELD.

×, Bully Hill

B. UPPER CANYON FIELD FROM HIGH CLAY HILL ABOUT S. 80° W. FROM BULLY HILL.



A. VIEW EASTWARD ACROSS NORTHERN PART OF UPPER CANYON FIELD FROM HIGH CLAY HILL WEST OF AMARGOSA RIVER.



B. RAINBOW MOUNTAIN, ACME.

gravel-covered hill at the north. It shows the Bully Hill district, part of the eastern district, and the canyon of Amargosa River below Acme.

The road from Tecopa to the China ranch and Acme is so steep where it passes from the upper surface of the fan into one of the tributary canyons that it is almost impassable for automobiles going north. A view of the gravel escarpment and of some of the neighboring nitrate-bearing hills is shown in Plate XVIII, *B*.

Below Acme the river enters a gorge in the older rocks, which, on the east side, are so arched and colored as to receive the local name Rainbow Mountain. (See Pl. XX, *B*.) The south boundary of the nitrate-bearing clays is, at least locally, a fault. This is well exposed west of the river.

The road that formerly passed through the canyon below Acme has been washed out and, though temporarily repaired and used by the Survey party, is treacherous and impassable for automobiles. It has been practically abandoned.

The river emerges from its canyon a mile or more above Sperry, east of which is the Lower Canyon nitrate field. The general features of this field are so similar to those of the Upper Canyon field that no further description of them here is necessary.

ZABRISKIE FIELD.

By G. R. Mansfield and F. C. Calkins.

GENERAL FEATURES.

The Zabriskie field is distinctly different in geologic and topographic character from the Saratoga Hills and Confidence fields. It lies in a broad, flat-bottomed basin, surrounded by mountains of the older rocks and underlain by lake beds that are younger than those in the other fields and have not been displaced from their original approximately horizontal attitude. The beds have been less deeply eroded than the older beds that occur in the Upper and Lower Canyon fields, lower down Amargosa River, and the chief topographic forms resulting from their erosion are not rounded hills but mesas and buttes. (See Pl. XXI, *A*.)

In the area that is occupied by such forms, with intervening washes, only a small proportion of the surface consists of the moderate slopes underlain by clay and covered with fine soil, which experience has shown to favor the accumulation of caliche. The flat tables are strewn with gravel or with fragments of the harder strata, and on the steep slopes the bedrock is largely exposed. In the lowest part of the basin erosion has worn the mesas down to low and softly rounded hummocks. Caverns are numerous in the mesas (see Pl. XXII), and guano deposits, seen in the accessible caverns, give evidence that they are inhabited by bats.

The bedrock strata of the Zabriskie field consist of clay, marl, and sandstone. The clay beds range in color from olive-green to chocolate and terra cotta. The clay is remarkably fine and smooth in texture, and when mixed with water it settles much more slowly than the saline clays that are common in the other fields and is very difficult to filter. The soil does not have quite the same appearance as that on the older clays; instead of being soft and earthy it is a rather incoherent aggregate of hard angular pellets. The marl beds and sand beds either crop out at the surface or are covered with a powdery soil.

The caliche of the Zabriskie field is unusual in several respects. In the first place, nitrate-bearing caliche is remarkably scarce. The stratified clay nearly everywhere grades upward into the soil, no recognizable caliche intervening; the soil derived from sandstone or marl is distinct from the bedrock but usually rests immediately upon it. The caliche is in part compact, resembling the Saratoga type, but the saline layer is generally composed of loose crumbly clay, with which crystals of various salts are mingled and to which the term "caliche" hardly seems applicable. The salts in it include a larger proportion of alkaline carbonates than is found in the caliche of other fields. The beds are on the whole apparently much less saline than the Tertiary deposits in which the other nitrates occur, but at some localities there are noteworthy amounts of sodium sulphate in either powdery or crystalline form.

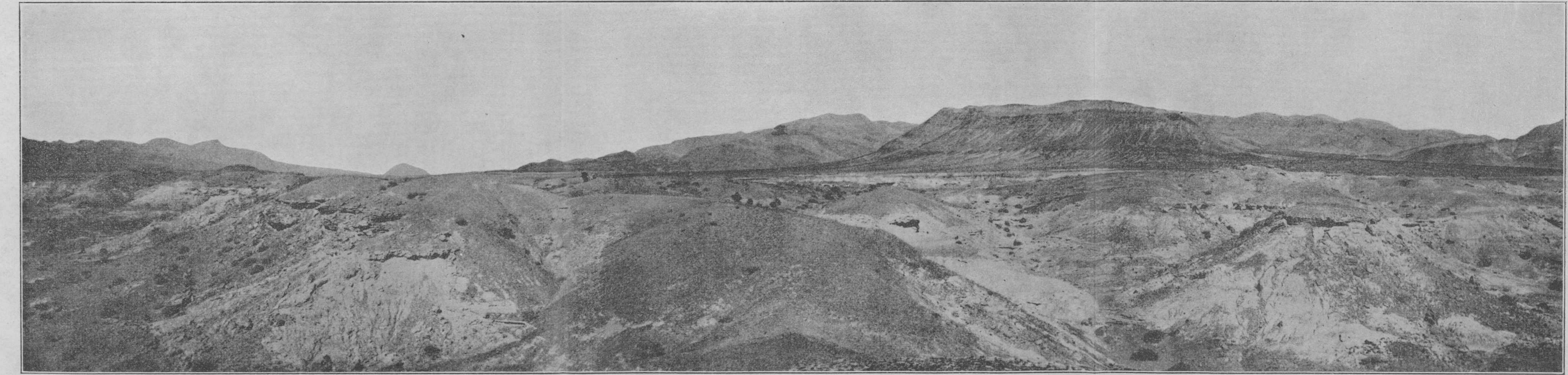
SUBDIVISIONS.

Detailed examination was made of three separate parts of the Zabriskie field in which the lake beds are especially well exposed and which were regarded as especially promising. These three areas may be designated the southern, middle, and northern. The southern area is south of Zabriskie; it comprises part of the Merrill-Black-Young claims and some ground east of them. The middle area consists of a part of the Pacific Exploration Co.'s claims, lying in general eastward from Zabriskie. The northern area is another part of the same group of claims, lying east of Shoshone. (See Pl. XXIII.)

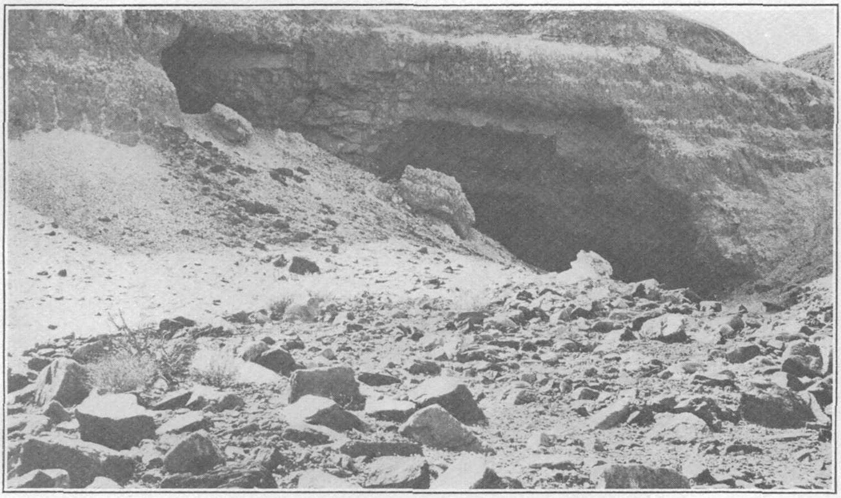
PROSPECTING AND ITS RESULTS.

The examination of the southern part of the Zabriskie field required about a week's work by three geologists and two miners. Although this amount of work was much less than that devoted to the Saratoga, the Confidence, or the Upper Canyon field, it was sufficient to satisfy the examining geologists that the Zabriskie

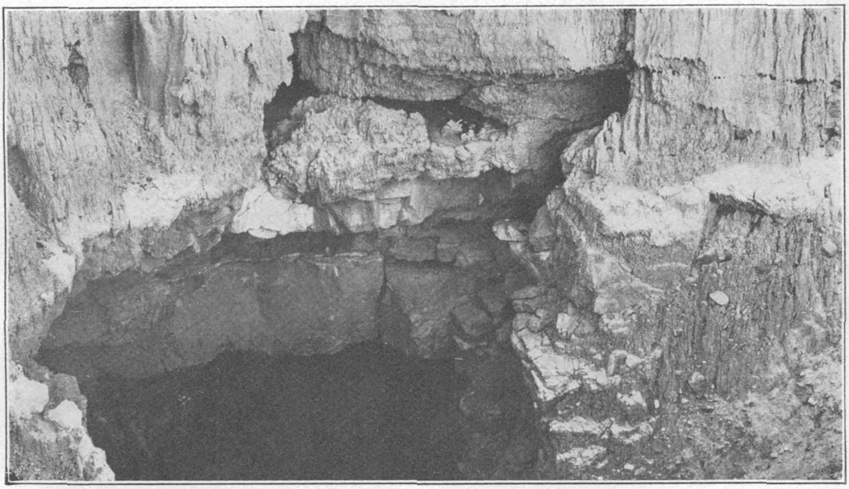
A. BUTTE AND MESA TOPOGRAPHY IN LAKE-BED CLAYS SOUTHWEST OF ZABRISKIE, IN THE SE. ¼ SEC. 1, T. 20 N., R. 6 E. (UNSURVEYED).



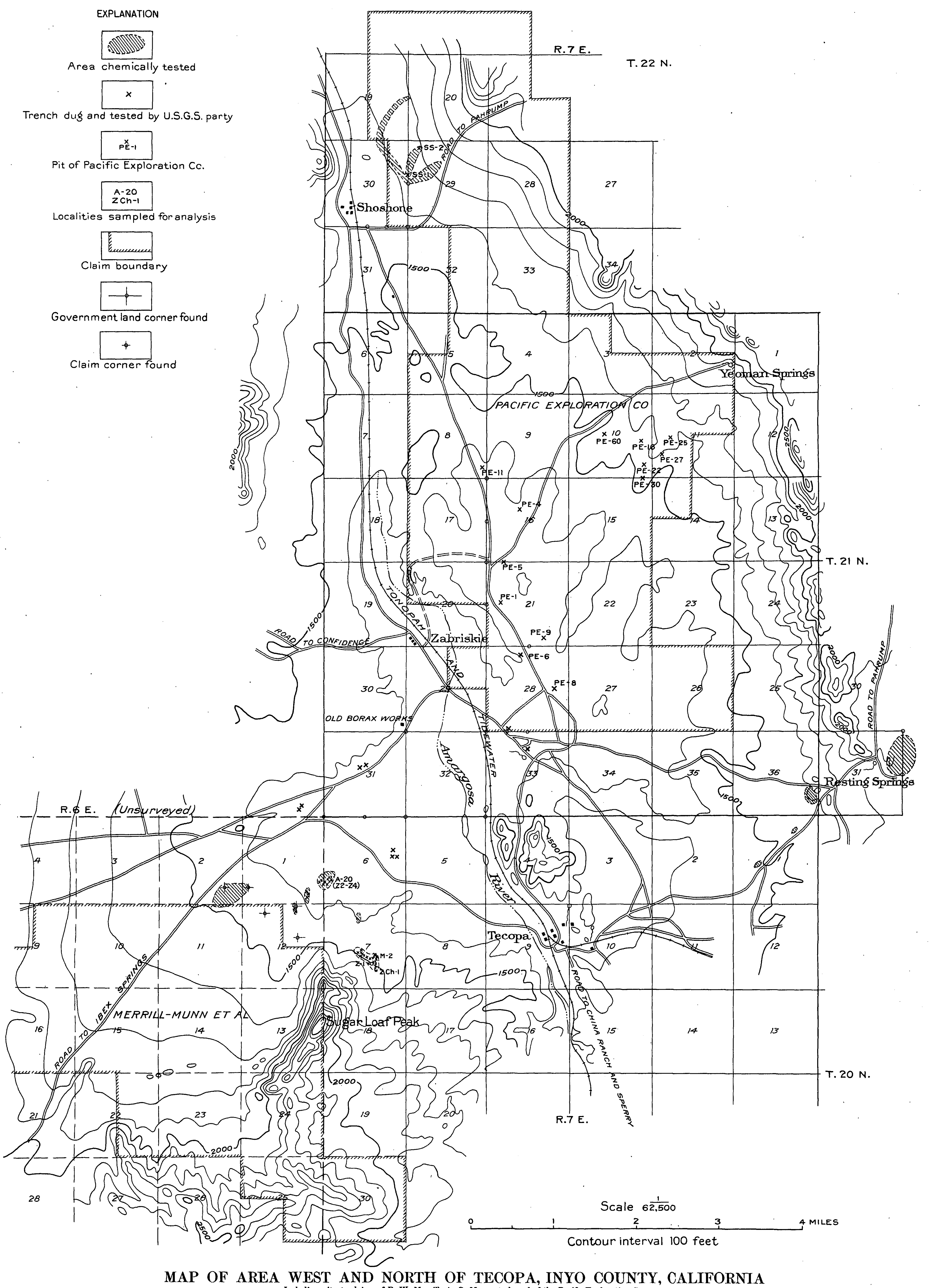
B. LAKE BEDS NORTHEAST OF SHOSHONE, IN T. 20 N., R. 7 E.



A. ADJOINING CAVERNS IN GREENISH-GRAY CLAY, SEC. 7, T. 20 N., R. 7 E.



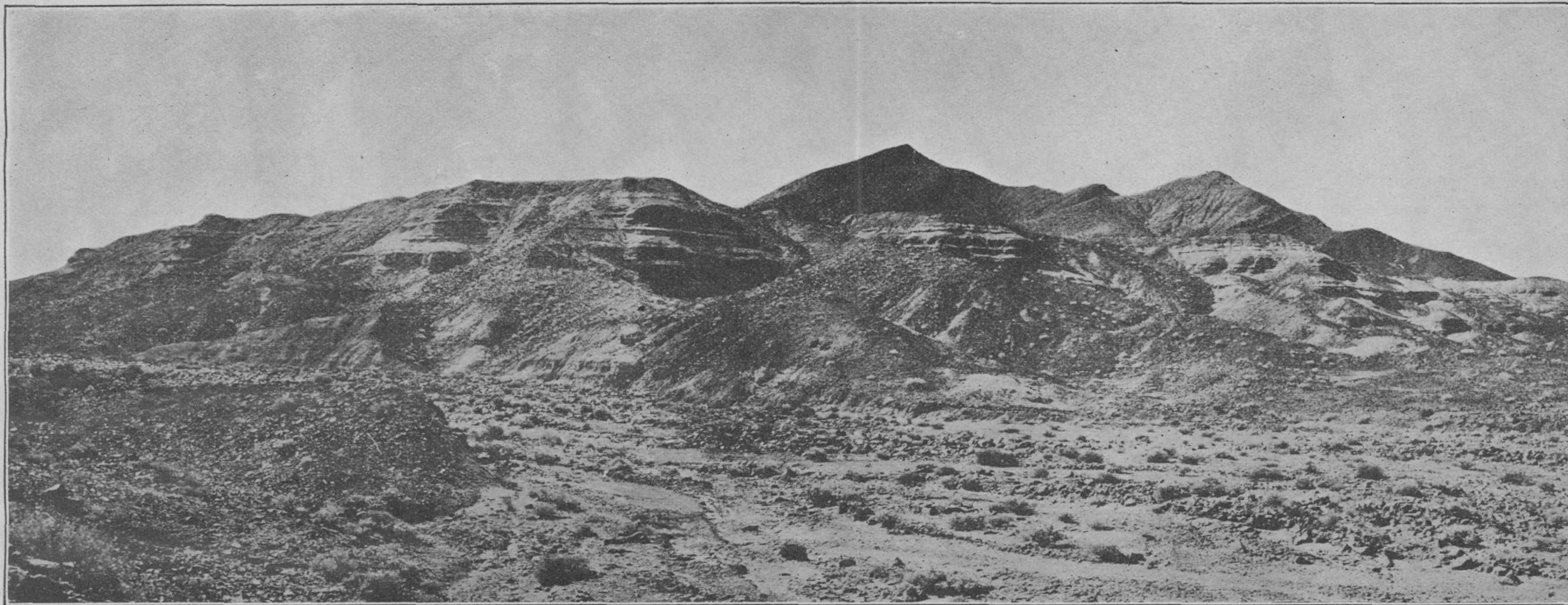
B. CAVERN IN GREENISH-GRAY CLAY, SHOWING SMALL GUANO DEPOSIT.



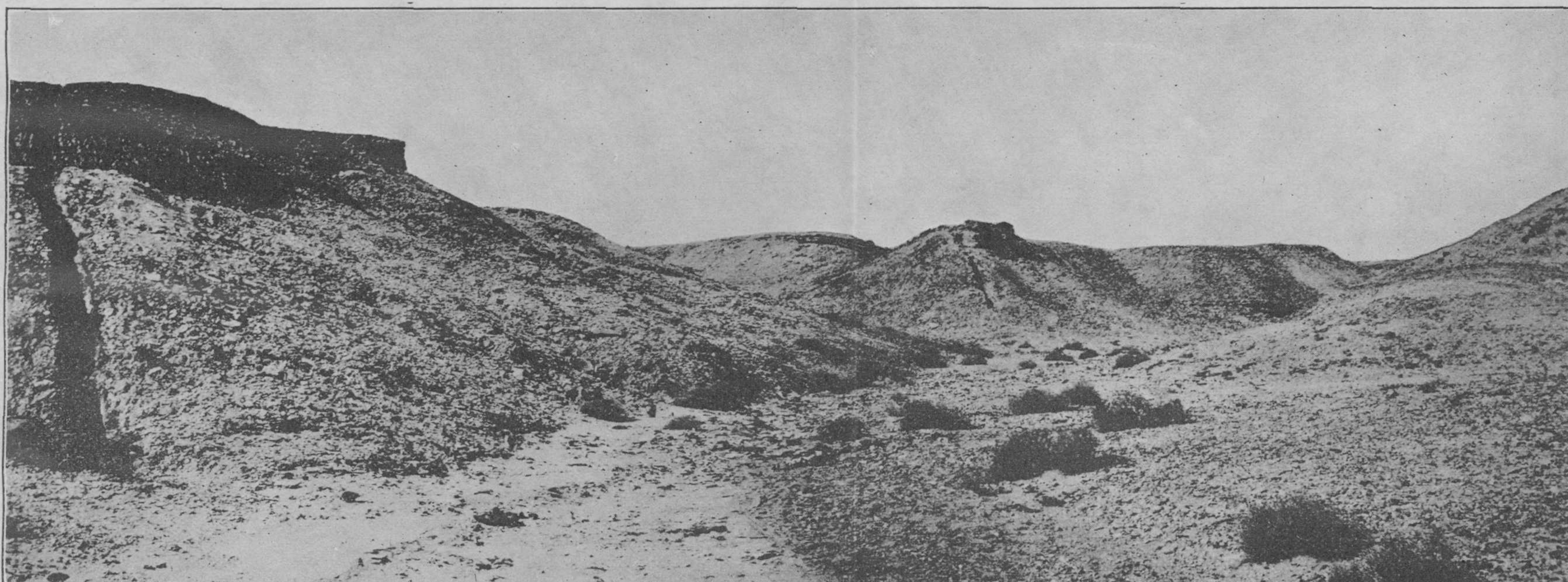
MAP OF AREA WEST AND NORTH OF TECOPA, INYO COUNTY, CALIFORNIA

Including nitrate claims of R. W. Merrill, A. G. Munn et al, and of the Pacific Exploration Co.

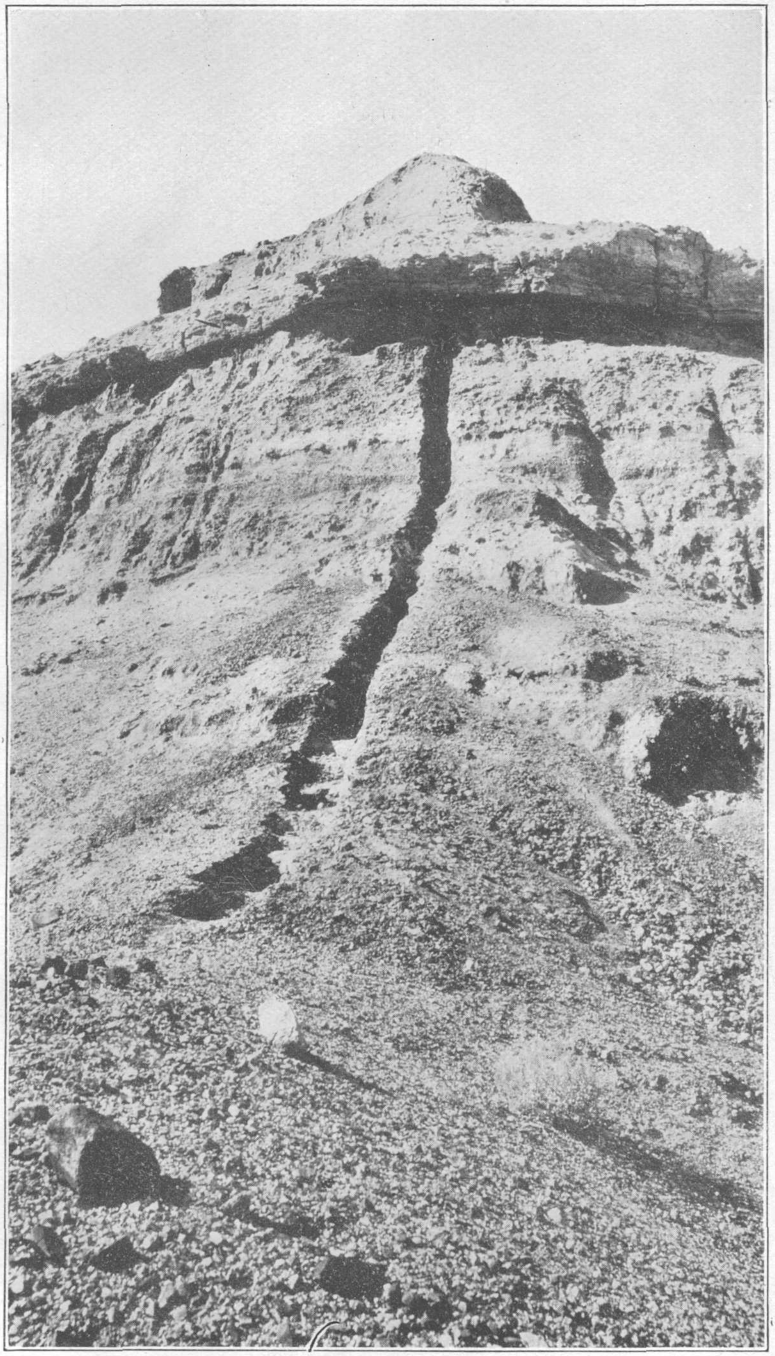
ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY



A. HILLS OF GREENISH CLAY BORDERING ANCIENT INCLINED STRATA IN SEC. 7, T. 20 N., R. 7 E.

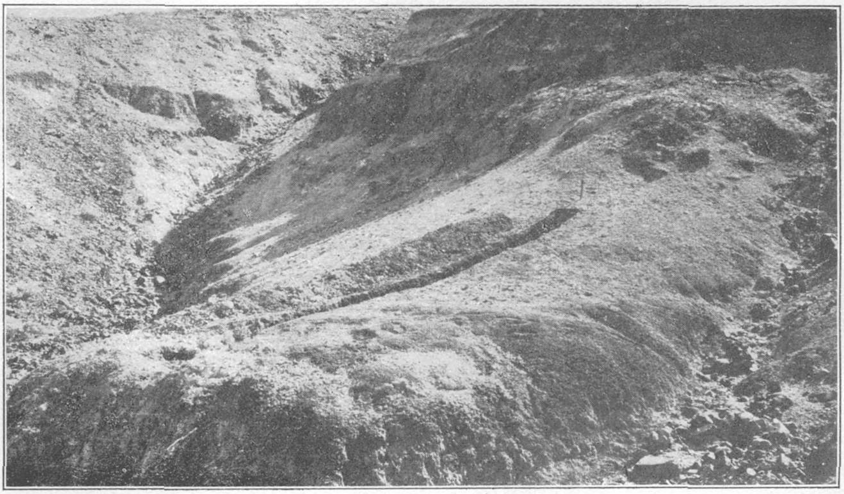


B. WHITISH HILLS IN THE SW. ¼ SEC. 7, T. 20 N., R. 7 E.



SURVEY TRENCH Z CH-1, IN THE SE. ¼ SEC. 7, T. 20 N. R. 7 E.

A. LOWER SLOPE OF GREENISH HILLS IN SEC. 7, T. 20 N., R. 7 E.



B. TRENCH NORTH OF LOCALITY Z-1, IN THE NW. ¼ SW. ¼ SEC. 7, T. 20 N., R. 7 E.

field contains no workable nitrate. To the northern area, east of Shoshone, the labor of three geologists for half a day was given with results so nearly negative that no further examination was thought necessary. The middle area was examined for about two days by a geologist, who collected many samples which were analyzed for nitrate but none of which contained more than a small percentage.

SOUTHERN AREA.

Especially close attention was given to a group of claims southwest of Zabriskie, because of the favorable report upon them that had been made by a local engineer, and two localities that had been pointed out by this engineer as places where promising material had been found were examined in great detail.

The first locality was on some greenish bluffs of horizontally bedded lacustrine clays at the base of a high, rocky hill that lies almost directly on the line between Rs. 6 and 7. (See Pl. XXIV, *A*.) According to the engineer it was here that a rich sample of niter had been taken; the exact spot was not located by him, but the general locality was clearly identified, and all the principal exposures in the vicinity were minutely examined. By means of trenches and pits, 24 of the largest of which are shown on the map (Pl. XXIII; see also Pls. XXV, XXVI), every stratum was exposed on each of several spurs. It soon became evident that caliche was virtually absent. The geologists, however, tested foot by foot the material near the contact of bedrock and soil and probably made in all between 150 and 200 tests. The result of nearly all these tests was wholly negative; a few showed a faint reaction; and about three were fair or strong.

The second locality indicated by the engineer as promising is a group of whitish hills a little less than 1 mile due south of the northeast corner of T. 20 N., R. 6 E. It was here that he claimed to have collected his best samples. Twelve trenches and some small pits were dug in this general vicinity, exposing all the beds throughout a considerable thickness of strata that lie somewhat lower in the series than those of the first locality and that consist in part of clay beds, but in larger part of a whitish rock having fine sandy texture. In one of the first of these excavations (trench A–20; see Pl. XXIV, *B*) the results were more encouraging than those previously obtained, showing several fair and a few strong reactions. The richest material was a crumbly, visibly saline caliche, lying on a 4-foot bed of chocolate-colored clay; other beds of clay and the white sandy beds gave weaker tests. In other excavations that exposed the same beds as trench A–20 the results were less favorable, and in still others, which exposed higher beds, only negative or feeble reactions were obtained.

Some further trenching was done on the softly rounded knolls nearer the river, but although more of the saline material was found here than on the cliffs, the reactions obtained were all weaker than the best obtained in trench A–20.

Inasmuch as the field tests had virtually proved that most of the prospects would yield no material containing more than a small fraction of 1 per cent of nitrate, it would have been a waste of time to take many specimens for quantitative analysis. For the sake of completing the record, however, samples were taken of the most promising material from the two general localities described. Sample Z–1 is from the only place at the first locality where several tests called "fair" or "strong" were obtained close together; the other samples are all from trench A–20 at the second locality. The best sample contains less than 1 per cent of sodium nitrate. (See p. 66.)

MIDDLE AREA.

The part of the Pacific Exploration Co.'s ground which lies east of Zabriskie contains a large number of openings made by the company in a search for other minerals than sodium nitrate. Through the courtesy of the company many of the openings were examined by a Survey geologist, and although the examination was not made primarily in search of nitrate a number of samples from these openings were assayed for nitrate in the Survey laboratory. The localities from which the samples analyzed were taken are shown on the map (Pl. XXIII) and a table of the results that pertain to the nitrate investigation is given on page 65.

The middle area is underlain by horizontal lake beds like those that underlie the southern area, but its surface is smoother and lower. Soil, usually including a layer of sulphates in its lower part, covers most of the area, but caliche containing nitrate, such as occurs in the Saratoga Hills or Bully Hill districts, was not found at any place.

This general absence of nitrate in the caliche makes the area valueless as a source of nitrate, for here, as in the other districts, the proportion of nitrate in the soil and bedrock is insignificant. Although none of the samples analyzed are wholly free from nitrate, most of them contain only a trace, and the richest contains less than 0.4 per cent. Soluble salts are abundant, as is suggested by the efflorescence on the faces of some of the pits and confirmed by the chemical determinations, but these salts appear to be chiefly the sulphate and chloride of sodium.

Analyses of samples from claims of Pacific Exploration Co. in middle area of Zabriskie field.

[Made in laboratory of U. S. Geological Survey.]

Sample No.	Material.	Depth below surface (inches).	Soluble salts at 180° C. (per cent).	Nitrate as $NaNO_3$ (per cent).	Remarks.
PE-1....	Clay, greenish, horizontal.....	18 -42	....	Trace.	24 inches of clay.
PE-1a....	Efflorescent salts............	0 -42	....	Trace.	White salts on face of cut.
PE-4.....	Clay with small masses of sulphates.	0 -60	....	Trace.	5 feet of clay.
PE-5(2)..	Efflorescent salts............	0 -35	....	Trace.	White salts in patches on gravel in cut.
PE-6(2)..	.....do......................	0 -30	3.56	Trace.	White salts on gravel face of cut.
PE-8.....	Clay below soil and sulphate layer.	13 -79	6.86	0.23	5 feet 6 inches of clay.
PE-9(1)..	Clay, brown, powdery, with white crystalline material.	0 - 3½	....	Trace.	Soil and sulphate layer, 3½ inches.
PE-9(2)..	Clay, greenish, with small masses of white salts.	3½-21½	41.74	.07	18 inches of powdery clay.
PE-9(3)..	Clay, greenish, without visible salts.	21½-62½	10.26	.14	41 inches of clay, upper 15 inches powdery.
PE-11....	Clay, fractured..............	0 -72	....	.08	6 feet of clay, lower 3 feet with masses of clear crystalline sodium sulphate.
PE-16....	Clay, light green to whitish...	8 -80	....	Trace.	6 feet of clay.
PE-22....	Clay, drab to greenish gray...	8 -80	....	Trace.	6 feet of clay about 18 inches stratigraphically below that of PE-16.
PE-25....	Clay, greenish gray, massive..	6 -78	....	.12	6 feet of clay; trench in several benches exposes about 14 feet of tuffs and sands above the clay.
PE-27....	Clay, reddish drab, with few sandy layers.	0 -10	1.24	.37	10 feet of clay; lower slope on side of wash; gypsum crystals and some saline incrustations in joint cracks near top.
PE-30....	Saline incrustations in cracks in greenish-gray clay.	0 -18	....	Trace.	Probably mostly sodium chloride.
PE-60....	Clay, drab and white, fractured.	8 -53	....	Trace.	45 inches of clay.

NORTHERN AREA.

The adverse conclusion reached with respect to the southern area established a presumption against the value of the northern area, which is underlain by the same beds and has the same topographic character. (See Pl. XXI, *B*, p. 62.) It was therefore planned to make a brief reconnaissance of this area and to carry the investigation no further unless some decided encouragement to do so was obtained.

Three geologists accordingly made traverses extending northwestward, northward, and northeastward from the quarter-section corner on the line between secs. 29 and 30. Each man dug with his geologic pick a number of pits to bedrock and tested on the spot, with field chemical outfit, chips from the caliche where it was present and from the top of the bedrock. Caliche with nitrate was found to be almost as scarce as in the middle area. In all 50 tests were made in places judged most favorable, along a total distance of about 2 miles. The reactions obtained were classified as follows: Negative, 35; weak, 8; fair, 2; strong, 5. The strong reactions were all obtained from a caliche 5 inches or less in thickness, lying on rather coarse sandstone near the top of the series. This condition was found at three rather widely separated localities and might be interpreted as evidence that one of the highest strata of sandstone is impregnated throughout with nitrate, but in view of the fact that the bedrock at the same localities gave only weak tests and of the evidence obtained from the region as a whole, it is considered rather that the character of this sandstone was in some way favorable to the formation of caliche.

Two samples (Ss1 and Ss2) of material that gave strong field tests were saved and analyzed. They were found to contain, respectively, 5.48 and 11.65 per cent of sodium nitrate. These samples thus proved to be relatively rich for the Amargosa region, but the greatest area that they can represent is a very small fraction of that part of the Shoshone area which was reconnoitered, and a far smaller part still of the whole Zabriskie field. The average nitrate content for all the 50 samples tested near Shoshone could not be more than 1 per cent. It was therefore the unanimous opinion of the examining geologists that no further examination of this area was justified.

RESULTS OF TESTS.

Results of analyses of samples from Zabriskie field.

Southern area.

No. of sample.	Material.	Depth below surface (inches).	Nitrate $NaNO_3$ (per cent).
Z-1	Material along contact of soil and bedrock in 14-foot trench	4–6	0.30
Z-2	Crumbly chocolate-colored clay mixed with salts at base of soil, trench A-20. Represents entire thickness of bed, about 3½ feet.	6–8	.74
Z-3	Like Z-2 but still more saline; from lower part of same bed, trench A-20. Best-looking material found in southern area.	6–8	.12
Z-4	Material along contact of soil and bedrock, representing entire length of trench A-20, 68 feet.	2–12	.56
M-20	Caliche 3 inches thick on clay	6–9	.51

Northern area.

No. of sample.	Material.	Depth below surface (inches).	Nitrate $NaNO_3$ (per cent).
Ss1	Caliche consisting of coarse sandstone impregnated with salts	10–16	5.48
Ss2	do	10–14	11.64

Analyses of samples from the middle area are given on page 65.

GENERAL CONCLUSION.

The Zabriskie field is the least promising of all the large fields examined. It is occupied in greater proportion than the other fields by surfaces unfavorable to the formation of caliche, and even on the slopes that appear most favorable the caliche is generally thin or is altogether absent. The caliche sampled, except that taken at three localities in the Shoshone area, is poorer in nitrate than the average caliche of other fields, and the bedrock and soil are here, as elsewhere, virtually barren. There is no evidence that any of the strata below the caliche contain considerable quantities of nitrate, and although a larger proportion of the lower strata is probably concealed in this field than in the others, the considerations set forth on pages 20 and 69 make it improbable that there is any justification for deep drilling in this field.

UPPER CANYON FIELD.

By G. R. Mansfield.

GENERAL EXPLORATION.

The Upper Canyon field lies on both sides of the canyon of Amargosa River, in San Bernardino and Inyo counties. For purposes of exploration it was divided into four parts—the Bully Hill district and the southwestern, northwestern, and eastern areas. These will be described in the order named.

The investigation of the Upper Canyon field was begun January 15, 1918, by a geologist and one assistant. After two weeks of mapping and testing the party was augmented by the arrival of three geologists and a mining engineer, accompanied by a force of 10 other men, most of them experienced miners. Intensive prospecting then began and continued until April 3, 1918. The greatest share of attention was devoted to Bully Hill, but each of the other districts was mapped and sampled to a degree sufficient to give a fair idea of its character.

While the Survey's explorations were still in progress a field party of the General Land Office sectionized T. 20 N., R. 7 E., in which the Upper Canyon deposits are located. It was thus possible to tie the areas mapped to legally established landmarks.

BULLY HILL DISTRICT.

Reported character.—Bully Hill is cited in the Robbins report (see "Previous work," p. 12) as conspicuously the best ground in the Upper Canyon field. In an area of 34 acres which was sampled by numerous long trenches in 1912 the caliche was reported to average 10.5 per cent of sodium nitrate and the soil and caliche together 6.5 per cent, whereas other portions of the Upper Canyon and Lower Canyon fields, which were sampled by Robbins in the same way, did not show results even half as good. It was concluded by Robbins that the only hope of finding a commercial supply of nitrate in the region lay in finding other areas as good as Bully Hill.

Nature and duration of investigation.—It was decided to prospect the Bully Hill area first and very thoroughly, because it was clear that if the best results obtained by Robbins could not be confirmed, in view of the disappointing results already obtained in the Saratoga and Confidence fields, further exploration on a large scale was not justified.

The exploration of the Bully Hill district began on January 15 and continued with some interruptions until March 22, when the intensive sampling operations were completed. The last observations, delayed by bad weather, were made on March 31. While the Bully Hill work was in progress simultaneous investigations were

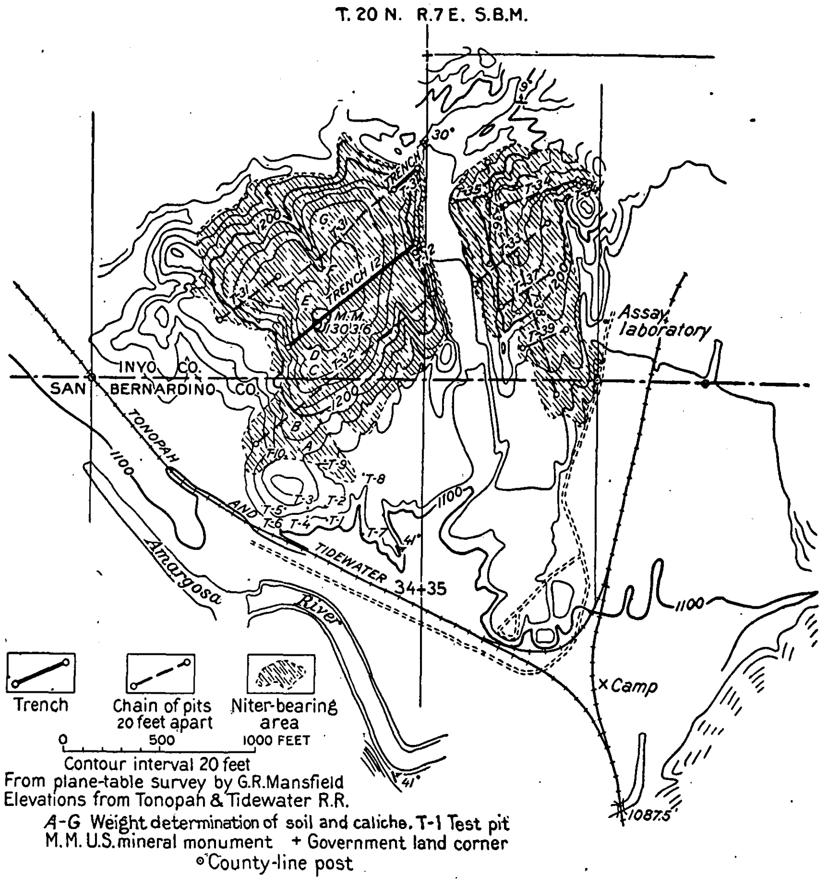
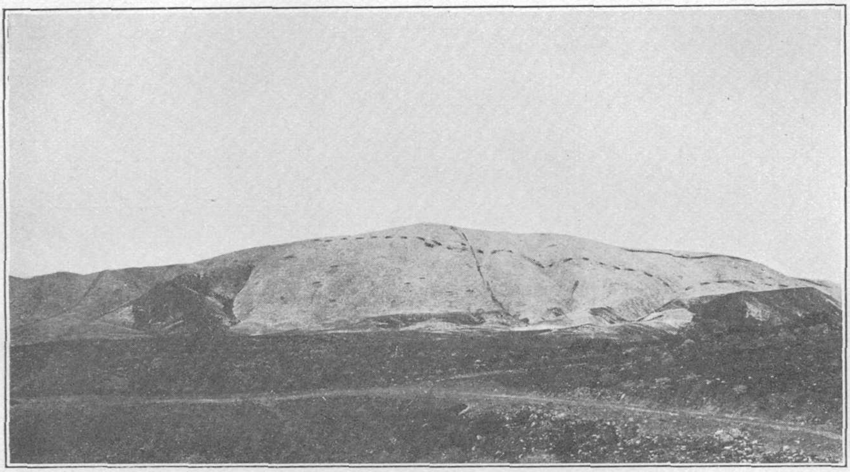


FIGURE 6.—Map of the Bully Hill district.

undertaken in the Zabriskie, Resting Springs, and Tule Springs districts and in other parts of the Upper Canyon field.

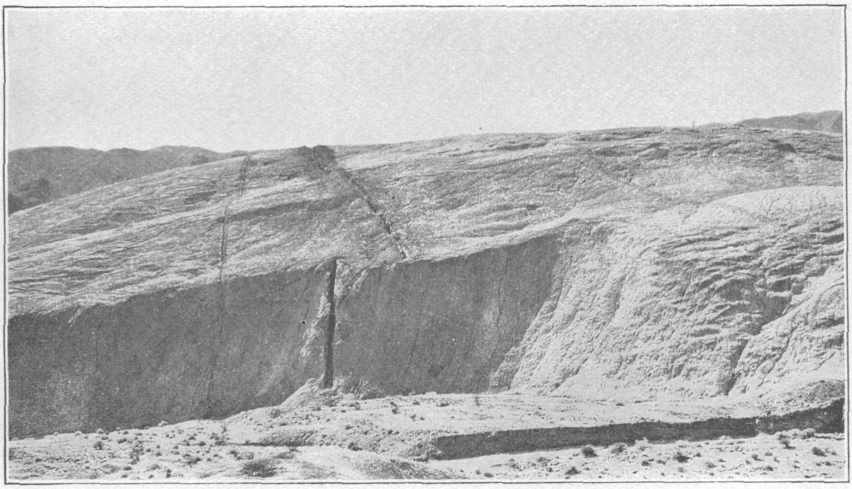
The preliminary work at Bully Hill was devoted to testing various parts of the district by means of the brown-ring reaction and to preparing a topographic map of the district on a scale of 500 feet to the inch. This map is reproduced on a smaller scale as figure 6.

Location and extent.—The Bully Hill district as here mapped comprises an area of about 160 acres in "niter beds" 1 and 2 of the



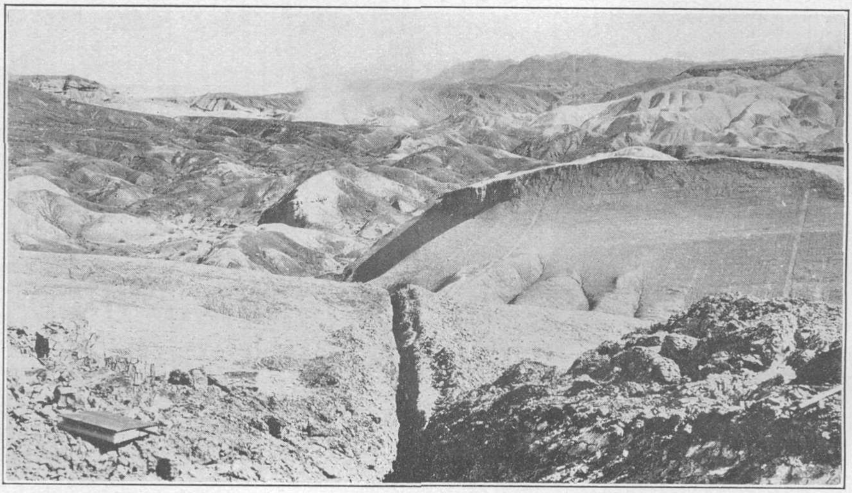
A. BULLY HILL FROM THE WEST.

Showing trench T-12 (center) and line of old pits.

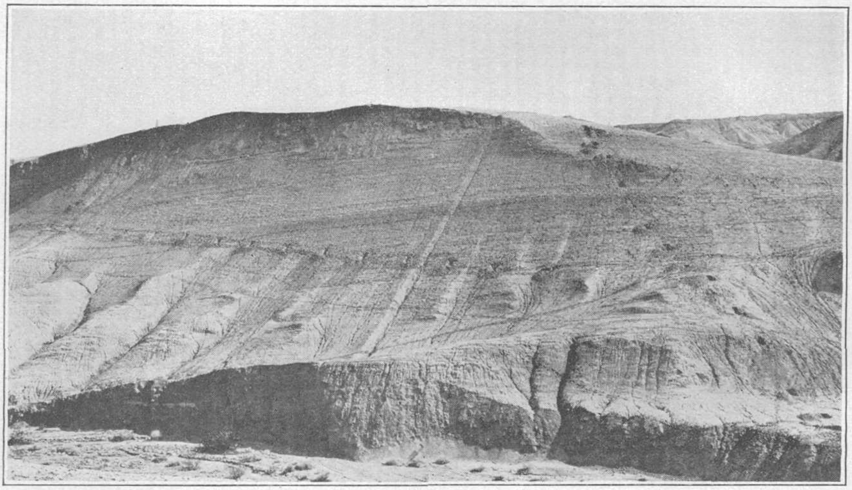


B. EAST SIDE OF BULLY HILL.

Showing end of trench T-12.



A. VIEW EASTWARD ALONG TRENCH T-12, BULLY HILL



B. INTERSECTING CHAINS OF PITS ACROSS HILL EAST OF BULLY HILL.

Pacific Nitrate Co.'s patented claims at Acme, a siding on the Tonopah & Tidewater Railroad 5 miles south of Tecopa. The hill itself is a quarter of a mile northwest of the siding and is traversed from west to east by the county line.

The nitrate deposits cover only about 45 acres, distributed in two areas as indicated on the map. The larger area, estimated at 31 acres, includes the summit and slopes of Bully Hill (Pl. XXVII); the smaller area, estimated at 14 acres, occupies the summit and slopes of a hill to the east (Pl. XXVIII), separated from Bully Hill by a deep wash. The remainder of the 160-acre tract consists of dry creek beds and gravel-covered slopes that are practically barren of nitrate.

Geologic features.—The two hills named are underlain by beds of cream-colored hard, brittle clay, which are rather massive. The beds strike N. 39° W. and dip 26°–35° NE. The portion of the tilted clays contained in the nitrate-bearing areas and exposed to view during the investigation thus represents a thickness of about 1,200 feet.

The upturned strata are covered by a sterile clay soil averaging 9 inches in thickness. The caliche lies beneath the soil, along its contact with the bedrock, and includes most of the sodium nitrate. It averages 5 inches in thickness.

A peculiar feature that is characteristic of all the nitrate fields of the Amargosa region and is well shown at Bully Hill is the development of funnel holes (Pl. XXIX, *A*) and underground drainage channels. The saline clay strata are locally perforated to unknown depths by these holes and are honeycombed by the channels.

Character of the deposits.—The caliche in this field, as in the Saratoga and Confidence fields, is essentially a blanket deposit, conforming in general with the shape of the hills on which it lies. It differs somewhat from that in the other two fields named. It contains much less common salt, is not nearly so hard, and in part at least has a peculiar flaky structure. (See Pl. XXIX, *B*.) Most of the nitrate occurs in films and crusts along the innumerable cracks between the flakes. The upper part of the caliche layer is exceedingly crumbly and falls to pieces at the touch; it grades upward into the loose soil. The lower part is rather compact and grades downward into bedrock. The nitrate-bearing films descend locally into the bedrock along favorable cracks to depths of several feet.

The character and composition of the surface materials are represented by the following section, taken from a vertical channel cut in the side of the big trench near the top of Bully Hill:

Section of surface materials on Bully Hill.

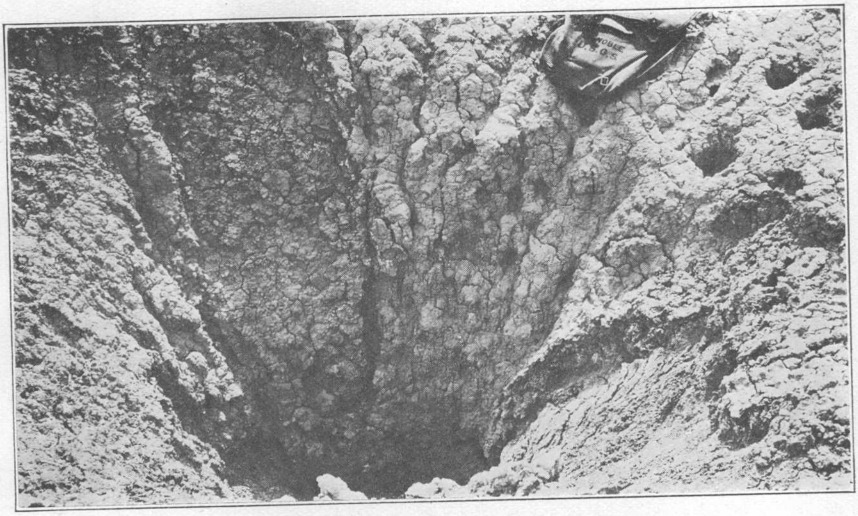
Sample No.	Character of material.	Depth from surface (inches).	Soluble salts (per cent).	Nitrate as sodium nitrate (per cent).
1027	Surface; dry, caked mud	1	2.35	Trace.
1028	Loose soil	1–3	6.96	2.60
1029	Loose flaky ground ("piecrust")	3–6	10.82	5.78
1030	Mostly compact caliche, including some loose flaky material	6–9	18.32	9.62
1031	Hard clay next below caliche layer	9–12	2.36	1.32
1032	Gray-brown clay shale; no evident salts	12–18	1.90	.62
1033	.....do	18–24	2.00	.40

This section illustrates very well the relation of the caliche layer to the overlying soil and the underlying stratified clays. The caliche is a concentration of water-soluble salts in a zone below the leached soil at the surface and above the less pervious "bedrock" clays. The soluble salts were undoubtedly deposited in this situation by the evaporation of ground moisture, which brought them in solution to the surface, and the salts have been protected from being dissolved or washed away in surface water by the peculiarly impervious character assumed by the surface clay when it becomes wet.

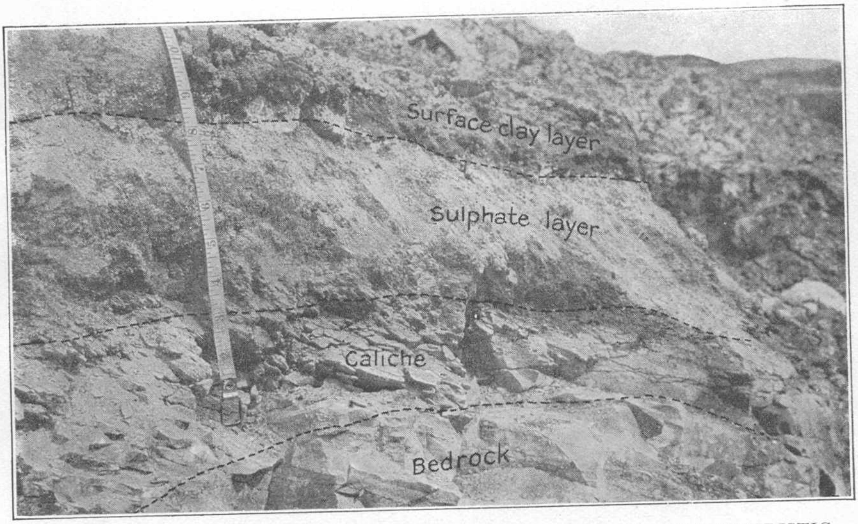
Near many of the sink holes the caliche is thoroughly leached of its nitrate content. These holes are indeed one of the chief causes of the spotty or patchy distribution of the nitrate deposit, which is a noteworthy feature of the caliche throughout the Amargosa region. Apparently a considerable amount of nitrate has been carried away by the underground drainage.

The soil here, as in the Saratoga field, is in two distinct layers—an upper layer of compact clay with a peculiar cauliflower-like surface (see Pl. XXIX, *A*) and a lower powdery white sulphate layer (see Pl. XXIX, *B*). When dry the soil is cracked and porous and well aerated. When moistened the upper clay soil expands rapidly, closing and sealing the cracks and thus protecting the lower soil and caliche from wetting by any except relatively severe and long-continued rains.

Method of sampling.—The 31-acre tract of niter-bearing ground that includes Bully Hill was prospected and sampled first. At the begininning of this work, as in other fields, the sampling was done in a long trench (T–12), which was dug deep enough to penetrate several feet into bedrock, in order to make sure that none of the bedrock strata contained valuable amounts of nitrate. This trench was run entirely across Bully Hill. Later, when the results obtained in the trench had proved that the nitrate is confined to the caliche, the sampling was carried on in two long lines of pits (T–31 and



A. FUNNEL HOLE IN NITRATE GROUND, BULLY HILL



B. NITRATE DEPOSITS IN THE BULLY HILL AREA, SHOWING CHARACTERISTIC ARRANGEMENT.

T–32), which needed to be dug only deep enough to penetrate through the caliche. Similarly intersecting lines of pits (T–33 to T–39) were dug in the 14-acre tract east of Bully Hill. The individual samples were weighed, ground, and divided in practically the same manner as outlined for the Saratoga Hills district. After the sampling was completed a third line of pits (A to G) was dug to determine by direct measurement the unit weights of the caliche and soil for computations of tonnage.

The location of the trench and the lines of pits is shown on the map (fig. 6, p. 68).

Trench and pits.—The trench across Bully Hill was 904 feet long and from 4 to 6 feet deep. It traversed the hill from southwest to northeast at right angles to the strike of the upturned bedrock strata (see Pls. XXVII, *B*; XXVIII, *A*; XXX), thus exposing every foot of every stratum in the bedrock beneath the hill. The trench was divided into 20-foot sections, and in each section the soil and caliche together, the caliche alone, and the bedrock were sampled in turn. The bedrock samples were taken in continuous strips 20 feet long along the bottom of the trench. The method of sampling the soil and caliche together and the caliche alone differed somewhat from that of sampling the bedrock. Each 20-foot section of the trench was laid off in 5-foot lengths. At the 0 and 10-foot marks vertical prisms of material about 4 inches square reaching from the base of the caliche to the top of the soil were taken out of the wall of the trench. All this material removed was mixed together, ground, and averaged down as one sample, which was considered to represent the 20-foot strip of soil and caliche together. Similarly vertical prisms of material were taken from the entire thickness of the caliche layer at the 5 and 15 foot marks, ground, and averaged as one sample, and this sample was considered to represent the caliche in the 20-foot strip. The thickness of soil and caliche was noted at each 5-foot mark, and from these data the soil and caliche were plotted on the profile of the trench (Pl. XXX), upon which details of structure in soil, caliche, and bedrock were also sketched.

To complete the sampling of the 31-acre tract two lines of pits were dug across the hill, one on each side of the trench, each line parallel to the trench and about 400 feet distant from it (fig. 6; Pl. XXXI). One line of pits (T–31) was 1,260 feet long; the other (T–32) was 1,180 feet. The pits were spaced 20 feet apart and were dug only deep enough to penetrate through the caliche layer. One sample of the caliche was taken in each pit. Except in a few pits samples of soil and caliche together were not taken, because the sampling in the trench had shown conclusively that the assertion in Robbins's report that the soil as well as the caliche contained valuable amounts of nitrate was unwarranted. Each caliche sample from a pit represented a square prism of material taken from the entire thickness of the caliche layer. Measurements of soil and caliche were taken in each pit, as in the trench. Profiles were also prepared to show the relative thickness of the soil and caliche and to demonstrate the blanket-like character of the deposit. (See Pl. XXXI.)

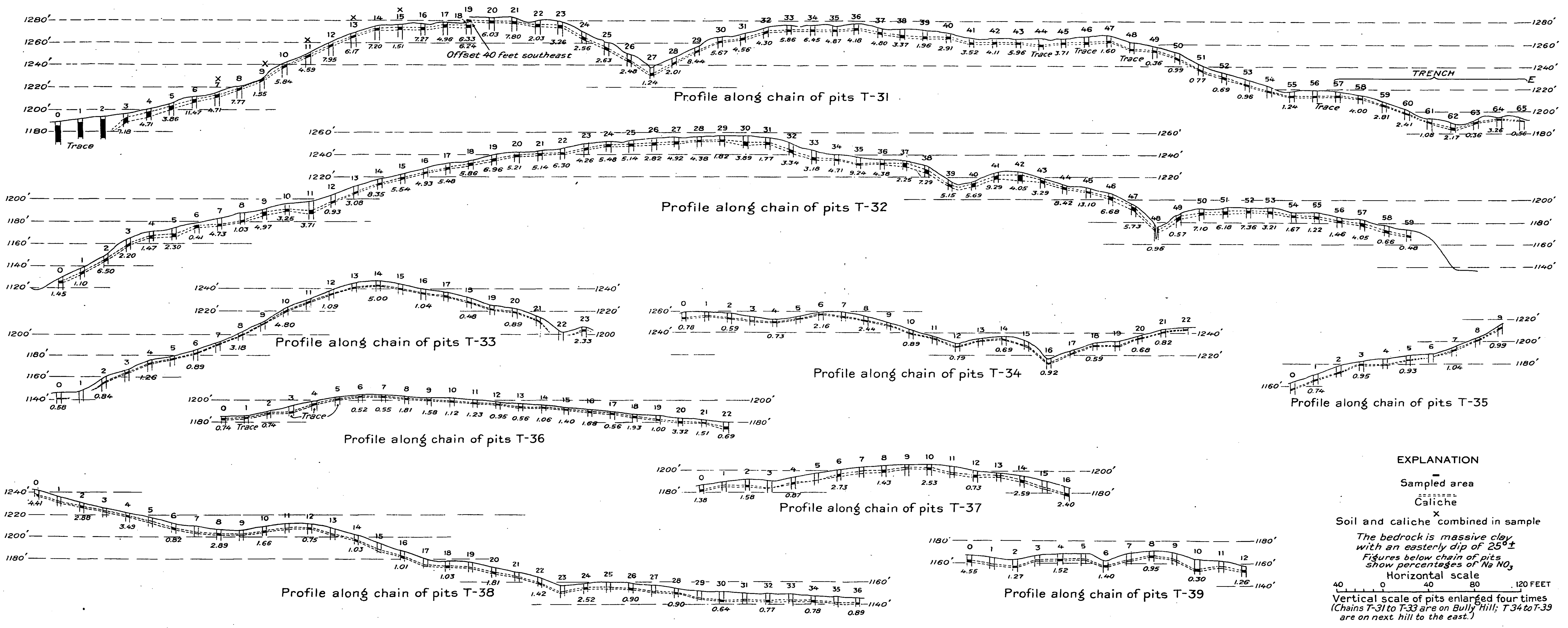
Cross lines of pits had been planned for Bully Hill, but these were abandoned in view of the numerous data already gathered for that area and the time and labor expended in procuring them.

In prospecting the 14-acre tract east of Bully Hill, intersecting lines of pits (see Pl. XXVIII, *B*, p. 69) were used to insure a more uniform distribution of data than had been obtained on Bully Hill. The pits were spaced at 20-foot intervals, as in Bully Hill, and measurements of thickness of soil and caliche were obtained from each pit and platted to profiles. (See Pl. XXXI.) After the first line (T–36) had been completely sampled it was decided to take samples only from alternate pits for the remaining lines, thus extending the interval between samples to 40 feet and reducing the time and labor of procuring them.

Weight determinations.—The pits A to G dug on Bully Hill for the determination of the respective weights per cubic foot of the caliche and soil were spaced at 200-foot intervals in an approximately north-south line, corresponding roughly with the crest line of the hill. The dimensions of the pits varied somewhat, but were approximately as follows: Length, 3 feet; breadth, 1½ feet; depth, 1 to 1½ feet. They were dug through the soil and caliche to the top of the bedrock as nearly as could be determined. All material removed was carefully weighed, first the soil and then the caliche. The dimensions of each pit were then determined from the average of six measurements for each dimension. The soil was still quite moist from heavy rains that had taken place 11 days before, but the moisture had apparently not penetrated the caliche. In computing the weight of the soil allowance was made for moisture as determined from the soil samples.

Soil samples.—The collection of soil samples, deferred several times in the hope that the soil might dry after the rains of an unusually wet season, was finally made just before the party disbanded and was accordingly somewhat curtailed. Samples were taken from six pits, three each in the T–31 and T–32 lines, at intervals of 200 feet. They were sealed in tin cans and forwarded to Washington for the determination of moisture and of sodium nitrate, the last as a check on soil determination from the analyses of the soil and caliche together.

Pits T–31 (0, 1, 2) and T–32 (0) yielded no caliche. The sample taken from each was really soil. These four samples are therefore



PROFILES ALONG CHAINS OF PITS ON BULLY HILL

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY.

grouped with the six above mentioned in the table of analyses of soil sampled.

Results of tests in detail.—The averages in the subjoined tables were obtained by multiplying the percentages by the lengths and dividing the sum of the products by the sum of the lengths.

Trench T-12 across Bully Hill.—Length 904 feet; depth, 4 to 6 feet. Analyses available, 132. Samples represent 20-foot strips. (See Pl. XXX, in pocket.)

Length of sections averaged (feet).	Nitrate as $NaNO_3$ (per cent).				
	Bedrock 5 feet below surface.	Caliche and soil taken together.	Caliche only.	Highest caliche sample.	Lowest caliche sample.
295 {175	0.27	4.34	7.26	10.00	5.49
120	.25	1.95	2.89	5.90	.99
100	.25	.82	1.89	2.67	.62
100	.23	2.55	4.34	6.25	1.87
100	.19	1.86	2.87	4.33	1.93
309	.34	.33	1.52	5.28	Trace.
	[a] .28	[a] 1.79	[a] 3.33		

[a] Average for 904 feet.

Line of pits T-31 across Bully Hill.—Length, 1,260 feet. Pits 20 feet apart. Analyses available, 61. All samples caliche.

Length of sections averaged (feet).	Nitrate as $NaNO_3$ (per cent).		
	Average.	Highest.	Lowest.
40	Negative; not included in niter-bearing area.		
820 {380	6.74	11.47	3.67
140	2.31	5.26	1.24
180	5.46	5.86	4.18
120	3.64	5.96	1.96
280	.79	3.71	Trace.
160	1.98	4.00	.36
	[a] 3.84		

[a] Average for 1,260 feet.

Line of pits T-32 across Bully Hill.—Length 1,180 feet. Pits 20 feet apart. Analyses available, 59. All samples caliche.

Length of sections averaged (feet).	Nitrate as $NaNO_3$ (per cent).		
	Average.	Highest.	Lowest.
260	2.85	6.50	0.41
680	5.41	13.10	1.77
240	2.79	7.10	.48
	[a] 4.31	....	....

[a] Average for 1,180 feet.

Soil samples.

No.	NO_3 (per cent).	Nitrate as $NaNO_3$ (per cent).	Moistur (per cent).
T-31 (0)	Trace.	Trace.	(a)
(1)	Trace.	Trace.	(a)
(2)	Trace.	Trace.	(a)
(20a)	0.72	0.99	13.06
(30a)	.94	1.29	12.61
(40a)	1.86	2.55	10.56
T-32 (0)	1.06	1.45	(a)
(20a)	Trace.	Trace.	8.64
(30a)	Trace.	Trace.	7.20
(40a)	1.00	1.37	(a)
Average		.77	10.41

[a] Not tested.

Unit weights of caliche and soil.

Locality.	Weight (pounds per cubic foot).	
	Caliche.	Soil.
A	89.02	71.59
B	58.48	68.38
C	76.45	63.53
D	96.80	63.04
E	97.80	72.54
F	85.56	69.40
G	93.97	59.21
Average	85.44	66.81

The only sections shown by the foregoing tables to average more than 5 per cent of sodium nitrate are those marked 295, 820, and 680 feet in the first three tables respectively.

Summary.—In Bully Hill proper the area of niter-bearing ground is 31 acres. The niter content of the richer ground was determined as follows:

Location.	Length of trench or line of pits (feet).	Average nitrate as $NaNO_3$ in caliche (per cent).	Continuous sections that average over 5 per cent.	
			Length (feet).	Average nitrate as $NaNO_3$ (per cent).
Trench T-12	904	3.33	295	5.08
Line of pits T-31	1,260	3.84	820	5.25
Line of pits T-32	1,180	4.31	660	5.41
Total or average	3,344	3.87	1,795	5.28

Probable acreage of richer ground, roughly estimated by multiplying the total area of niter-bearing ground by the ratio of lengths of continuous richer sections of trenches and pits to the total length of trenches and pits:

$$\frac{1{,}795}{3{,}344}\times 31=16.6$$ acres that will average 5.28 per cent of sodium nitrate.

Tables of thickness of soil and caliche indicate that the average thickness of the caliche in the area is about 5 inches, and the average thickness of the soil overburden 9 inches.

The results in trench T–12 show conclusively that the nitrate is concentrated in the caliche layer, the soil and bedrock containing only small amounts. They indicate that the soil and caliche together may be expected to average about 1.79 per cent of sodium nitrate and that the bedrock at depths of 5 feet averages 0.28 per cent.

The highest average shown in the Bully Hill area for any strip over 100 feet long is 7.26 per cent for 175 feet of trench; the lowest average is 0.79 per cent for 280 feet of pits.

The nitrate content of the soil as derived from the analyses of the soil samples is 0.77 per cent; as computed from the values for the averages of the combined samples of soil and caliche and of the caliche alone, it is 0.93 per cent. The average of all in proportion to the respective groups of samples is 0.90 per cent.

The average weight per cubic foot of the caliche, as determined by direct measurement, is 85.44 pounds. The weight per cubic foot of soil, with allowance for moisture, is 59.85 pounds.

In the hill east of Bully Hill the area of niter-bearing ground is 14 acres, and 77 analyses were available.

Line of pits.	Lengths (feet).	Nitrate as $NaNO_3$ (per cent).
T-33	440	1.86
T-34	440	1.00
T-35	180	.93
T-36	440	1.00
T-37	320	1.80
T-38	720	1.61
T-39	240	1.61
	2,780	[a] 1.40

[a] Average.

Tonnage estimates.—On the assumption that the thickness of the caliche in the 31-acre tract is 5 inches, or 0.42 foot, and its weight per cubic foot 85.44 pounds, the quantity of caliche per acre would be

$$\frac{85.44 \times 43{,}560 \times 0.42}{2{,}000} = 780+ \text{ short tons.}$$

It has been suggested by Mr. Huntington Adams (see Appendix, p. 95) that the quality of the caliche could be raised to 5 per cent by hand sorting, with a minimum loss of 30 per cent for sorting and blasting. On such an assumption the 31 acres would yield $780 \times 0.70 \times 31 = 16{,}920+$ short tons of 5 per-cent nitrate.

For the sake of argument it was assumed that a process of treatment might be devised, more efficient than that in general use in the Chilean fields, which would reduce the residue to 1.5 per cent nitrate. On such a basis the total production of refined nitrate from the area would be

$$\frac{16{,}920 \times 0.035}{0.95} = 620+ \text{ short tons.}$$

The percentage of sodium nitrate in the 14-acre tract east of Bully Hill (1.40) is so low that the deposit is valueless in a commercial sense, and no estimate of its tonnage was attempted.

If the thickness of the soil is 9 inches, or 0.75 foot, and its weight per cubic foot 59.85 pounds, the weight of the overburden to be handled in connection with the nitrate of the 31-acre tract would be

$$\frac{59.85 \times 43{,}560 \times 0.75 \times 31}{2{,}000} = 30{,}310 \text{ short tons.}$$

Summary for Bully Hill district.—Of the 160 acres in the Bully Hill district, 45 acres, or more than 25 per cent of the whole tract, was found to contain noteworthy amounts of nitrate.

This area of 45 acres averages, on the basis of available data, 3.10 per cent of sodium nitrate in a layer of caliche about 5 inches thick and 9 inches below the surface. The 45 acres is made up of two tracts, containing 31 and 14 acres.

The 31-acre tract, essentially the same as the 34-acre tract sampled by Robbins, averages 3.87 per cent of sodium nitrate. Of this area 1 or 2 acres may average as high as 7.26 per cent, 17 acres as high as 5.28 per cent, and probably 24 acres as high as 5 per cent.

The 14-acre tract averages only 1.4 per cent of sodium nitrate.

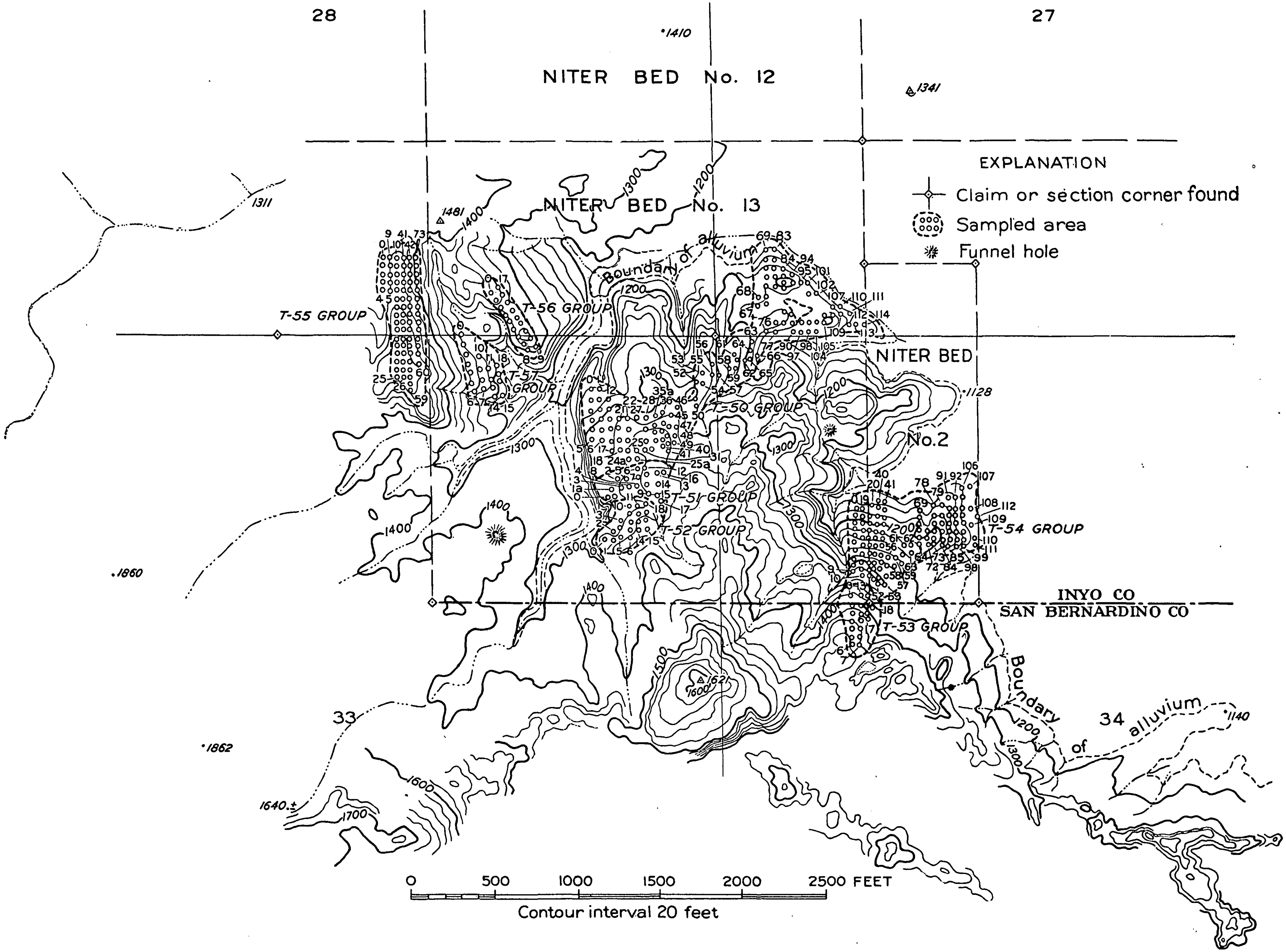
Probably 620 tons of refined nitrate could be produced from the 31-acre tract, but in order to recover this material the handling of 16,920 tons of sorted caliche and 30,310 tons of overburden would be necessary. Little or no nitrate could be produced from the 14-acre tract.

The results obtained by the Survey party in the Bully Hill district are very much lower than those obtained by Robbins in the same area. The samples taken by the Survey show a nitrate content of only 3.87 per cent in the caliche and of 1.79 per cent for soil and caliche together, where the Robbins report showed 10.5 and 6.5 per cent, respectively.

The nitrate is shown to be very unevenly distributed in the caliche, areas in the vicinity of funnel holes being very low in nitrate.

SOUTHWESTERN AREA.

Location and extent.—The southwestern area (see Pl. XXXII) comprises the portion of the Pacific Nitrate Co.'s claims west of Amargosa River and south of the broad dry wash near the boundary between "niter beds" 12 and 13. It thus includes "niter beds" 13 and 2, or 190 acres of patented ground in sec. 33 and 34, T. 20 N., R. 7 E., and some adjacent territory. The area as a whole is about 1 mile west of Bully Hill. The south boundary is the line between San Bernardino and Inyo counties.



MAP OF THE SOUTHWESTERN AREA, UPPER CANYON FIELDS.

Nature of exploration.—While work was still in progress at Bully Hill F. C. Calkins made preliminary brown-ring tests in the southwestern area and prepared a topographic map of the most promising part of it on the scale of 1,000 feet to the inch with a contour interval of 20 feet. (See Pl. XXXII.) Small tracts west and northwest of the one mapped, aggregating perhaps a quarter of a square mile, were also tested. This work occupied in all about ten days.

The smaller map scale was adopted because this area was regarded as relatively less promising than the Bully Hill district and only a reconnaissance examination of it had been planned. Ultimately, when it had been found how rapidly pits could be made and sampled, it was decided to sample thoroughly the better-looking portions, as outlined by Mr. Calkins. Systematic sampling of these portions was therefore begun at the completion of the Bully Hill project by a force of seven men, including a geologist, an engineer, and five miners. In all 400 pits were dug, measured, and sampled during the week ending March 30, 1918.

Geologic features.—The soil and caliche overlie a bedrock of tilted clays that are similar in character and appearance to those of Bully Hill, but may represent somewhat lower members of the stratigraphic series. The blanket-like nature of the caliche is apparent throughout the district. Gypsum veins and veinlets are numerous in the clays, and weathered fragments of gypsum lie here and there on the surface. Sodium chloride occurs in films and crusts, more or less mingled with the sodium nitrate in the caliche and in cracks descending into the clay.

The topography of the southwestern area is more rugged than that of Bully Hill. (See Pls. XX, *A*, p. 60; XXXIII, *A*). Steep slopes and sharply cut ravines are numerous, and the sink-hole drainage already noted as a feature of the Bully Hill district is much more intensively developed here. Patches of gravel also overlie the clays here and there. All these features tend to reduce the extent of the possibly workable nitrate ground and to divide it into separate tracts of relatively small size. These tracts are outlined on the map.

Character of deposit.—The caliche and the soil have the same general character as on Bully Hill, but the caliche proved to be poorer, its average content as deduced from 400 analyses being only 2.25 per cent of sodium nitrate.

A vein of white salts whose tests and reaction to the brown-ring test indicate a high proportion of nitrate was found in the bedrock at one point near a fault. The occurrence has some scientific interest, and it suggests a possible explanation for the very high percentage of nitrate reported, without description of method of sampling, by some previous explorers; but it can have no practical significance and was not followed up in the sampling operations.

Method of sampling.—In each of the selected tracts a series of pits was laid out in north-south lines so that the pits were spaced at rectangular intervals of 50 feet. Each series was given a group number—for example, T–50. The individual pits in each group were numbered in running order southward from zero in the northwest corner. The scale of the map is too small to permit the inclusion of the numbers of the individual pits, but the numbers at the end of each line are given, and from them the location of any intermediate pit may be determined.

The work was divided among four crews, of which the first laid out, dug, and prepared the pits, the second collected the samples and procured the necessary data, the third weighed, ground, and divided the samples in the manner illustrated for the Saratoga district, and the fourth located the pits by stadia.

No samples of soil or bedrock were collected. The soil was scraped away at one side of each pit, and the caliche samples were cut so far as practicable to represent vertical prisms of approximately 4-inch cross section.

Measurements were made at each pit of the thickness of the soil and of the caliche, and a record was kept of the weight of each sample, both in its original form and as divided for preservation and analysis.

Results of tests.—The average thickness of the soil for the tracts sampled is 10.6 inches and of the caliche 6.2 inches. The average weight of the original samples collected is 6.5 pounds and of the portions preserved for analysis after division 0.85 pound. The average nitrate content of the tracts examined is 2.25 per cent of sodium nitrate, derived as indicated in the following table:

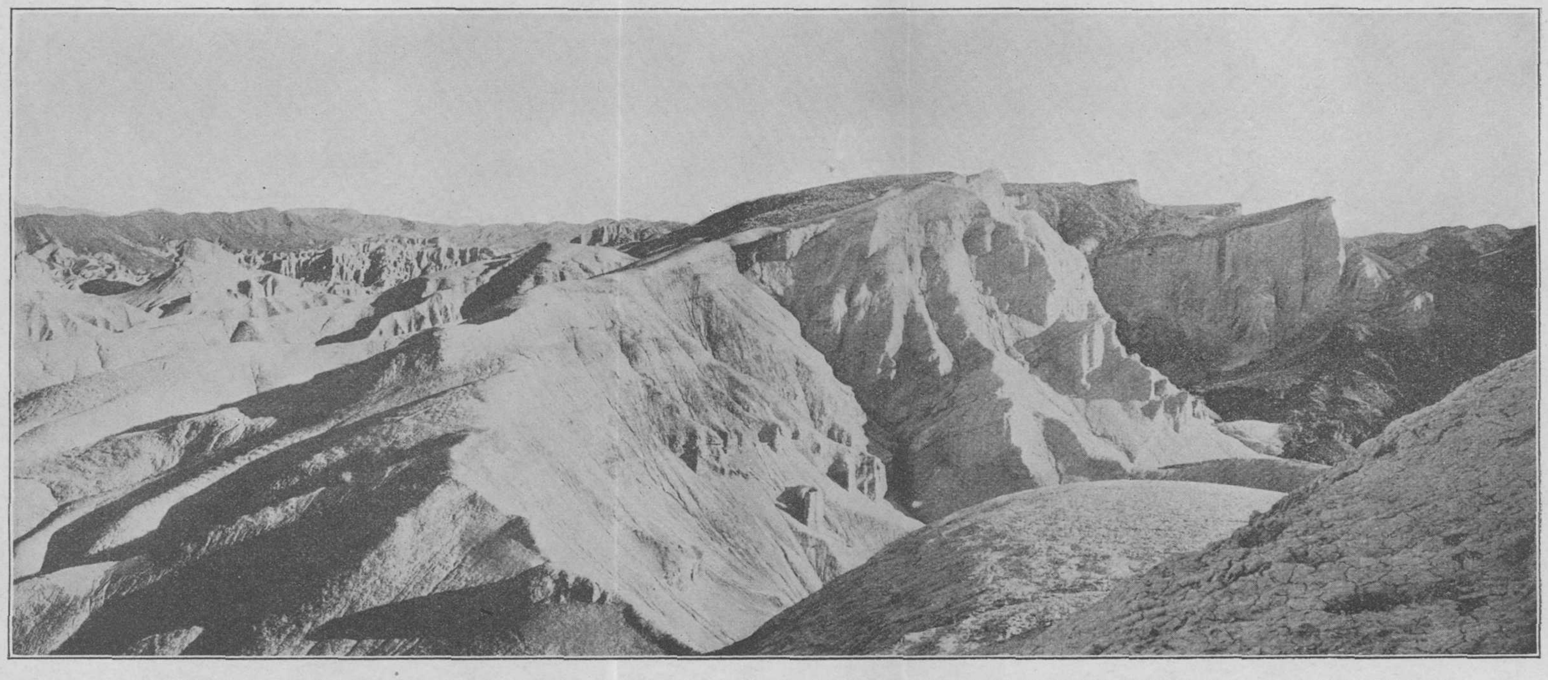
Analyses of samples from southwestern area.

Group.	Number of samples.	Average nitrate as $NaNO_3$ (per cent).
T–50....	118	2.31
T–51...	20	4.24
T–52...	19	2.23
T–53...	19	2.37
T–54...	113	1.70
T–55...	74	2.57
T–56...	18	1.77
T–57...	19	2.22
	400	[a] 2.25

[a] Obtained by multiplying each average by the number of samples represented by it and dividing the sum of these products by the total number of samples.

Of the 400 samples only 24, or 6 per cent of the whole, ran 5 per cent or more sodium nitrate, the best two samples being T–51 (6), which gave 11.01 per cent, and T–54 (27), which gave 10.15 per cent.

A. "NITER HILLS" WEST OF MARGOSA RIVER AT ACME.



B. EASTERN PART OF THE UPPER CANYON NITRATE FIELD FROM THE HIGH CLAY HILL ON THE COUNTY LINE EAST OF WILLOW CREEK.

Acreage.—The estimated areas of the respective tracts sampled and the average nitrate content of each tract are given in the following table:

Area and nitrate content of tracts included in southwestern area.

Group.	Number of samples.	Estimated area (acres).	Nitrate as $NaNO_3$ (per cent).
T-55.....	74	5.0	2.57
T-57.....	19	2.5	2.22
T-56.....	18	2.0	1.77
T-50-52..	157	20.0	2.55
T-53-54..	132	12.5	1.79
	400	42.0	2.25

Tonnage.—The five tracts above indicated contain about 42 acres, of which 5 acres falls outside the patented ground. The remainder of the area, including 81 per cent of claims numbered 13 and 2, is regarded as valueless for exploitation because of the unfavorable topographic and other conditions noted, aside from the fact that the nitrate content of the sampled areas is so low as practically to exclude them from commercial consideration. An estimate of their tonnage, however, may have theoretical interest.

On the assumption that the weight of the caliche of this area is 85.44 pounds per cubic foot, as determined for the Bully Hill area, and the thickness 6.2 inches, or 0.52 foot, the quantity of caliche per acre in round numbers would be

$$\frac{85.44 \times 43{,}560 \times 0.52}{2000} = 970 \text{ short tons.}$$

and the total available caliche for the area would be $970 \times 42 = 40{,}740$ short tons.

The loss in blasting, sorting, and treating such poor material (2.25 per cent) can not well be estimated, but perhaps 50 per cent might be a fair minimum. On that basis 42 acres would yield in refined sodium nitrate

$$\frac{970 \times 0.0225 \times 42}{2} = 580 \text{ short tons.}$$

The thickness of the soil being assumed as 10.6 inches, or 0.88 foot, and its weight per cubic foot as 59.85 pounds, as in the Bully Hill district, the weight of the overburden to be removed in recovering the nitrate would be

$$\frac{59.85 \times 43{,}560 \times 0.88 \times 42}{2000} = 48{,}180 \text{ short tons.}$$

Summary for southwestern area.—The southwestern area includes 190 acres of patented land, 81 per cent of which was judged from the preliminary examination to be certainly valueless. The remaining

19 per cent, together with 5 acres outside the patented ground—42 acres in all—fell into five tracts, which were for the time assumed to be of possible commercial value and were thoroughly sampled.

A production of 580 short tons of refined nitrate might be obtained, but this would require the mining, sorting, and treatment of 40,740 tons of caliche and the disposal of 48,180 tons of overburden.

Although the nitrate-bearing ground of the southwestern area is about a third greater than that of Bully Hill proper, the quality of the caliche is distinctly inferior, and the total refined product would be less.

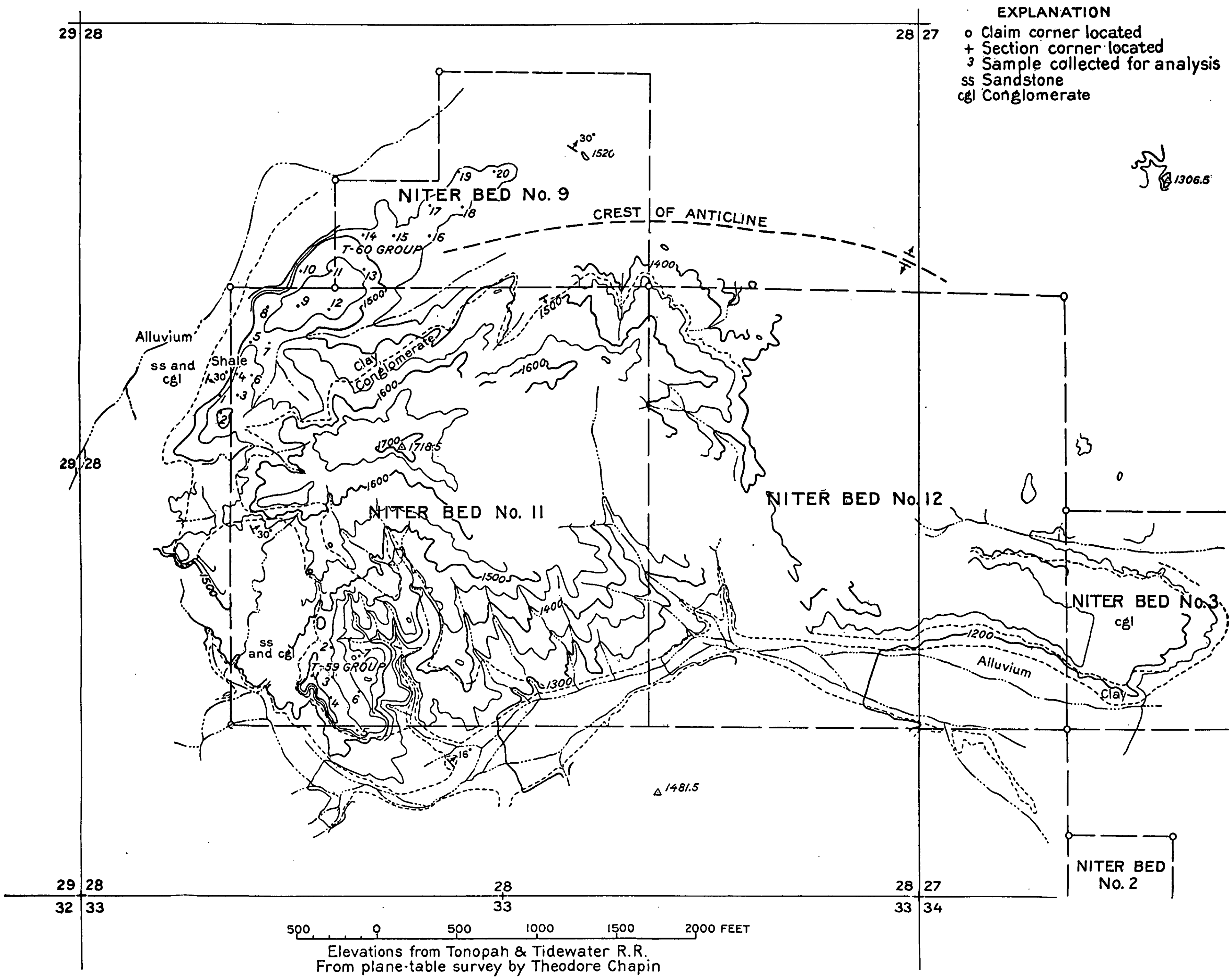
NORTHWESTERN AREA.

Location and extent.—The northwestern area lies on the west side of Amargosa River, adjoins the southwestern area on the north, and is about 1½ miles northwest of Bully Hill. It includes "niter beds" 9, 11, and 12 of the Pacific Nitrate Co.'s claims, or 370 acres of patented ground, with some adjacent territory. The area lies in secs. 28 and 27, T. 20 N., R. 7 E., Inyo County. It is more remote from present transportation facilities than any other portion of the patented lands of the Upper Canyon field.

Nature of exploration.—The northwestern area, according to the Robbins report, was supposed to rank with Bully Hill in quality and extent. A map with 100-foot contours (Pl. XXXIV) was therefore prepared on the scale of 500 feet to the inch by Theodore Chapin, with an assistant, while work was still in progress at Bully Hill and in the southwestern area. Preliminary tests were made with the brown-ring reaction, as in the other areas described. The time required for this work was about ten days, including the last week in March, 1918, and a few scattered days earlier.

By the time that the digging and sampling crews were ready to begin work on this area, orders had been received from Survey headquarters at Washington to stop intensive work on the whole Amargosa region and to disband the party. In closing the work it was decided to spend one day sampling in each of the three remaining areas in order to obtain a record that would give a fair clue to the character of these areas. Thus, on April 2 the northwestern area was visited by two geologists and four miners, and 27 pits were dug and sampled.

Geologic features.—The northwestern area is underlain by tilted clays with accompanying sandy and gypsiferous beds that belong to the same series as those of Bully Hill and the southwestern area. Throughout much of the area these beds are covered with massive conglomerate, the erosion of which has uncovered the clays and their accompanying beds along the southwestern, northwestern, and northeastern borders. The area as a whole is the highest portion of the Upper Canyon field (maximum elevation 1,718 feet) and has the



MAP OF THE NORTHWESTERN AREA, UPPER CANYON FIELDS greatest relief (about 500 feet). Although the upper slopes are relatively smooth, the ravines are deep and the topography is generally rugged. Sink holes and underground drainage are present, as usual in the Amargosa region.

The outlines of the clay and conglomerate areas in the southwestern and northwestern parts of the area are shown on the map. The mapping of the northeastern part was not completed.

Character of deposit.—The deposit is a blanket-like caliche between the soil and bedrock, as in the portions of the Amargosa region already described. In the pits that were sampled the soil, with the usual sulphate layer locally developed, is 10.5 inches thick on the average, and the caliche 5.7 inches thick. The caliche of this area is perhaps less affected by sink-hole drainage than that of either the Bully Hill district or the southwestern area. The available caliche is contained in the three clay tracts that border the area on the southwest, northwest, and northeast. The clays of the northeastern part, which lie chiefly in "niter bed" 12, were not examined because of their less promising appearance.

Method of sampling.—The pits were arranged in two groups, T-59 and T-60, corresponding to the distribution of the more favorable ground. They were arranged in parallel north-south lines and spaced at rectangular intervals of approximately 100 or 200 feet. The work of preparing the pits and sampling was divided between two crews, and when completed the pits were located on the map by stadia.

In order to facilitate the work of sampling, the milling and dividing processes were omitted. Samples weighing approximately 2½ pounds each were taken by chipping regularly across the fresh face of the caliche and the entire sample from each pit was preserved for analysis.

Results.—As the number of samples was not large the analyses are given in full in the following table:

Analyses of samples from northwestern area.

Group No.	Nitrate as Na NO_3 (per cent).	Group No.	Nitrate as Na NO_3 (per cent).
T-59: 1	0.49	T-60: 7	2.06
2	2.26	8	.58
3	2.41	9	8.30
4	1.07	10	Trace.
5	7.21	11	1.40
6	6.08	12	1.66
7	4.77	13	.62
		14	1.80
Average	3.47	15	3.10
		16	1.99
T-60: 1	1.92	17	3.34
2	1.27	18	.59
3	2.67	19	3.56
4	3.30	20	.48
5	.30		
6	3.32	Average	2.11

The average content of sodium nitrate for the smaller tract, represented by the T–59 group, is 3.47 per cent, and for the larger tract, represented by the T–60 group, 2.11 per cent. The average content of the two tracts combined is only 2.46 per cent, which is decidedly inferior to the average for Bully Hill, 3.87 per cent. The nitrate content ranges from a trace to 8.30 per cent, both highest and lowest values being from the larger area. Only three of the 27 samples showed more than 5 per cent, and two of these were from the smaller tract. The distribution of the nitrate is irregular.

Acreage.—Although the two tracts sampled are connected by a strip of exposed clays, this strip occupies steep slopes or areas of underground drainage and may be excluded from consideration. The northeastern group of clay hills in claim No. 12 may also be excluded, as these hills are more or less dissected and unpromising. The portions of the sampled tracts suitable for exploitation have not been carefully determined. They are less extensive than the clay tracts as mapped and may be conservatively estimated at 4.6 and 20.6 acres respectively, an aggregate of 25 acres, or 7 per cent of the northwestern area as a whole. This acreage is smaller than that of Bully Hill proper or of the southwestern area.

Tonnage.—On the assumption that the weight of the caliche is 85.44 pounds per cubic foot, as determined at Bully Hill, and the thickness 5.7 inches, or 0.48 foot, the quantity of caliche per acre would be

$$\frac{85.44 \times 43,560 \times 0.48}{2,000} = 890 + \text{ short tons.}$$

For the 25 acres this would amount to 22,250 tons.

The average content of the sampled tracts is 2.46 per cent. With losses in mining, sorting, and treatment, it seems doubtful if more than a 50 per cent recovery could be made for such poor material. On that basis the 25 acres would yield in refined nitrate

$$\frac{890 \times 0.0246 \times 25}{2} = 270 + \text{ short tons.}$$

If the weight of the soil is 59.85 pounds per cubic foot, as determined at Bully Hill, and its thickness 10.5 inches, or 0.88 foot, the weight of overburden to be handled in the 25 acres would be

$$\frac{59.85 \times 43,560 \times 0.88 \times 25}{2,000} = 28,680 \text{ short tons.}$$

Summary for northwestern area.—The northwestern area is the highest, most rugged, and most remote of the subdivisions of the Upper Canyon claims of the Pacific Nitrate Co. It is mostly covered with conglomerate and boulders, but in the southwestern, northwestern, and northeastern parts niter-bearing clays are exposed. A tract of approximately 4 acres in the southwestern part averages, on the basis of seven well-distributed samples, 3.47 per cent of sodium nitrate. In the northwestern part a tract of approximately 21 acres averages, on the basis of 20 samples, 2.11 per cent. The aggregate 25 acres in the two tracts averages 2.46 per cent.

The remaining clay tracts are regarded as valueless because of unfavorable topographic or other conditions.

It is estimated that the 25 acres would yield 270 short tons of refined nitrate, but to obtain this material 22,250 tons of caliche and 28,680 tons of overburden would have to be handled.

The northwestern area is disappointing as to both the quality and the quantity of its nitrate deposits. Though reported to equal Bully Hill, it is distinctly poorer both in acreage and in percentage of sodium nitrate.

EASTERN AREA.

Location and extent.—The eastern area occupies parts of sections 25, 26, 35, and 36, T. 20 N., R. 7 E., and lies mostly in Inyo County, though the southern part is in San Bernardino County. It is about 1 mile east of Bully Hill and stretches from Willow Creek and the China ranch more than 1½ miles eastward and southeastward. The patented claims of the Pacific Nitrate Co. include only a small part of this territory, however, namely, about 200 acres in "niter beds" 4, 15, and 16.

A spur track of the Tonopah & Tidewater Railroad lies along the west side of the area, and a broad wash southeast of the China ranch gives easy access to the heart of the area.

Nature of exploration.—Because of its large size and the fact that it had not been reported as one of the richer districts, only a reconnaissance examination had been planned for this region. Accordingly a map (Pl. XXXV), on the scale of 1,000 feet to the inch, with 100-foot contours, was begun by Theodore Chapin with an assistant while work was still in progress at Bully Hill. Three days in February and early March were spent in traversing and control work, and a beginning was made on topographic sketching.

On March 20 and 21 a testing and digging crew composed of an engineer and five miners carried on a series of tests and laid out lines of pits, two groups of which, T-40 and T-41, on the most promising-looking hills, were dug. At the same time Mr. Chapin, geologist, with his assistant, located the proposed pits on his map by stadia. The results of the tests proved so unfavorable that the work was discontinued.

When the order came to disband the party it was decided to collect a few representative samples from the pits already dug, in order to obtain analyses that would check the impressions gained by the unfavorable tests. On April 2, therefore, 26 samples were collected, 4 from the T–40 group of pits and 22 from the T–41 group. The hills on which these pits were dug had broad tops with rounded and gentle slopes, were relatively free from ravines and underground drainage, and represented respectively areas of about 7 and 20 acres. The best tests of the entire area examined had been obtained in the T–41 group.

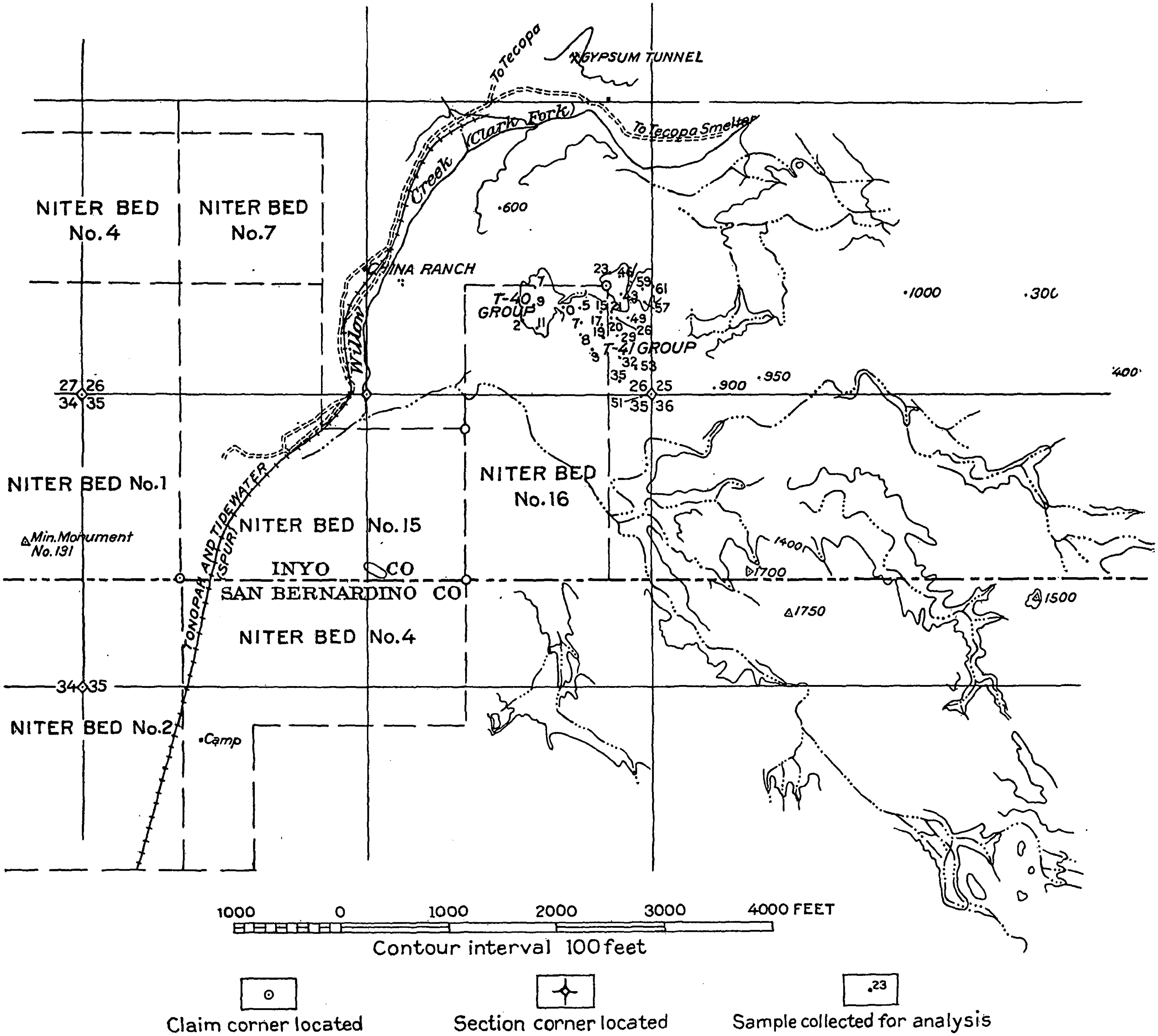
Geologic features.—The tilted clays and associated gypsiferous and sandy beds that underlie the eastern area belong to the same series that form the niter-bearing hills elsewhere in the Upper Canyon field. In the eastern area, however, gypsum is more abundant, and to the north, across the main fork of Willow Creek, the gypsum beds are 18 inches to 3 feet or more thick and have been rather extensively mined. The soil with its sulphate layer that occurs locally averages about 15 inches in thickness, and the caliche 5 inches, as determined from measurements at the pits sampled.

Much of the eastern area, especially in its eastern part, is deeply cut by ravines, the slopes of which are steep and in places vertical, so that the canyons are boxed. Underground drainage is also well developed in certain places. The area as a whole has a rugged topography, and a relief nearly as great as that in the northwestern area. (See Pl. XXXIII, *B*.)

Character of deposit.—The caliche is not as well developed here as in the other portions of the Upper Canyon field. It is poorer in quality and more patchy in its distribution. There appears to be present also a larger proportion of gypsum and of common salt than in the other areas.

Method of sampling.—The pits previously dug had been arranged in north-south lines and spaced at intervals of 50 or 100 feet. The pits sampled were selected at intervals of 100 to 200 feet, and the original numbers were retained. Each pit was refaced to obtain a fresh surface. The soil was then removed and the sample obtained by chipping regularly across the face of the caliche. To save time the milling and dividing processes were omitted, and the entire sample, weighing approximately 2.5 pounds, was preserved for analysis. The work was done by two geologists assisted by two miners.

Results.—The analyses of the samples are given in the following table:



MAP OF THE EASTERN AREA, UPPER CANYON FIELD.

Analyses of samples from eastern area.

Group No.	Nitrate as Na NO_3 (per cent).	Group No.	Nitrate as Na NO_3 (per cent).
T-40: 2	1.19	T-41: 23	3.86
7	1.03	26	3.75
9	.43	29	.38
11	.71	32	1.08
		35	.52
Average	.84	43	.85
		46	.95
T-41: 0	1.22	49	1.51
5	1.18	51	85
7	.90	53	.42
8	.75	57	.75
9	1.85	59	.85
15	2.36	61	4.55
17	3.74		
19	1.41	Average	1.57
21	.90		

The patchy distribution and uneven character of the caliche is suggested by the analyses. Not one of the analyses runs as high as 5 per cent, and half of them are less than 1 per cent. The average of the T-41 group is nearly twice that of the T-40 group, as suggested by the preliminary tests, but is only 1.57 per cent, and the average of the 26 analyses representing both groups is only 1.46 per cent. If, as Mr. Adams suggests in his letter previously referred to (see appendix, pp. 94–96), the residue from the treatment of sorted caliche might contain 1.5 per cent, it is apparent that the eastern area can not be expected to furnish any workable nitrate unless other districts can be found with higher-grade caliche. The preliminary tests and examination indicate that this is extremely unlikely.

Summary for eastern area.—The eastern area contains a considerable tract of niter-bearing clays, but the caliche is poor and unevenly distributed. Samples from 26 pits representing an area of approximately 27 acres of the best-looking ground give an average of only 1.46 per cent of sodium nitrate. None of this nitrate can be regarded as recoverable.

LOWER CANYON FIELD.

By G. R. Mansfield.

Location and extent.—The Lower Canyon field lies at Sperry, a siding on the Tonopah & Tidewater Railroad, about 5 miles south of Acme and the Upper Canyon field. It is approximately in the southeastern part of T. 19 N., R. 7 E. (unsurveyed), in San Bernardino County. The field lies mostly on the east side of the railroad and includes 760 acres of patented land belonging to the Pacific Nitrate Co., with some adjacent territory.

Reported character.—The Lower Canyon field was regarded by Forney in his report of 1892 as the best nitrate-bearing ground of the region. He remarks, "There is not a single hill in this whole area of 2,760 acres that does not carry paying quantities of nitrate." Robbins, in 1912, considered these beds inferior to the Bully Hill area and cut down the acreage estimate to 860. The area patented was even less, but from reports available at the time of the Survey's exploration the Lower Canyon field appeared to afford some promise of workable nitrate.

Nature of exploration.—Early in February, 1918, one of the Survey geologists spent one day in a reconnaissance of the area, making tests with the brown-ring reaction. The tests on the whole

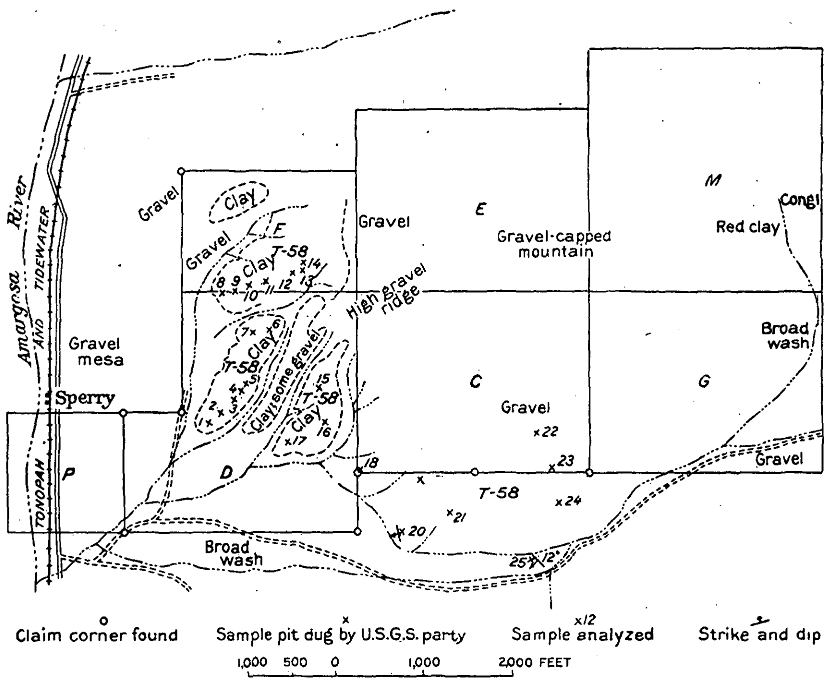


FIGURE 7.—Map of the Lower Canyon field.

gave favorable results, and it was planned to examine and sample the area thoroughly. Bad roads and floods delayed intensive work in the area and the order to disband the party came before anything further had been done. In closing work, however, a single day, April 1, was spent in prospecting and sampling these beds in order that some clue to their character might be obtained. The working party consisted of two geologists, a mining engineer, and five miners. E. R. Lloyd, one of the geologists, prepared a sketch map on the scale of 1,000 feet to the inch (fig. 7). The others laid out, dug, and sampled 25 pits.

Geologic features.—The niter-bearing clays of the Lower Canyon field probably belong to the same general stratigraphic series as those of the Upper Canyon field, but they are reddish and more sandy. They are inclined 10°–20° W. or SW. The clays are overlain throughout much of the area by rough, bouldery gravel, which ascends toward a high gravel-capped mountain near the center of the area. Broad marginal dry stream washes nearly surround this central mass, and the gravel has been stripped away by erosion from parts of its lower slopes, exposing the clay, which now forms rounded hills and ridges. The clay hills are considerably cut by ravines, but underground drainage is not so conspicuous as in parts of the Upper Canyon field.

Character of the deposit.—The same arrangement of soil, caliche, and bedrock occurs here as in the other parts of the Amargosa region, but the caliche is poorly developed, locally absent, and at some places badly leached. The soil with its sulphate layer averages 7 inches in thickness at the pits sampled, and the caliche 4 inches. At some places there is no well-defined caliche, but the bedrock is impregnated with saline matter and is fairly hard. At other places the caliche is represented by caky or incoherent soil between the sulphate layer and the bedrock. Where the caliche is present it is unevenly distributed.

Method of sampling.—The work in this field was divided between two crews, one of which prepared the pits and the other gathered the necessary data. The pits were not laid out with regular rectangular spacing but were distributed as evenly as practicable upon promising-looking slopes. They are all included in group T–58, and their location is shown on the map (fig. 7). Because of the shortness of time the milling and dividing processes were omitted. So far as practicable the soil was removed and the sample chipped regularly across the face of the caliche. Where the caliche was absent or poorly developed the sample was taken from the zone most nearly corresponding with the position of the caliche. Each sample weighed approximately 2½ pounds and was preserved entire for analysis.

Results.—The analyses of the samples are given in the following table:

Analyses of samples from the Lower Canyon field (beds near Sperry).

Group No.	Nitrate as $NaNO_3$ (per cent).	Group No.	Nitrate as $NaNO_3$ (per cent).
T–58: 1	5.18	T–58: 15	2.47
2	3.70	16	.81
3	6.00	17	1.16
4	1.59	18	.84
5	.42	19	.92
6	.78	20	4.25
7	.85	21	.81
8	4.19	22	2.11
9	1.97	23	.78
10	.41	24	.84
11	1.93	25	6.02
12	4.99		
13	4.85	Average	2.36
14	1.12		

The average sodium nitrate content of the 25 samples is 2.36 per cent. Only three of the samples, or 12 per cent of the material collected, ran over 5 per cent; 10 samples, or 40 per cent of the whole, ran less than 1 per cent. The area sampled included the bulk of the more promising ground, and the samples gathered may be considered fairly representative. The acreage is larger than that of Bully Hill, but the percentage of sodium nitrate is lower. The results as a whole are decidedly less favorable than those of Bully Hill, which in themselves are disappointing.

Acreage and tonnage.—The area represented by the samples may be conservatively estimated at about 70 acres. The remainder of this field is regarded as less promising and is excluded from further consideration.

On the assumption that the weight of the caliche is 85.44 pounds per cubic foot, as in the Bully Hill district, and its thickness is 4 inches, or 0.33 foot, the available caliche per acre would be

$$\frac{85.44 \times 43{,}560 \times 0.33}{2{,}000} = 615 \text{ short tons.}$$

For 70 acres this would amount to 43,050 tons.

Considering probable losses in mining, sorting, and treatment, as suggested by Mr. Adams in his letter previously mentioned, it is doubtful if more than a 50 per cent recovery could be made from such poor material. On this basis the total production of refined nitrate from the Lower Canyon field is estimated at

$$\frac{43{,}050 \times 0.0236}{2} = 510 \text{ short tons.}$$

If the weight of the soil is 59.85 pounds per cubic foot, as determined at Bully Hill, and its thickness is 7 inches, or 0.58 foot, the weight of overburden to be handled in recovering the nitrate would be

$$\frac{59.85 \times 43{,}560 \times 0.58 \times 70}{2{,}000} = 52{,}920 \text{ short tons.}$$

Summary for Lower Canyon field.—The 760-acre tract of patented ground in the Lower Canyon field is so largely occupied by gravel-covered slopes or dry washes that only about 70 acres, or 9 per cent of the whole, is regarded as nitrate-bearing.

The caliche is thin and poor, averaging at 25 well-distributed localities 4 inches in thickness and 2.36 per cent in sodium nitrate content.

With a 50 per cent recovery it is estimated that the 70 acres would produce 510 short tons of refined sodium nitrate. To get this product 43,050 tons of caliche and 52,920 tons of overburden would have to be handled.

The Lower Canyon field is therefore not as promising as the Bully Hill district.

GEOLOGIC CLASSIFICATION OF DEPOSITS.

By L. F. Noble.

The following summary and classification has been compiled to present clearly the several types of the occurrences in which nitrate salts have been found. It will be of interest particularly as bearing on discussions as to origin, whether from particular types of sedimentary rocks or from volcanic rocks.

Geologic classification of areas in the desert region of southeastern California examined for nitrate in 1918.

[The areas are numbered in the order in which they were examined, and the location is indicated by corresponding numbers on Pl. 1 (p. 6). Nos. 1 to 9 are described in the present report.]

No. of area.	Character of deposit.						Reported to contain nitrate but found barren.
	Clay-hill caliche.		Cavities.			Clay surface of dry lake.	
	Developed upon strata steeply tilted.	Developed upon strata horizontal or nearly horizontal.	In gypsum travertine overlying schist.	In volcanic rocks.	In sedimentary rocks.		
1	Saratoga and Round Mountain.						
2	Valley						
3		Salt Spring					
4	Confidence						
5	Upper Canyon.						
6		Zabriskie			Few places, Zabriskie.		
7		Resting Springs.					
8		Tule Springs					
9	Lower Canyon.						
10	Barstow syncline.						
11						Dry lake in Superior Valley.	
12	Pilot						
13						Leach Lake	
14	Owl Spring						
15	Twenty-nine Palms.						
16		West Well		Few places, West Well.			
17		Beale					
18			Vivet Eye				
19		Vidal					
20							Danby Lake.

GENERAL SUMMARY FOR THE AMARGOSA REGION.

By G. R. Mansfield.

The Amargosa region includes 11 fields lying in or near the valley of Amargosa River, namely, the Zabriskie, Resting Springs, Tule Springs, Upper Canyon, Lower Canyon (Sperry), Salt Springs, Saratoga, Round Mountain, Valley, Confidence, and Owl Spring fields. The Salt Springs, Tule Springs, and Resting Springs fields were eliminated by preliminary tests. The Saratoga, Confidence, Zabriskie, Upper Canyon, and Lower Canyon fields were explored and sampled in some detail in the order named. The remaining fields were visited but were not examined in detail. None of them appear to offer any promise of yielding workable nitrate.

In the course of the exploration scores of trenches and many hundred pits were dug, from which hundreds of samples were taken for quantitative analysis. The data regarding this work are summarized in the following tables. Probably more than a thousand qualitative tests by means of the sensitive brown-ring reaction were also made; these tests, which can not well be tabulated, were of special use in eliminating the less promising areas.

Survey excavations in Amargosa region.

Field.	Trenches and cuts.			Pits.	
	Number.	Average depth.	Approximate total length.	Number.	Average depth.
		Ft. in.	*Feet.*		*Ft. in.*
Saratoga	13	5 4	556	16	1 10
Confidence	12	1 9	1,000	59	[a] 1 6
Zabriskie	50	[a] 1 0	[a] 1,000+	[a] 50	0 [a] 9
Upper Canyon	3	4 6	1,064	809	[a] 1 6
Lower Canyon				25	[a] 1 6
	78	[b] 2 11	3,700	959	[b] 1 7+

[a] Estimated.
[b] Average depth of trenches represents sum of products of depths and lengths divided by sum of lengths. Average depth of pits represents sum of products of numbers and depths divided by sum of numbers.

Samples collected from Amargosa region.

Field.	Soil only.	Soil and caliche.	Caliche only.	Bedrock.
Saratoga	17		53	67
Confidence			108	
Zabriskie	3		8	12
Upper Canyon:				
Bully Hill	10	52	231	46
Southwestern area			400	
Northwestern area			27	
Eastern area			26	
Lower Canyon			25	
	30	52	878	125

Available analyses from Amargosa region.

Field.	Number of analyses.	Average nitrate as $NaNO_3$ (per cent).			Highest nitrate content in caliche (per cent).	Number of analyses over 5 per cent.
		Soil.	Caliche.	Bedrock.		
Saratoga	134	0.06	1.94	0.215	10.96	5
Confidence	45	....	1.45	....	15.63	1
Zabriskie	23	.12	2.54	.10	10.97	2
Upper Canyon:						
Bully Hill (45 acres)	252	.9	[a] 3.10	[a] .28	13.10	53
Southwestern area (42 acres)	400	....	2.25	....	11.01	26
Northwestern area (25 acres)	27	....	2.46	....	8.30	3
Eastern area	26	....	1.46	....	4.55	0
Lower Canyon	25	....	2.36	....	6.02	3
	932	[b] .71	[b] 2.41	[b] .23	10.07	93

[a] Based on lengths of trenches or lines of pits.
[b] Obtained by multiplying each average by the number of samples represented by it, as shown in the preceding table, and dividing the sum of the products by the sum of the corresponding numbers. For the Confidence field the figure 45 is used instead of 108, so that the divisor becomes 815 instead of 878.

Estimated acreage and tonnage of Amargosa region.

Field.	Area (acres).	Refined $NaNO_3$ (short tons).	Weight of overburden (short tons).
Upper Canyon:			
Bully Hill	31	620	30,310
Southwestern area	42	580	48,180
Northwestern area	25	270	28,680
Eastern area	....	....	....
Lower Canyon	70	510	52,920
	168	1,980	160,090

The significance of the averages of analyses of samples taken from the different fields is unequal because of the unequal thoroughness with which the fields were sampled, the thoroughness of the sampling being determined by conditions, as already stated.

The Upper Canyon field was most promising and was most thoroughly examined. The averages given for this field, except the eastern area, must approximate closely the actual nitrate content of the tracts which were considered most favorable and whose tonnage has been computed.

Similarly the nitrate content of the 70-acre tract of the Lower Canyon field for which an estimate is given is doubtless fairly well represented by the average of the 25 samples analyzed.

In the Saratoga field and the eastern area of the Upper Canyon field certain small tracts and narrow slopes in situations that seemed rather favorable were sampled, and practically all the samples taken were analyzed and are represented in the average. It may fairly be assumed that no considerable portions of the Saratoga field will yield a higher percentage than that stated, although a detailed examination of the whole field would probably reveal many small tracts that would run higher. It was not considered worth while to delimit the more favorable tracts in either field or to estimate tonnage, because of the very spotty distribution of the caliche and the preponderance of areas that are poor in nitrate.

The same statement applies in the main to the Confidence field, with the qualification that many of the poorer samples from the chief group of prospects were not analyzed. The average given in the table is therefore somewhat too high.

The averages for all but one of the fields above named give at least a rough idea of the actual nitrate content for tracts of several acres, whether outlined or not. This is not true of the Zabriskie field, which is represented by only eight samples, selected as the best from hundreds that were tested. The results of these tests indicate that no single acre in this field, if sampled by means of regularly spaced pits, would give an average as high as even the Confidence field.

CONCLUSIONS.

The Survey's explorations lead to the following conclusions:

1. The nitrate deposits of the Amargosa region are blanket deposits that occur in a layer of caliche about 5 inches thick, that lie about 9 inches below the surface of the ground, and that are accompanied by other salts, chiefly sodium chloride.

2. The soil above and the bedrock below the caliche carry only insignificant amounts of nitrate.

3. The inclined attitude of the bedrock and the thickness of the strata exposed to view render it improbable that rich nitrate beds occur at depth.

4. Contrary to earlier optimistic reports the caliche in general is of poor quality, averaging less than 2.5 per cent of sodium nitrate, and is very unevenly distributed.

5. It is estimated that the Upper Canyon and Lower Canyon fields, the most promising parts of the Amargosa region, contain together 168 acres that could produce 1,980 short tons of refined nitrate.

6. The available quantity of nitrate in this region is so small in comparison with the country's needs and with the cost of production that the region as a whole can not be regarded as of commercial importance.

7. No further work on the areas already examined is justified except for scientific purposes, to determine the origin of the nitrate, or, possibly, to determine whether small tracts of richer caliche exist.

in some of the fields, which might, under favorable conditions, be worked on a small scale.

8. The occurrence of the caliche type of nitrate deposit in the Amargosa region, rather than of the usual cave and disseminated types, makes it possible, though improbable, that really valuable deposits of nitrate may occur elsewhere in the general region.

9. Scouting should be continued until all reported deposits in similar districts and the unexamined parts of some of the Amargosa fields have been tested sufficiently to disclose their character.

APPENDIX.

HUNTINGTON ADAMS,
Mining Engineer,
3 Sheridan Square,
New York City.

APRIL 2, 1918.

DIVISION T, OFFICE OF THE CHIEF OF ORDNANCE, U. S. ARMY,
Sixth and B Streets, Washington, D. C.

DEAR SIRS: In accordance with instructions received from Lieut. Col. A. H. White, O. N. A., I present my second report on the Death Valley nitrate deposits.

My conclusions are that work on these deposits should be abandoned, because of the very small amount of nitrate which could be produced from them and the unfavorable cost of such production.

It should be noted, however, that my recommendation to abandon the work is based upon the fact that I do not consider it good policy to produce a small quantity of nitrate uneconomically, just because it can be done in this country instead of Chile. If a different view of the matter be taken, however, it might affect the question of the advisability of working these deposits. Nitrate can be produced from them. The quantity would be small and the cost very high. But the question depends upon how high a cost it is decided to pay to have nitrate produced here rather than imported from abroad.

Respectfully, yours,

(Signed) HUNTINGTON ADAMS.

DEATH VALLEY NITRATE DEPOSITS.

The following report is based upon further conferences with Mr. Hoyt S. Gale, of the United States Geological Survey, together with Mr. L. F. Noble, who has just returned from the examination work on these deposits.

Extent of deposits.—The areas in Death Valley which have been the object of the present work are known as the "upper Amargosa nitrate claims" and are distributed as follows:

	Acres.
1. Bully Hill area	160
2. Beds east of Willow Creek, one-half mile east of (1)	200
3. Northwest area, 1 mile northwest of (1)	600
4. Southwest area, 1 mile southwestward of (1)	300
5. Sperry beds, 4 miles south of (1)	160

This is a total of 1,420 acres, or 2.25 square miles, and is the area referred to in my report of March 23. In that report I considered the possibility of the whole area being caliche beds, in order to make an assumption which was as good as possible. However, Mr. Noble, who is thoroughly familiar with the whole of the grounds, has given me the following information:

1. Bully Hill—160 acres. This has been gone over the most thoroughly in a qualitative way, and the possible area of caliche has been mapped out. Mr.

Mansfield, who is in charge of the exploration work, estimates that this area of possible caliche is 45 acres, or 28 per cent of the whole, and that outside of that area there is no ground in the Bully Hill tract worth further investigation.

2. Mr. Mansfield considers that none of this area is worth investigation.

3. Mr. Noble considers this tract is about as good as Bully Hill—that is to say that not over 30 per cent contains caliche beds.

4. Considered about as good as Bully Hill.

5. Probably not as good as Bully Hill.

Assuming that 29 per cent of the areas 1, 3, 4, and 5 are caliche beds, which Mr. Noble considers to be the best that could be hoped for, there would be a total of 350 acres of caliche beds.

Possible nitrate content.—Mr. Noble considers that the average caliche would not be over 5 inches in thickness. The results so far obtained indicate that it is improbable that the average assay will be as high as 5 per cent $NaNO_3$, but as the sorting factor has not been determined I will assume 5 per cent for the sorted product. With such thin beds a loss in blasting and sorting of 30 per cent of the raw material is a safe minimum.

Specific-gravity determinations have not been made, but assuming a weight in place of 2.1 sp. gr., equivalent to 1.75 short tons per cubic yard, the recovery of caliche per square yard of surface will be 3,500 pounds×0.139 cubic yards×70 per cent recovery=340 pounds of caliche, and per acre=825 short tons. The content of the whole grounds will be 350 acres×825 tons=290,000, or, say, 300,000 tons of caliche.

Assuming that an improved process of treatment is possible which will reduce the residue to 1.5 per cent nitrate, the total production from the area would be 300,000×3.5×0.95=11,000 short tons of nitrate.

Other deposits.—Five or six miles farther up the Amargosa River there commences an area of 20 or 30 square miles of lake beds in which traces of nitrate were found. Some 36 small trenches and numerous pits were made, and 150 to 200 field tests. These were practically all negative. The best samples analyzed gave from 0.4 to 1.6 per cent $NaNO_3$, which is entirely valueless from any possible point of view of operation. No other deposits are known to exist in the vicinity.

Cost of production.—A plant to treat the upper Amargosa deposits even on the basis of two years' life would have to treat 450 tons of caliche per day. The following is a rough provisional estimate of the results obtainable:

Cost of plant and equipment	$600,000.00
Amortization and interest per annum	330,000.00
Capital charge per ton of caliche	2.20
Capital charge per ton of nitrate	50.00
Operating cost per ton of caliche	2.25
Operating cost per ton of nitrate	75.00
Cost per ton of nitrate produced	135.00
Comparative cost of producing nitrate in Chile and laying it down f. o. b. American ports with war freight rates (see my report of Mar. 23)	50.00

Importance of the possible production.—Considered from the point of view of this country's needs, the production of 5,500 short tons of nitrate per year for a life of two years only would be of no material assistance in increasing the supply; and since the nitrate can not be produced at less than 250 per cent of the cost of producing it in Chile, the operation itself would be entirely unsatisfactory.

Nitrate can be produced from the Death Valley deposits. The quantity would be very small compared with the total needs of this country, and the price at which it could be produced would be very high compared with the cost of producing nitrate in Chile and importing it.

The decision to drop these deposits from further consideration depends, however, upon the point of view from which their possible production is to be considered.

Conclusions.—Personally I consider that the deposits are valueless from a commercial or practical national standpoint and that further work on them should be abandoned.

My opinion, however, is based upon the fact that I consider it useless at the present time to provide for nitrate production at a large financial sacrifice in this country when it can be produced under favorable conditions in Chile. (See my letter of March 15.)

I consider that if an increase in the supply of nitrate is needed it should be secured from Chile by either or by both of the following methods:

1. An arrangement for the operation of the German nitrate companies there.
2. The acquisition and equipment of new grounds in Chile through a corporation to be controlled by the United States Government.

If, however, the view is taken that all increase should be made in this country only, notwithstanding the fact that there is no likelihood of the Chilean source being endangered unless control of the sea were lost to us, that our European allies depend entirely on Chilean nitrate and could not continue the war at all if that source of supply were lost to them, and that if control of the sea were lost to us our present supply in this country would be quite sufficient for any conceivable needs for repelling an invasion of our shores, then the problem is a different one, and a comparison should be made of the cost of producing nitrate from such deposits as those of Death Valley with the cost of capital and operating charges on synthetic plants such as those now provided for.

The exploratory work in Death Valley proves that there exist in this country deposits of true bedded caliche somewhat similar to those in Chile, and distinct from the type of commercially valueless cave and cliff-bottom deposits described by Mr. Gale (U. S. Geol. Survey Bull. 523). I consider it, therefore, advisable that exploration work should be continued in the hope that deposits may be discovered more valuable than those of Death Valley.

(Signed) HUNTINGTON ADAMS.

NEW YORK,
April 1, 1918.

INDEX.

O