Bulletin 186 May, 1913

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

The Fixation of Nitrogen in Colorado Soils

THE DISTRIBUTION OF THE NITRATES AND THEIR RELATION TO THE ALKALIS

By WM. P. HEADDEN

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1913

The Agricultural Experiment Station

FORT COLLINS, COLORADO

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THE FIXATION OF NITROGEN IN COLORADO SOILS

By WM. P. HEADDEN

Shortly after the publication of Bulletin 155, "The Fixation of Nitrogen in Some Colorado Soils," my attention was called to the question of the transportation of the nitrates from other sources to where we found these exceptional quantities and also to the question of their distribution both laterally and vertically in the soil. It was distinctly stated that the occurrences of these salts, the nitrates, were confined to certain characteristic "brown spots." The cause of the brown color was attributed to the Azotobacter films, i. e. pigmentation. The smallness of the areas when first observed, their erratic occurrence and wide distribution without regard to character of soil or geological horizon, practically precluded the idea of their being the products of any general concentration process. These questions, however, had already received consideration, especially in connection with the water which we found seeping from certain shale banks, in which connection we made this statement, "One question has undoubtedly suggested itself in regard to the origin of these nitrates, i. e., whether the popular idea that the irrigation water brings them to the surface, may not be correct. Some at least will deem this question as deserving a definite answer, especially as I have found that the waters issuing from the shales underlying the mesas carry significant quantities of nitrates. The shales themselves, when a sufficient quantity of them, 1,280 grams, was extracted with water, actually showed a trace of nitric acid. There are two samples of water and one of shale. They represent three different localities, two of them within three miles of one another, while the third is more than fifty miles from either of the other two." It might be argued "that the shale area is very large and though it contains but a trace of nitric acid, it might suffice to furnish all of the nitric acid which has been found, especially as the water has been issuing from these shales and filling up the lower portions of the country for a very long period."

"The occurrence of nitrates in the waters and apparently in the shale, is susceptible of an easy explanation, i. e., the nitre spots, which are only exaggerated instances of a general condition, occur in the lands above these shales. The water that falls or is put upon these lands, washes the nitrates down into the shales. The soil has no power, or but a very small one, to retain these salts and this seepage water is simply washing the nitrates out of the land." We considered the soil overlying these shales and not the shales themselves as the source of the nitrates. Those who believe in the leaching of these nitrates out of the shales will have to account for the fact that these overlying mesas are dotted with brown spots, rich in nitrates, while there are no shale banks above them from which the nitrates may have been leached.

If we are to consider seriously the shales as the source of these nitrates, we are compelled not only to consider them rich enough in nitrates to permit of capillarity carrying them to the surface and causing their deposition, but we must consider the shales as holding a very great store of them, so great that the time and the water necessary to erode our valleys has been insufficient to wash them out.

It is well known, that under certain conditions, nitrates may occur in soils in sufficient abundance to permit of their crystallization. These conditions are, however, by no means very common. Such occurrences of nitrates are given in our text books, particularly in our mineralogies, and are matters of common knowledge, so much so that some such origin would in all cases be the first one suggesting itself for consideration. Concerning the application of these facts to the shales as the origin of the nitrates it was plainly stated that we did not consider that they played this part for two reasons: First because many brown spots occur on the mesas above the shales; Second, because the brown spots occur in entirely different geological horizons where the shales do not occur, in alluvial deposits and under our ordinary prairie conditions; in other words the shales, provided that they contained nitre, could not be considered as the explanation for the greater number of the occurrences and independent of any other reason than their insufficiency, we must seek for a more general cause, one sufficient to account for all of the occurrences. This assumes that they have a common cause, which is a reasonable assumption so long, at least, as we are not sure that they actually have several different causes.

The origin of the alkalies in such countries as ours is beyond doubt correctly explained by attributing their formation largely to the various changes suffered by the felspars under the action of water, more or less strongly charged with carbonic acid, but in the absence of a sufficient supply of water to carry away the products of their decomposition. This appears to be an entirely adequate source to yield the chlorids, carbonates, sulfates, etc., which we find in our soils, or present as alkalis. but these are not the source of the nitrates.

I am fully aware that students of geology made record, more than twenty-five years ago, of the observation that the Cretaceous shales seem everywhere to be charged with alkalis. These alkalis are, in some cases, composed wholly of sulfates, in others they are mixtures of sulfates, carbonates and chlorids. Under special conditions, such as have been previously mentioned, small quantities of nitrates may be present. The amount of nitric nitrogen found in a shale underlying a cultivated mesa on which nitre spots occurred abundantly and from which the seepage passed into the shale, was 0.00399 percent, 40.0 p p m. This shale had, furthermore, been ground with the addition of this same seepage water and dried so that the amount given is, even for this condition, too high rather than too low.

The question whether the "black alkali" is not brought up by irrigating waters added, though a popular one, is perfectly proper, and is entitled to serious consideration, perhaps to more serious consideration than I gave it in either Bulletin 155 or 178, though I take cognizance of it in both of these bulletins.

Our Colorado alkalis consist essentially of sulfates, chlorids and carbonates. The sulfates are represented by calcic, magnesic and sodic sulfates. The ratio of these salts to one another varies exceedingly, but they are usually all present. In some cases one or the other may be wanting. The chlorids found are those of calcium, magnesium, sodium and small amounts of the chlorid of potassium. The carbonates are quite subordinate. Traces of nitrates are sometimes present, but they may be wholly absent.

Our study of a very alkaline soil, i. e. one which was strongly alkalized, will present the facts that we may expect to meet with under these conditions. This was a soil under cultivation for the purpose of studying, on the one hand, the effects of the alkalis on the crop, and on the other, the effect of cropping and cultivation upon this alkalized soil.

The alkali appeared on the surface of this soil as an incrustation, attaining, under favorable conditions, a thickness of one-half inch or more. These incrustations carried from two to five percent of chlorin and from none to a heavy trace of nitric nitrogen. The top two inches of portions of this plot yielded as much as three and nine-tenths percent of water-soluble material, of which five and one-half percent was chlorin. The second two inches of this soil yielded two and one-half percent of water-soluble of which only nine-tenths of one percent was chlorin. The nitric nitrogen was determined in these samples and we find the following results for these and other sections of the plot. The results are given in parts per million of the air-dried soil, in which there may have been a slight increase in the nitric nitrogen during drying.

This table shows what we found in four different sections of this plot on the date that the samples were taken. At the time these samples were taken I considered 36 p. p. m. nitric nitrogen in the air-dried soil, quite a notable quantity. The quantity varied in these samples apparently independently of the other factors, i. e. the amount of nitric nitrogen present bears no definite and direct relation to the amount of water-soluble, nor to the carbonates, nor to

	Total Water-Sol.	Sodic Carbonate	Chlorin	Nitric Nitrogen	Ratio N:Cl.
1.	39,314.0	779.8	2,145.0	7.08	1:302.0
	25,500.0	1,060.0	229.5	Trace	tr.:229.0
2.	7,500.0	236.8	300.0	36.06	1:8.3
	3,890.0	456.6	112.0	0.39	1:330.0
3.	20,544.0	190.6	881.5	12.33	1:72.0
	8,130.0	199.2	218.7	1.63	1:173.0
4.	8,000.0	147.2	216.0	19.20	1:11.3
	8,640.0	293.4	54.0	2.07	1:27.0

the chlorid present. If there is any relation to the carbonates it would seem that the carbonates depress the nitrates. We have given the ratio of nitric nitrogen to the chlorin, but it is evidently of no value, varying from 1:330 to 1:8.3, and showing but very little or nothing.

At this time we paid much more attention to the ground-water and its composition than to the variation in the composition of the alkali on the surface of the soil. There is no doubt obtaining but that the alkalization of limited areas is due to the evaporation of water which finds its way into them, but which has no free underground outlet. We made no attempt to determine how much water was coming into this ground, but we did try to determine the composition of the water that came in and whether there was much, if any, lateral movement of the salts in the soil. The chief thing which interests us at this time is the variation in the substances held in solution both in regard to their quantity and composition. There were drains in some neighboring lands, supposed to cut off the water which would otherwise flow into this land. They were, however, not effective, and this water did flow into our plot. We made two analyses of these drain-waters with the following results given in parts per million:

	Total Solids	Chlorin	Nitric Nitrogen	Ratio N:Cl.
Drain No. 1.	888.0	40.7	0.24	1:170
Drain No. 2.	1,047.0	44.3	0.48	1:100

It is evident that such water, by its evaporation, might give rise to large quantities of mineral matter, but to only very moderate quantities of nitrates which, owing to their ready solubility, would probably not be deposited at all.

The study of the ground-waters within this alkalized area led to some interesting observations, for instance, they show that the character of the total solids contained in the water is not determined by the salts contained in the soil above the level of the water-plane, but represent much more nearly the salts held in the soil at this plane. This would of course be modified if there were a considerable volume of water moving freely downward through the soil, this, however, was not the case, and we found that there was an intimate relation between the height of the water-plane and the salts held in solution. In other words it was the salts in the soil and not those in the ground-water *per se* that determined the quantity and character of these salts in our case. We dug two holes at a period when the water was very high and, shutting out as best we could, by means of tiles, the water from the higher sections, we collected water representing three sections in one hole and four in another. The results are given in p. p. m. in the following statement:

		Total solids	Chlorin	Nitric Nitrogen
Hole No. 1	1st Sec.	2,842.8	232.9	1.28
	2nd Sec.	2,450.0	177.9	0.76
	3rd Sec.	1,938.5	117.9	0.36
Hole No. 2	1st Sec.	3,395.7	213.6	1.76
	2nd Sec.	2,848.5	146.4	1.00
	3rd Sec.	3,092.8	149.3	1.76
	4th Sec.	2,985.7	156.4	1.68

The total solids in the water obtained from the first hole decreased rapidly with depth, but this decrease was not so marked in the second hole. The chlorin in the top sections of these holes is comparatively high and falls abruptly in the second section. The nitric nitrogen in these waters is very moderate in quantity, and in the first hole falls rapidly with depth, but the second section of the second hole alone shows any considerable variation. The ratio of nitric nitrogen to the chlorin in these cases is altogether erratic and bears no definite relation to the total solids or to the chlorin, even if the nitric nitrogen were present in quantities to be of any significance, which it is not. This relation between the depth of the water-plane and the total solids held in solution, was shown, too, in the variations in the waters of the permanent wells which we observed for more than three years. Each well had its own peculiarities, even when they were located close to each other. The following may illustrate this point. We will designate the wells as 1, 2 and 3.

Wells numbered 1 and 2 were close together, in fact were less than twelve feet apart, while number 3 was not more than 150 feet away. The results in the case of well number 3 are scarcely more striking than those obtained with the air-dried soil, but they are easily explained. When the water in the well was low, the salts in solution were also low, as the water-plane rose, in this case very nearly to the surface, the salts that went into solution increased. The nitrates were near or at the surface of the soil, as is clearly shown by the air-dried samples already given. The fact is that in this section of the land they were very abundant. The ratio of the nitric nitrogen to the chlorin in this water was 1:3.63. The ground-water at the bottom of this well, that is the water underlying this section, contained an exceedingly small quantity of nitric nitrogen and the drain-waters, i. e. the ground-waters that were coming into this section, gave 0.24 and 0.48 parts per million for two different drains, and cannot justly be considered the source of the nitrates found at the surface. I have given the data for this case for the reason that the land was very rich in alkali, and affords us, I believe, reliable information relative to the probabilities that the nitrates discussed in Bulletin 155 and 178 may owe their origin to a process of concentration of ground-water rising through the soil, or filtering in from adjacent lands; in other words, of their having a common origin with the alkalis. We see in these samples of soil and ground-water only moderate quantities of nitrates, from a trace to thirty-six parts per million, in the soil, while in the well-waters it varies from a trace

THESE WELL-WATERS GAVE THE FOLLOWING RESULTS:

	Total Solids	Chlorin	Nitric Nitrogen
Well No. 1	10,357.0	971.4	3.6
	7,590.0	689.3	6.0
	8,387.0	792.9	3.4
	10,312.0	962.1	3.3
	9,831.4	895.4	3.1
	6,215.7	556.4	2.2
	6,461.4	525.0	1.9
	2,705.7	162.3	1.9
	2,388.5	165.0	1.7
	2,164.3	107.0	1.6
	1,990.0	105.0	1.9
	1,882.8	85.7	0.4
	1,752.8	80.5	0.4
Well No. 2	7,297.0	578.0	28.0
	7,478.5	595.0	27.2
	6,821.4	522.9	26.0
	6,711.4	521.4	22.8
	6,717.1	571.0	9.2
	7,442.0	602.9	9.2
	7,561.3	610.0	8.2
	7,778.5	612.9	8.4
	5,564.3	503.6	28.0
	5,378.5	385.7	16.0
	8,492.8	397.1	16.0
	5,514.3	398.5	12.0
Well No. 3	1,600.0	68.0	Trace
	7,863.0	384.7	106.0
	5,385.7	240.8	54.0
	3,928.6	121.0	20.0

to 28 parts per million under ordinary conditions, and rises to 106 parts per million under special conditions, while the chlorin varies from 80 to 971 parts per million without any relation whatsoever to the amount of nitric nitrogen; the same is true, too, of the total solids, the sulfates and carbonates, so far as the latter have been given.

The accepted origin of the alkalis has already been indicated and is, I believe, of universal application. In regard to their presence in the shales perhaps the sulfids of iron ought to be considered as a possible agency contributing to their formation.

A question may be raised as to whether there are any occurrences of nitrates in the immediate vicinity. I think the nitrates appearing in well three owe their presence in such abundance to formation on the surface of the soil, but we will waive this point and give an analysis of a surface-soil from a typical "brown spot" where there is no unusual amount of alkali and whose limits are as distinctly marked as the margin of this printed page. The sample is a surface one, taken not more than one inch deep. The surface of this spot was moist due to the deliquescent character of the magnesic and calcic nitrates. The soil proper is a red, gypsiferous clay.

One of the effects of the presence of the nitrates in soil was set forth with emphasis in Bulletin 155, i. e. they brought about a muddy condition of the soil, a deflocculated condition which retained the water persistently. The statement was made, that while a certain soil was a veritable mud at two to two and one-half feet below the surface, no proper water-plane was met with at a depth of six feet; and in another which was muddy quite to the surface, we found no proper water-plane at six feet and had to wait nearly two hours to collect two gallons of water. It is easily conceivable that the presence of highly deliquescent salts, such as calcic and magnesic nitrates formed in the surface soil, should change the action of capillarity in the underlying soil and bring about excessive surface deposition of the salts already present in the mass of the soil. In the case here presented the surface-soil contained 11.56 percent of substances easily soluble in water, and the soil when dried in the air bath and exposed to the atmosphere, quickly becomes so moist that it forms a coherent mass when pressed between the thumb and finger. This spot occurs on the road side. The land here is not seeped and is not alkali land like the preceding. This sample is chosen because it is located in the same section of country as the land just discussed, and no explanation can be offered that the differences are due to location and general conditions and not to the causes that I have assigned, i. e. to excessive fixation of nitrogen and the formation of the nitrates *in situ*. I have already stated that the soil is a gypsiferous clay, and it follows that the amount of water-soluble found will depend almost altogether upon the amount of gypsum present and the persistency with which it is extracted with water.

ANALYSIS OF WATER-SOLUBLE FROM BROWN SPOT.

	Percent
Silicic acid	0.206
Calcic sulfate	80.440
Calcic chlorid	3.835
Magnesic chlorid	0.326
Magnesic nitrate	7.766
Potassic nitrate	0.093
Sodic nitrate	7.334
	100.000

The alkali incrustations, as well as the aqueous extracts of the surface soils, consist very largely of the sulfates of calcium, magnesium and sodium. The amount of the sodium sulfate varies exceedingly but in this case we find a small amount of sodic salts and a relatively small amount of chlorin. The soluble portion is 115,-600.0 p. p. m., the chlorin is 3,112 and the nitric nitrogen is 3,120 p. p. m. It is evident in this case that the nitric acid must be combined with other bases than sodium, but to make our statements uniform we will give the nitric nitrogen and chlorin as the sodic salts corresponding to their respective quantities. The ratio of nitric nitrogen to chlorin in this case is 1:1 and the corresponding amounts of sodic nitrate and chlorid are 18,720 and 4,979.2, or in the ratio of 1:0.27.

The soil first given with its large quantity of alkalis and no unusual quantities of nitrates, and this sample of a "brown spot" with large amounts of nitrates and small amounts of alkali, gypsum excepted, which in this case is clearly a portion of the clay, illustrates the extreme difference between an alkali soil and a "brown spot" or nitre-area. I may add that I have seen a soil which is exceedingly rich in gypsum, so much so that it is ordinarily quite white, very strongly discolored with Azotobacter pigments and found it quite rich in nitric acid. This was in the immediate neighborhood of this "brown spot."

I answered this question of concentration fully in Bulletin 178 and showed that the nitrates could not have come from the adjacent lands. I presented the whole case, the favorable and unfavorable features, so fully that persons conversant with our conditions cannot doubt the competency of the data given to present the conditions really obtaining, and they gave no support to the concentration theory. Concerning this case I stated, "There is not another instance of the occurrence of nitre within this state which is so favorably located for justifying the theory of concentration from adjoining lands as this one, and it is for this reason that I have set forth these facts pertaining to the composition of the alkali, the soils to a depth of three feet, the aqueous extracts made from these soils, and the solids held in solution by the ground-waters." These facts were that there were no nitrates in the alkalis and none in the soils beyond such quantities as usually occur in soils. The aqueous extracts of these samples did not contain enough nitrates to give even a perceptible violet tinge when tested with ferrous sulfate and sulfuric acid in the usual way and the ground-waters were practically free from them. The soils yielded to water from 24,000 to 42,000 parts per million with from 5,000 to 7,000 p. p. m. of chlorin. The ground-waters carried from 12,600 to 15,400 parts of total solids per million, with from 3,100 to 4,600 parts of chlorin per million and only such traces of nitrates in the soils or the waters as it is usual to find under ordinary conditions. The alkali gathered from the surface of this soil carried 43.5 percent of sodic chlorid or 26.1 percent chlorin, but no nitrates. I stated that such alkalis, soils and waters could not be the source of nitrates found in neighboring lands even though these lands were lower and either the surface-water or the ground-water or both, flowed through and over this land. I think that this conclusion is fully justified. The facts in the case are that these waters do not find their way into the land discussed, at least, I could find no reason for thinking that they did then or do at the present time. The nitre spots presented in this connection were first observed in 1904. They were described as being sharply defined "brown spots on which nothing would grow." They have not yet become much better though the successive owners have combated this condition by fertilizing heavily, by continuous cultivation and by excessive irrigation. The general condition of this soil is represented by the following facts. The surface two inches carries 44,200 parts of water-soluble per million, of which about 30 percent is chlorin or 13,260 parts, and 1.6 percent is nitric nitrogen or 707.2 parts. The first foot of soil from the adjacent, we may say alkali field, gave 24,500 parts water-soluble per million with approximately 4,900 parts of chlorin and no nitric nitrogen beyond a trace. The alkali scraped off of the surface of this soil gave 27.6 percent soluble in water or 276,000 parts per million with 71,760 parts of chlorin and no nitric nitrogen. It is evident that the nitrates in the "brown spots" did not come from this source and that there is no relation beween any individual constituent of the alkali and the amount of nitric nitrogen which may be present.

We even went further in considering the part that the ground-water might play and presented the fact that the drain-water taken from a drain that runs east and west between the heavily alkalized land and some of these nitre-spots, so that the alkali land was north and the nitre-spots south of the drain with the fall of the land to the south. This drain-water carried one-tenth part nitric nitrogen per million and is the water which, if not intercepted by the drain, would flow beneath the nitre-areas. It carried 8,489 parts total solids in solution with 2,122 parts chlorin and one-tenth part of nitric nitrogen. The surface soil of the nitre-spots in this soil carried 98,820 parts water-soluble per million, 43,480 parts of chlorin and 494.0 parts of nitric nitrogen. Another sample from the area here considered gave 44,200 parts water-soluble, 13,260 of chlorin and 884 parts of nitric nitrogen. There is no relation between the alkalis of the neighboring lands, the solids held in solution by the ground-waters, or the water-soluble portion of the alkalized soil and the nitrates found in these nitre-spots. A similar soil in the same section of the country, perhaps seven miles distant from the preceding locality, gave the following results: 55,300 p. p. m. of water-soluble, 5,500 p. p. m. of chlorin and 4,203 p. p. m. of nitric nitrogen in which we have the ratio for nitric nitrogen to chlorin 1 :1.33.

It may be convenient for some purposes to state our results in the form of this ratio, nitrogen to chlorin, but it means nothing and fails to convey an adequate idea of the relative quantities of the respective salts represented, especially to those who may be accustomed to think in terms of these salts, i. e. in terms of nitrates and chlorids instead of nitric nitrogen and chlorin. In the last sample for instance, we have the ratio of 1 :1.33 for the nitric nitrogen to the chlorin, which tends to leave the impression upon the reader that the nitrates are subordinate in quantity because the value one and one-third is greater than one. The amounts of these salts present, calculated as sodic salts, were really 25,218 parts of sodic nitrate and 8,800 parts of sodic chlorid; in other words, instead of the chlorid predominating, the nitrates were present in three times as great a quantity as the chlorids. The actual ratio for these salts is 1 :0.34. We will take another example from another section of the State, in which we have 33,200 p. p. m. of water-soluble, 658.4 p. p. m. chlorin, and 987.6 p. p. m. of nitric nitrogen. The ratio for the nitric nitrogen to the chlorin in this case is 1 :0.66. To the person who knows the respective factors for converting this ratio into that of the nitrates and chlorids, it may convey a definite idea of their relative quantities, but even such a person is apt to overlook the great difference in the quantites of these salts actually present, which quantities, in this case are 5,926 parts of nitrates to 1,053 parts of chlorids, or in the ratio of 1 :0.17, or stated differently, 0.6 per cent of the dry soil is composed of sodic nitrate and 0.1 percent of sodic chlorid.

We have now presented the details of two very distinct localities in which we find some lands seeped and strongly alkalized and in which also occur "brown spots on which nothing will grow," nitre-spots. These have been given to show that the nitre found in the "brown spots" does not owe its origin to the alkalis nor to the concentration of the ground-waters. We will briefly restate our results to show that there is no relation whatsoever between the alkalis and these nitre-spots which in any way justifies the view that the "brown spots" owe their origin to seepage, or have a common origin with the alkalis.

In the first case cited the alakalis were gathered and analyzed and while they always carried chlorin, some of them as much as five percent of their weight, none of them carried more than heavy traces of nitric nitrogen, and some of them carried none at all.

The soil samples taken from four different parts of this piece of land showed no unusual amounts of nitrates. These samples represent the first and second two inch sections of the soil and gave the following results in parts per million:

FIRST TWO INCHES.				SECOND TWO INCHES.			
Water-Sol.	Chlorin	Nitric Nitrogen	N :Cl.	Water-Sol.	Chlorin	Nitric Nitrogen	N :Cl.
39,314.0	2,145.0	7.1	1 :302.0	25,500.0	229.0	Tr.	Tr :229.0
7,500.0	300.0	36.0	1 : 8.3	3,890.0	112.0	0.3	1 :130.0
20,544.0	881.5	12.3	1 : 72.0	8,130.0	218.0	1.6	1 :147.0
8,000.0	216.0	19.2	1 : 11.0	8,640.0	54.0	2.1	1 : 27.0

These samples were taken at the same time and show that in some sections of the land the alkali was very abundant but that there was no relation between the amount of alkali in the soil and the amount of nitric nitrogen present. Further they show that there is no relation between the chlorin in the soil and the nitric nitrogen. We find this true in both of the two-inch sections taken. The nitric nitrogen found in this strongly alkaline soil is by no means remarkably high unless the figure 36.0 p. p. m. nitric nitrogen be considered higher than usual which, I think, would in general be justified, but not in Colorado, for we often find much higher figures than these for ordinary, cultivated soils.

We also examined the ground-waters from this area and found them to contain total solids varying in quantity from 1,600 to 10,357 p. p. m., chlorin from 68 to 971.0 p. p. m., and nitric nitrogen from a trace to 106.0 p. p. m. There is no relation between the amounts of nitric nitrogen and those of chlorin. We have with

3.6 p. p. m. of nitric nitrogen 971.0 p. p. m. of chlorin with 106.0 p. p. m. nitric nitrogen 384.7 p. p. m. chlorin; with 3.3 p. p. m. nitric nitrogen 962.0 p. p. m. of chlorin, and with 54.0 p. p. m. of nitric nitrogen 240.8 p. p. m. of chlorin. These data, the favorable and unfavorable, have been given for a strongly alkalized piece of ground to show what the facts are which obtain under such conditions. The high nitric nitrogen in well No. 3 is easily explainable.

For the purpose of comparison we have also given the facts presented by a "brown spot" in the same section of the country. This "brown spot" occurs on a red, gypsiferous clay and is not on seeped land. The water-soluble was mostly gypsum, but the results were water-soluble 115,600 p. p. m., chlorin 3,112.0 p. p. m., and nitric nitrogen 3,120.0 p. p. m.

In the second case presented we have followed the same order of presentation and of course for the same purpose, and as this case has been previously published in its most essential points, I shall give it very briefly:

The alkali;	water-soluble	435,000.0 p.p.m.
	Chlorin	261,000.0 p.p.m.
	Nitric Nitrogen	None
The Soil;	water-soluble from	24,000.0 to 42,000.0 p.p.m.
	Chlorin	5,000.0 to 7,000.0 p.p.m.
	Nitric Nitrogen	Traces usually found in soils
Ground-Water;	Total Solids	12,600.0 to 15,400.0 p.p.m.
	Chlorin	3,100.0 to 4,600.0 p.p.m.
	Nitric Nitrogen	None or only traces
Drain-Water;	Total Solids	8,489.0 p.p.m.
	Chlorin	2,122.0 p.p.m.
	Nitric Nitrogen	0.1 p.p.m.

The "brown spots" in land immediately below this and through a part of which the drain-water just given had flowed:

Soil from "brown spot";	Water-soluble	98,820.0 p.p.m.
	Chlorin	43,480.0 p.p.m.
	Nitric Nitrogen	494.0 p.p.m.
Soil from another spot;	Water-soluble	44,200.0 p.p.m.
	Chlorin	13,260.0 p.p.m.
	Nitric Nitrogen	884.0 p.p.m
Soil from another "brown spot" on land in the same district. Soil;	Water-soluble	55,300.0 p.p.m.
	Chlorin	5,500.0 p.p.m.
	Nitric Nitrogen	4,203.0 p.p.m.
Soil from another "brown spot," not in the same district. Soil;	Water-soluble	83,200.0 p.p.m.
	Chlorin	658.4 p.p.m.
	Nitric Nitrogen	987.5 p.p.m.

The above drain-water contains 21,220 times as much chlorin as nitric nitrogen. But this is the water that underlaid the soil on which the "brown spots" showed only 87.6 times as much chlorin as nitric nitrogen in one case and 15 times as much in the other case. When one considers the fact that the sodic nitrate is more than twice as readily soluble as the chlorid and attracts moisture quite readily while the nitrates of calcium and magnesium are deliquescent, any concentration of these quantities of nitrates from such waters is wholly out of the question. Furthermore, these data show that any ratio given for the nitric nitrogen to the chlorin is utterly valueless.

The question of how much nitric nitrogen do ordinarily good, cultivated soils in Colorado contain, can properly be raised in this connection. I endeavored to answer this question in Bulletin 155, pages 33-35. I think that from 5 to 8 parts per million of the dry soil may be considered as maximum quantities under ordinary conditions. This is for samples taken to a depth of two inches and not after heavy rains or recent irrigation. If the samples be taken to greater depths it will usually be lower, provided the moisture conditions are the same. According to this the first alkaline soil given carried rather large amounts of nitric nitrogen in three out of four cases, 12, 19 and 36 p. p. m., but the second soil carried no unusual amounts. The brown spots from the respective sections, however, carried 3,462, 494.0, 884.0 and 4,203.0 p. p. m.. of nitric nitrogen..

Apropos to the chlorin in ordinarily good, cultivated soils I have no data pertaining to samples taken to depths of only two or three inches, but I have quite a number of soil samples taken to depths of from one to three feet; these indicate that the chlorin in such soils under favorable conditions varies between 200 and 900 p. p. m., but in alkali soils whether nitrates be present or not the surface portions may be very rich in chlorin. I have a surface sample of soil from an orchard which was in fairly good condition but the trees, though apparently healthy, were small. The chlorin in this sample amounted to 1.5 percent of the dried soil or was 15,000 p. p. m. There was no incrustation on this soil, but it was dark, due to the large amount of chlorids present, among which was a large proportion of calcic chlorid. There was only a trace of nitric nitrogen in the aqueous extract of this soil, corresponding to such quantities of nitric nitrogen as we would expect to find in any ordinary soil. Further, the samples of alkali soils already given show that we may have very considerable amounts of chlorin occurring in the surface portions without any nitrates. In the case of the alkali previously given the chlorin amounted to 261,000 p. p. m. and there was no nitric nitrogen. It is often, but not always, the case, that we find large amounts of chlorin in such samples as are rich in nitrates and the same thing is true of the sulfates. That the chlorids are not always high when the nitric nitrogen is high is shown by the sample already given in which we have 987.6 p. p. m. nitric nitrogen and 658.4 p. p. m. chlorin, but the sulfates in this case were high.

OBSERVATIONS OF 1912.

The work done preparatory to writng up Bulletin 178 showed, when collected, that it would be desirable to follow the variations in the nitric nitrogen present in a definite locality and in these spots from time to time throughout several months. Accordingly we planned to make such observations but we have not been able to carry out these plans as we wished. Still we have gathered quite a mass of data. The fact that we have been prevented from carrying out our plans *in extenso* is not the only feature that contributes to making the data less valuable than they otherwise would have been, but other factors have also contributed to bring about these results. These nitrate conditions in general were much less severe in 1912 than they were in 1910 and 1911. There was, in some sections at least, a more general distribution of the trouble, but by far fewer cases of intense injury due to this cause, than in preceding years. In writing Bulletin 183 I had occasion to note that there was a general improvement in the quality of our sugar beets over that shown during the preceding four or five years. This was shown in a still greater measure in 1912. I do not doubt but that the intensity of this nitre trouble varies with different seasons though I have no definite figures to prove this assertion. Still it is true that in 1907, 1908, 1909 and 1910, the molasses in some factories gave a great deal of trouble in the crystallizers, whereas in 1911 they worked very easily. We had in certain sections other evidence of this change. The growth and physical properties of the beets were entirely different from those of the preceding years, the tops were small, prone, and of a yellowish green color. The beets were relatively large in comparison with the size of the tops, and their flesh had an opaque, yellowish white color and not the glassy, semi-transculent, watery white color of the previous years. In 1912 the crop was still better and the average precentage of sugar was two percent higher than it had been in some of the previous years. The nitric acid in the molasses of 1911 was less abundant than in 1909 and 1910. I have not analyzed the molasses of 1912. In addition to such general facts as these, there were fewer cases of intense injury to fruit trees in 1912 than in 1910 and 1911. This too is based upon general observation and not upon actual numbers. There were too many bad cases and too much general injury done in 1912, however, to escape notice or to be considered as a negligible factor in our fruit growing or in our general agriculture. We are simply giving the facts and not making any excuses for the data that we are about to present.

Our plan was to collect samples from certain measured areas at stated intervals and observe the variations in the amount of nitrates and chlorids present and also to note the appearance of any "brown spots" within these areas and the development of the nitrates in them. The lands chosen were supposed to be favorable for our purposes and were sufficiently varied in character to meet any objections which might be based upon the assumption of our being too strongly influenced in making the selection. Some of the land suffered a change in management during the period of our observations and we were deprived of intelligent cooperation, in fact of any kind of cooperation, and the land received no kind of care, which further changed the conditions. Our series of samples could not be made complete because of inopportune rains. This hindrance happened to me several times during the season.

THE FIRST PLACE CHOSEN.

The first place selected was a piece of land situated near the river and its drainage into the river was so free that the water backed up into the land when the water rose in the river and fell with it. This soil was sampled 20 Oct., 1911, to a depth of 60 inches, i. e. to the gravel which varies from 5 to 8½ feet from the surface. The results are given in parts per million.

ANALYSES OF SAMPLES FROM THE FIRST PLACE CHOSEN.

	Nitric Nitrogen	Total Nitrogen
1 to 6 inches	109.0	931.6
7 to 12 inches	14.0	768.4
13 to 22 inches	11.0	510.0
23 to 32 inches	6.0	469.2
33 to 42 inches	2.6	530.0
43 to 49 inches	2.0	312.8
50 to 60 inches	2.0	346.8

Another set of samples was collected 10 Dec., 1911. These samples are composite, each containing 22 subsamples.

	Nitric Nitrogen	Total Nitrogen
1 to 3 inches	50.0	972.4
4 to 6 inches	26.0	884.0
7 to 9 inches	8.4	884.0

Samples taken 15 April, 1912. Composite samples each containing 22 subsamples.

	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches	64.0	850.0	4,304.7
4 to 6 inches	40.0	816.0	2,366.6
Brown spot	1,722.0	2,148.8	19,832.0

Samples taken 10 July, 1912.

1 to 3 inches	486.9	1,196.8	12,344.0
4 to 7 inches	20.	748.0	1,443.0

No samples were taken at this place between the two last dates because it was too wet on the occasion of our visits either because it had just been irrigated or because it had just rained, or because the river was in flood.

THE SECOND PLACE CHOSEN.

The second place chosen was strongly alkalized and in part seeped. These are the factors that determined this selection. Some of this land is still under cultivation, but some of its has been abandoned for several years.

I will digress to state that many persons think that drainage would obviate the troubles met with in such land as this. I am sure that this is true, if we could drain it, but I hold it as entirely infeasible to drain this land, not because drains cannot be put through it, though this will be difficult on account of quaggy spots and quicksands, and cannot be done at any reasonable expense, but because the drains will be very difficult to keep open. The principal trouble, however, lies in the fact that this land will not drain. I have described such lands in previous bulletins and stated in one case that a hole made in such land held rain-water which flowed into it from the surface till it evaporated, and have further stated the necessity that I found myself under of letting a hole, sunk six feet in such muddy land, stand open over night in order to obtain a sample of water for analysis. I have also stated that I have seen some 7,000 feet of open trench in such land whose surface was muddy and yet there was not enough water in the bottom of the trench to form a flow. In this kind of land one may find water standing at the very surface and within a few feet of it find dry earth to a depth of from 6 to 16 feet or even more. The only way to drain this land would be to put a drain to every wet spot and I doubt whether this would be effective, even if the drain terminated in a well. *Drainage, where feasible, is undoubtedly the corrective measure to be taken in our alkali questions, but drainage is not always feasible.* Drainage often yields disappointing results. I recall having mentioned this in another bulletin and stating that I had opened a drain and found water enough flowing to show that this drain was not closed up, but that the land within a few feet of it was a perfect mudhole and partially covered with standing water. I recommend dranage for land that is wet, but I can see no use of with holding, what seems to me a patent fact, that it will cost more to effectively drain such land as this than the land will be worth for many years to come, if ever. The questions of drainage in some lands in Colorado are serious ones with which the alkali questions are intimately associated.

SAMPLES FROM THE SECOND PLACE CHOSEN.

The samples from this place are all surface-samples, namely none of them were taken to a greater depth than three inches. Other samples from this place, taken to a depth of three feet, have already been given. The samples here presented are composite, taken to represent a fairly large surface.

ANALYSES OF SAMPLES FROM SECOND PLACE CHOSEN.

	Nitric Nitrogen	Total Nitrogen	Chlorin
Samples taken April 4, 1912.			
1	8.0	1,196.8	18,273.0
2	16.0	992.8	19,180.0
3	30.0	1,312.4	19,560.0
Sample taken May 13, 1912.			
4	6.0	680.0	19,296.0
Samples taken July 10, 1912.			
5	29.0	1,312.0	19,560.0
6	20.0	1,047.0	33,920.0
7	30.0	1,142.4	17,960.0

These results are in perfect harmony with those obtained in previous years. There are, however, a few spots in which changes are taking place, which is rather surprising in consideration of the large amount of chlorin present in the surface portions. The amount of chlorin falls off rapidly with depth, for the first foot of soil, including the surface, carried only 3,870.0 p. p. m. of chlorin. The amount of chlorin is by no means constant. Samples of "brown spots" on this land, which were taken to see whether we were quite correct in our judgment, gave the following results:

Samples taken July 10, 1912.

	Nitric Nitrogen	Total Nitrogen	Chlorin
8	779.1	1,319.2	18,743.0
9	881.0	1,339.6	19,089.0

THE THIRD PLACE CHOSEN.

The third place selected was a larger area and was divided into equal sections, one-sixth-acre each. The surface-portion was sampled to a depth of seven inches, the top three inches was taken as one and the succeeding four inches as a second sample. Sixty samples were taken to these respective depths from each one-sixth-acre, united, thoroughly mixed and cut down to form a composite sample. We took, in sampling the whole acre, 720 individual samples. In the samples taken on April 15, 1912, only the surface-samples, i. e., the top three inches, were taken. This land was further sampled by taking vertical sections from the surface down to the water-plane. Three such sets of samples were taken during the period of observation. On one occasion seven such sections were made but on the other occasions we took only six sections. We did not use an auger in taking these samples, but opened a trench, prepared a clean vertical face, and took the samples from this. In order to exhibit still more fully the conditions in this ground, samples of surface-soil were taken from open spots in an adjoining alfalfa field similar in location and character to this land chosen for systematic sampling, and also samples of "brown spots" which occurred within this area. There were no "brown spots" in the alfalfa field. In addition to these soil samples, we also took three samples of ground-water obtained from the trenches dug for making the vertical sections. The acre of land chosen was located so that it gave us a variety of conditions and also included distinct cases of "brown spots." The samples from the open spots in the alfalfa field were taken because this land is as unfavorably situated as that chosen and is the continuation of it westward. This land, except for these spots, is occupied by a fairly good stand of alfalfa. To restate the matter of sampling: We have systematically taken composite samples each representing one-sixth of an acre. We have three series of vertical sections consisting of six members each, samples from "brown spots," surface-soil outside of the "brown spots," surface-soil from similar adjoining land, and samples of ground-water. I regret that this work could not have been done in 1910 and 1911 for the conditions were far less intense in 1912 and the land received much better care in these years than in 1912. The results are again given in parts per million. Each of the following sample, representing one-sixth of an acre, is a composite one containing 60 subsamples. The numbers 1, 2, 3, 4, 5 and 6 represent the same order of sections.

When I went in August to take my samples, I found this land so occupied by weeds, wild lettuce, Russian thistle, etc., that I considered it impossible to obtain satisfactory results and the sampling was given up and there are no general systematic samples subsequent to this date.

ANALYSES OF SAMPLES FROM THE THIRD PLACE CHOSEN.

Samples taken April 15, 1912.

	Nitric Nitrogen	Total Nitrogen	Chlorin
1. 1 to 3 inches	276.0	1,115.2	2,696.9
2. 1 to 3 inches	387.5	1,142.4	1,139.7
3. 1 to 3 inches	367.0	1,074.4	1,542.0
4. 1 to 3 inches	70.0	816.0	412.3
5. 1 to 3 inches	8.0	625.6	66.0
6. 1 to 3 inches	4.0	639.2	156.7
Alfalfa field	40.0	1,353.2	7,693.4
"Brown spot," southwest corner	1,803.0	1,897.2	18,884.0
Brown top soil	10,000.5	14,920.0	14,464.0

Samples taken May 15, 1912.

	Nitric Nitrogen	Total Nitrogen	Chlorin
1. 1 to 3 inches	190.0	992.8	1,797.7
4 to 7 inches	20.0	693.6	634.9
2. 1 to 3 inches	274.9	992.8	948.3
4 to 7 inches	74.8	666.4	659.7
3. 1 to 3 inches	253.1	965.6	329.8
4 to 7 inches	20.0	625.6	602.0
4. 1 to 3 inches	30.0	741.2	602.0
4 to 7 inches	15.0	625.6	371.1
5. 1 to 3 inches	5.0	639.2	140.2
4 to 7 inches	5.0	544.0	329.8
6. 1 to 3 inches	3.0	680.0	338.1
4 to 7 inches	1.5	557.6	359.8
Alfalfa field	80.0	1,761.2	18,554.0
Brown surface soil	3,814.0	5,412.8	12,493.0
12 feet from edge of "brown spot"	7.0	557.6	247.4
"Brown spot"	8,702.0	9,329.6	14,060.8
"Brown spot"	5,312.5	6,120.0	21,935.0

Samples taken June 12, 1912.

	Nitric Nitrogen	Total Nitrogen	Chlorin
1. 1 to 3 inches	253.6	938.4	2,597.5
4 to 7 inches	16.0	673.2	676.1
2. 1 to 3 inches	289.3	1,156.0	8,106.0
4 to 7 inches	194.5	843.2	890.6
3. 1 to 3 inches	324.2	1,081.2	2,185.3
4 to 7 inches	16.0	683.4	593.7
4. 1 to 3 inches	117.1	701.6	808.1
4 to 7 inches	12.0	5,511.6	222.7
5. 1 to 3 inches	24.0	632.4	453.5
4 to 7 inches	4.0	516.8	329.8
*6. 1 to 3 inches	6.0	686.8	313.3
4 to 7 inches	8.0	584.8	907.1
	Nitric Nitrogen	Total Nitrogen	Chlorin
Alfalfa field	20.0	1,999.2	19,024.0
Brown surface soil	6,970.9	7,684.2	23,304.0
Brown soil tree holes	1,228.7	1,873.2	4,813.0
"Brown spot"	15,275.0	17,272.0	18,908.0
"Brown spot"	5,231.5	6,079.2	19,131.0
"Brown spot"	7,077.0	8,500.0	13,812.0
Surface-soil 16 feet from edge of last sample	16.0	591.6	273.9

Samples taken 13 July, 1912.

	Nitric Nitrogen	Total Nitrogen	Chlorin
1. 1 to 3 inches	261.4	952.0	2,482.0
4 to 7 inches	12.0	754.8	667.9
2. 1 to 3 inches	351.9	1,081.2	1,896.5
4 to 7 inches	57.2	686.8	658.2
3. 1 to 3 inches	266.0	897.7	1,467.8
4 to 7 inches	35.0	625.6	247.4
4. 1 to 3 inches	107.8	870.4	676.2
4 to 7 inches	42.2	646.0	272.1
5. 1 to 3 inches	12.0	652.8	247.4
4 to 7 inches	6.0	646.0	164.9
6. 1 to 3 inches	10.0	693.6	123.7
4 to 7 inches	0.5	476.0	206.2
Alfalfa field	25.0	1,788.4	18,743.0
"Brown spot"	11,287.5	13,804.0	15,733.0
"Brown spot"	4,356.5	5,562.4	17,993.0

*This section No. 6 had been irrigated quite recently.

The first set of samples taken for the purpose of determining the distribution of the nitrates in depth was taken 12 December, 1911. While the results are somewhat erratic, I think that this is in a measure, if not altogether, due to the effects of late irrigation. I have, unfortunately, no means of obtaining data pertaining to this feature of the question. These holes, or sections, are arranged in pairs 1 and 4, 2 and 5, 3 and 6. This is done because 1 and 4 are similarly located and are about 50 or 60 feet apart, one being immediately north of the other; 2 and 5 constitute another pair; and 3 and 6, another. This pair, 3 and 6, is located in the very outer edge of the bad territory of 1911, which was apparently quite good territory in 1912. The seventh section was taken in territory which has not, up to the present time, shown serious trouble, if it has shown any trouble at all. The chlorin was not determined in the first series.

ANALYSES OF SAMPLES OF VERTICAL SECTION.

Samples taken 12 December, 1911.

	Hole No. 1		Hole No. 4	
	Nitric Nitrogen	Total Nitrogen	Nitric Nitrogen	Total Nitrogen
1 to 3 inches	422.7	1,128.3	3.0	992.8
4 to 6 inches	85.5	707.2	8.5	870.4
7 to 18 inches	26.0	516.8	20.0	501.4
19 to 31 inches	5.0	442.0	28.0	680.0
31 to 42 inches	0.2	442.0	48.0	469.2
43 to 54 inches	0.1	346.8	50.0	380.8

	Hole No. 2		Hole No. 5	
	Nitric Nitrogen	Total Nitrogen	Nitric Nitrogen	Total Nitrogen
1 to 3 inches	2.8	639.2	18.1	639.2
4 to 6 inches	6.0	605.2	18.5	530.4
7 to 18 inches	2.4	578.0	13.0	578.0
19 to 30 inches	24.0	455.6	28.0	487.8
31 to 42 inches	52.0	448.8	56.0	639.2
43 to 54 inches	80.0	537.2	32.0	516.8

	Hole No. 3		Hole No. 6		Hole No. 7	
	Nitric Nitrogen	Total Nitrogen	Nitric Nitrogen	Total Nitrogen	Nitric Nitrogen	Total Nitrogen
1 to 3 inches	0.8	652.8	24.6	904.4	1.2	829.6
4 to 6 inches	2.4	516.8	12.2	564.4	0.5	639.2
7 to 18 inches	1.6	374.0	9.6	564.4	0.6	401.2
19 to 30 inches	1.2	272.0	2.4	394.4	1.0	306.2
31 to 42 inches	1.2	244.8	2.4	435.2	1.2	326.4
43 to 54 inches	0.8	285.6	2.0	503.2	0.7	306.0

Samples taken 15 May, 1912.

	Hole No. 1.				Hole No. 4.			
	Water-Soluble	Nitric Nitrogen	Total Nitrogen	Chlorin	Water-Soluble	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches	13,475.0	237.4	918.0	3,158.4	3,925.0	52.9	1,020.0	387.6
4 to 7 inches	5,425.0	15.0	664.4	940.0	4,326.0	3.5	700.0	197.9
8 to 19 inches	9,000.0	6.0	530.4	560.7	3,215.0	12.0	556.7	577.2
20 to 31 inches	6,550.0	10.0	489.6	470.0	7,375.0	32.0	605.2	593.7
32 to 43 inches	10,625.0	6.0	448.8	494.8	8,600.0	57.0	503.2	634.9
44 to 55 inches	17,925.0	6.0	462.4	354.6	......	...	......	....

	Hole No. 2.			Hole No. 5.		
	Nitric Nitrogen	Total Nitrogen	Chlorin	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches....	4.5	693.2	206.1	28.0	632.4	123.7
4 to 7 inches....	1.5	401.2	206.1	24.0	508.2	1,154.5
8 to 19 inches....	0.5	435.2	313.3	2.5	557.6	395.1
20 to 31 inches....	16.0	326.4	387.6	Trace	476.0	296.8
32 to 43 inches....	20.0	312.8	321.6	2.0	448.8	123.7
44 to 55 inches....	24.0	244.8	123.7	2.5	455.6	230.9

	Hole No. 3.			Hole No. 6.		
	Nitric Nitrogen	Total Nitrogen	Chlorin	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches....	3.0	693.6	123.7	18.0	843.2	371.1
4 to 7 inches....	2.0	442.0	346.3	10.0	530.4	272.1
8 to 19 inches....	1.0	394.4	164.9	5.0	462.4	288.6
20 to 31 inches....	Trace	285.6	181.4	2.0	367.2	222.6
32 to 43 inches....	None	231.2	296.9	2.0	346.8	222.6
44 to 55 inches....	0.5	387.6	272.1	1.5	367.2	206.1

Samples taken 13 July, 1912.

	Hole No. 1.			Hole No. 4.		
	Nitric Nitrogen	Total Nitrogen	Chlorin	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches....	24.0	680.0	3,474.0	222.7	1,094.8	3,051.0
4 to 7 inches....	2.0	455.6	478.3	20.0	646.0	494.8
8 to 19 inches....	0.5	258.4	371.1	30.0	578.0	907.1
2 0to 31 inches....	24.0	278.8	395.8	12.0	469.2	511.2
32 to 43 inches....	5.0	380.8	494.8	16.0	340.0	288.6
44 to 55 inches....	Trace	350.0	313.3	20.0	530.0	395.8

	Hole No. 2.			Hole No. 5.		
	Nitric Nitrogen	Total Nitrogen	Chlorin	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches....	20.0	625.6	164.9	340.1	1,033.6	1,937.8
4 to 7 inches....	1.0	625.6	82.4	34.5	571.2	453.5
8 to 19 inches....	2.0	455.6	247.4	79.2	591.6	618.3
20 to 31 inches....	32.0	408.0	437.0	36.3	578.0	453.5
32 to 43 inches....	30.0	380.8	371.1	83.7	501.4	395.8
44 to 55 inches....	Water	....	....	71.5	508.2	445.3

	Hole No. 3.			Hole No. 6.		
	Nitric Nitrogen	Total Nitrogen	Chlorin	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches....	2.0	571.2	82.4	24.0	734.4	329.8
4 to 7 inches....	Trace	285.6	41.2	3.0	516.8	329.8
8 to 19 inches....	None	326.4	123.6	2.0	448.8	247.4
20 to 31 inches....	Trace	333.2	181.4	8.0	360.4	164.9
32 to 43 inches....	None	190.4	206.2	5.0	326.4	164.9
44 to 55 inches....	None	217.6	329.8	3.0	401.2	288.6
56 to 67 inches....	....	....	....	1.5	319.6	329.8

There were three samples of ground-water taken from this area, one on 12 December, 1911, and two 15 May, 1912. The sample taken 12 December, 1911, was taken from Hole No. 1. The sample of soil representing the top three inches of this section, carried 422.7 p. p. m. of nitric nitrogen, as is shown by the previous statement of results, and the nitrates diminished very rapidly with depth. The other two samples were taken 15 May, 1912, one from Hole No. 4 and the other from Hole No. 6. One of these samples would have been taken from Hole No. 1, because the preceding sample of water was taken from this hole, but under the conditions I would have had to dig another hole to do so, and as number 4 was only 50 to 60 feet north of it, I took this instead. It would have been better to have taken the sample at the first place instead of at the second, for a few feet, say 50, as in this case, may make too much difference in the composition of the ground-waters to permit of their comparison. This fact is shown by wells one and two given on page 8. These wells were sunk to different depths, but both entered the ground-water. Though these wells were only about twelve feet apart and the corresponding samples were taken on the same dates, the waters are scarcely comparable in any respect. The value of three isolated samples of water is but small in representing the underground conditions in an acre of land, especially as only two of them were taken on the same date. The study of ground-waters presents more difficulties than any subject that I know of and to interpret the results obtained is a very unsatisfactory task. We will give the analyses of these ground-waters for just what they may be worth. We do this, in fact we hold it as indispensable to give them, in order to complete our data regarding this land. This water was met with at different depths from the surface. I assumed that this land was so open and uniform in structure that the water-plane at least would be the same when the holes were dug in level land and only about 50 feet apart. I am not sure that this was true, still in spite of our doubts, we may assume it to have been so. The difference in the water-planes found in December and May was one foot and seven inches. The analytical results were as follows:

ANALYSES OF GROUND WATERS.

	Hole No. 1.	Hole No. 4.	Hole No. 6.
Depth of water-plane	4′ 9″	4′ 2″	8′ 7″
	Water-residue Percent.	Water-residue Percent.	Water-residue Percent.
Calcic Sulfate	20.286	10.174	20.593
Magnesic sulfate	41.753	40.947	32.658
Magnesic chlorid	....	....	7.169
Potassic sulfate	4.027	3.484	....
Potassic chlorid	....	....	3.120
Sodic sulfate	5.042	11.625	....
Sodic carbonate	14.763	8.670	7.129
Sodic chlorid	13.010	13.305	11.495
Sodic nitrate	0.164	11.343	17.528
Manganic oxid.	0.226	....	....
Sodic silicate	0.729	0.479	0.398
Total	100.000	100.000	100.000

Sanitary Analyses in Parts per Million.

Total solids	9,788.000	18,557.000	13,258.000
Free ammonia	0.170	0.310	
Alb. ammonia	0.128	0.525	
Nitrous nitrogen	Trace	Not determined	
Nitric nitrogen	4.000	318.800	441.500
Chlorin	760.000	1,390.300	1,567.000

We have given the results of the examination of thirty-six samples of ground-water which show from no nitric nitrogen up to 441 parts per million. In several cases we find very small amounts in the surface-soil at the time the samples were taken and find that this increased as we gained depth till we encountered the ground-water which was richer in nitrates than any section of the soil. There can scarcely be any doubt but that this was due to the washing of the nitrates down into the soil, which is the direction in which the nitrates are usually found to move. In one case we found that the ground-water before irrigation carried only traces of nitric nitrogen, but after a copious irrigation, whereby the ground-water was raised to within a few inches of the surface, we found 106 parts per million. The evident explanation of this is that the nitrates were dissolved out of the surface-soil and transferred to the ground-water. Three months later when this irrigating water had drained out of the soil, the nitric nitrogen had fallen to less than one-tenth-part per million. I have already stated that the total solids in these ground-waters decreased as the water-plane fell, this was the case in these samples. In July, immediately after irrigation when the water-plane was near to the surface, the total solids carried by the water amounted to 7,862 p. p. m. and the nitric nitrogen to 106 p. p. m. In October, when the water-plane had fallen, the total solids amounted to 1,201 p. p. m. and the nitric nitrogen to 0.04 p. p. m. This water carried, in July just before the ground was irrigated, only a trace of nitric nitrogen. We have here clear proof that the nitric nitrogen was not deposited by the evaporation of ground-water and was not brought into this area from adjoining land by ground-waters.

We have in another case, not referred to in the previous paragraphs, a demonstration of the same facts, i. e. that the nitrates do not come from below and are not deposited on the surface by evaporation of the water. In this case the land was in bad condition, the details of which we will not give. I made persistent inquiry regarding the underground-water conditions and dug a hole to a depth of about four feet, but could not find that the water-plane was very near the surface. The property changed owners and the new owner started to investigate these conditions by having holes dug in order to ascertain the depth of the water-plane. He obtained a small amount of water at about five and one-half or six feet, but there was much less water below this until he reached a depth of sixteen feet, at which depth he found water which was under some hydrostatic pressure. It rose to about five and one-half feet. The water found at about five feet, and that which had accumulated in the cellar under the house, was evidently surface-water which had accumulated at these depths. The surface-water was rich in nitrates, but this water that came from the greater depth contained none, though it was very heavily charged with alkalis; the total solids amounted to 22,104. p. p. m. This water which had percolated through the shales and formed the ground-water at this place, though heavily charged with the ordinary alkalis of the section, which were in no way abnormal in their composition, contained no nitrates and could not have been the source of the nitrates found in the surface-soil. On the other hand, the water that had percolated from the surface and was met with a depth of between five and six feet, was quite rich in nitrates. These nitrates had not been collected by the underground-waters at some distant locality and brought by them to this place and deposited here by their evaporation from the surface of the soil. This was not a newly irrigated district. These under-ground waters had been there for many years and the orchard had grown healthily for thirteen years. The land was alkalized but not worse than the land presented as the first case given in this bulletin. As the ground-water proper contained no nitrates, though heavily charged with alkalis, it was undoubtedly the source of the latter present in the soil, but could not be the source of the former. The nitrates found in the water met with at a depth of between five and six feet had been washed down from the surface and had not been brought up from below, that is they had not been gathered from the rocks of the country nor from other lands affected with this trouble.

There is a practical and suggestive question in this connection which has been raised by intelligent orchardists, i. e. is there danger of spreading the trouble by the inoculation of one soil from another, and by the use of drainage water for irrigation, and further, is there any danger of injury from the use of such water due to the presence of nitrates already formed? I do not believe that there is danger from the latter source, at least, not in general.

THE FOURTH PLACE CHOSEN.

The fourth place selected was a section of country on a mesa where a few years ago no "brown spots" were recognizable, but where they have made their appearance since our earlier observations of this section. The inconveniences and mishaps in collecting our samples at stated times at this place were so great that we succeeded in collecting only a few samples, which we will give as miscellaneous ones. They will be none the less interesting on this account. Perhaps they may be even more instructive. As just stated. a few years ago there were no pronounced, characteristic "brown spots" noticeable. There probably was, in many places, an abundance, perhaps an excess of nitrates, but for the past four or it may be five years there has been no doubt about their presence. The first sample that I will give was taken from a wheat field 4 May, 1912. The soil was a red, mesa clay. The surface was quite white. We judged this to be a case of ordinary alkali. In sampling, only the surface soil was taken, and we obtained the following results in parts per million:

ANALYSES OF SAMPLES FROM THE FOURTH PLACE CHOSEN.

	Nitric Nitrogen	Total Nitrogen	Chlorin
Ordinary alkali soil	14.0	516.8	6,031.8
Ordinary alkali surface soil	80.0	693.6	6,922.0
Brown surface soil	921.5	1,360.0	11,416.0
Very brown spot	5,498.0	5,548.8	17,016.0
Ordinary soil 50 feet away	12.0	612.0	45.3
White alkali soil	40.0	1,319.2	23,584.0
Brown spot	2,962.5	3,631.2	24,038.0
Brown spot	1,044.5	1,672.8	18,678.0
Very brown spot	6,444.5	6,629.6	19,692.0
Twenty feet outside of spot	2.0	435.2	206.2
White alkali soil	24.0	1,210.4	18,117.0

This whole group that we have given as miscellaneous samples was collected within an area of less than five miles in length by one-half mile in width. Some of the spots are small but the last white alkali soil given was from a field of probably forty acres.

An important question suggests itself in connection with the fact that the surface portions of these spots are often, but not always, rich in chlorin. The same thing is true of the surface portions of some other lands where there are no nitrates. There seems to be no general rule which holds good for all soils in regard to the concentration of the chlorin near or at the surface of the soil. We have given cases in which the surface salts were very rich in chlorin and the nitrates were practically absent, and we have also given samples in which the nitrates were very abundant and the chlorin, or the equivalent chlorids, were subordinate in quantity. We have further seen that the ground-water at a depth of about four and one-sixth feet, may be quite rich in nitrates and the surface soil be very poor in them. The water here referred to carries 318.8 p. p. m. while the surface soil carried 53.0 p. p. m., and the second section, 4 to 7 inches inclusive, carried 3.5 p. p. m. of nitric nitrogen.

On the other hand, a sample of ground-water taken only fifty to sixty feet from where this sample was taken, carried only 4.0 p. p. m., while the surface three inches of soil contained 422.7 p. p. m. of nitric nitrogen. In this case nearly all of the nitric acid was within 18 inches of the surface; from the 19th to the 31st inch inclusive, the soil contained only 5.0 p. p. m., and from the 43rd to the 54th inch it contained only 0.1 p. p. m. and the ground-water as stated 4.0 p. p. m. The former ground had been irrigated and the latter probably not.

We regret that we cannot give the results of more extended experiments to determine how the movement of the salts in the soil is influenced by the capillary movement of water in the same, and how the movement of one salt may be influenced by the presence of other salts. If others have studied these problems their work has not come to my knowledge. The work done in connection with this bulletin was too far advanced when the desirability of such a study in this connection became evident to us. We made an attempt to carry out three experiments but this is too small a number of experiments, and the time at our command was too short to arrive at more than tentative results. In these experiments we took a fine, sandy to silty loam which we had previously analyzed. We re-determined the total nitrogen, nitric nitrogen and chlorin. We brought this soil into tubes 1½ inches in diameter and 50 inches long. The tubes were cut into sections, 10 inches long, and united by rubber bands. In one case we brought the lower end of the soil column just below the surface of distilled water contained in an appropriate vessel. The lower end of the second tube was brought below the surface of an eight percent solution of calcic nitrate and sodic chlorid. In the third tube we mixed the calcic nitrate with soil and filled the top three inches of the tube with the mixture. This tube caused us trouble and as we had to try to manipulate the soil in the tube, finally taking out a portion of it and filling up one ten-inch section, there is too great a degree of uncertainty attaching to the results to justify us in giving them. We will give the other two only, i. e. the soil columns in which the distilled water alone or the solution of nitrates and chlorids were used and in which the water rose to a height of thirty-five inches.

DISTRIBUTION OF SALTS IN 40-INCH COLUMN OF SOIL BY THE ASCENTION OF DISTILLED WATER DUE TO CAPILLARITY.

	Nitrogen as Nitrates	Chlorin	Total Nitrogen
	Percent	Percent	Percent
Top 5 inches	0.0012	0.170	0.06120
Second 5 inches	0.0024	0.573	0.06528
Third 5 inches	0.0020	0.354	0.05848
Fourth 5 inches	0.0006	0.061	0.05644
Fifth 5 inches	0.0005	0.034	0.05508
Sixth 5 inches	0.0001	0.029	0.05508
Seventh 5 inches	None	0.043	0.05644
Eighth 5 inches	None	0.028	0.05780

The distilled water in the vessel was about a litre in volume, and it contained small amounts of nitrates and chlorids at the end of the experiment. The amounts of chlorin and nitric nitrogen in the soil, as put into the tube, were respectively 0.1578 and 0.00164 percent, and the total nitrogen 0.05168 percent. The soil was thoroughly mixed so that it was perfectly uniform in composition when put into the tubes. The lower portion of the soil column, i. e. the bottom ten inches, was entirely freed from its nitrates; this may have been due to washing out of the nitrates as well as due to upward movement in obedience to capillarity. The presence of nitrates in the distilled water at the end of the experiment indicates that there was an actual passage of the nitrates from the soil into the water. A third possible explanation for the disappearance of the nitrates might be their reduction, we have not considered this at all, and have paid no attention to the nitrites nor to the ammonia present in either the water or the soil. The duration of these experiments was only thirty days, too short a time, but it was not practical to continue them longer. The water attained a height of thirty-five inches in the case given. We observe that the five inches of soil marking the upper limit of moisture, shows an increase of nitrates, but this increase is insignificant compared with the increase of the chlorin. The original soil carried 16.4 p. p. m., this five-inch section carried 24 p. p. m., but the next five-inch section above this, carried only 12.0 p. p. m. As our results stand they indicate that the movement of the nitrates is probably very far from simple, and where the differences, i. e. gains over the amounts originally present, are so small that they fall below the values found for the nitrifying efficiency of our soils in the same time, it is wholly unsafe to draw even tentative conclusions. These statements are not to be applied to the chlorin for we find a very decided upward movement of this element. In the original soil as placed in the tube we find 1,578 p. p. m. but in the five inches of the column, containing the limit to which the moisture rose, we find 5,730 or 3.6 times as much as in the soil as put into the tube, we find too, that the next five inch section of soil above this shows an increase from 1,578 to 1,600. In regard to the total nitrogen there seems to be an increase as we approach the upper portion of the tube, and in fact throughout the whole soil column.

In the second case that we will give the conditions were different, and had been made so to see what the distribution of these salts would probably be if they were being brought up to the surface from the ground-water which had brought them into solution. For this purpose we made a solution containing eight percent of a mixture of equal parts of calcic nitrate and sodic chlorid.

DISTRIBUTION OF SALTS IN A 40-INCH COLUMN OF SOIL BY THE ASCENTION OF THEIR SOLUTION DUE TO CAPILLARITY.

	Nitrogen as Nitrates Percent	Chlorin Percent	Total Nitrogen Percent
Top 5 inches	0.0010	0.242	0.06120
Second 5 inches	0.0016	0.475	0.06460
Third 5 inches	0.0100	0.748	0.09316
Fourth 5 inches	0.0250	0.604	0.12308
Fifth 5 inches	0.0400	0.481	0.14280
Sixth 5 inches	0.0500	0.459	0.15504
Seventh 5 inches	0.0350	0.601	0.16116
Eighth 5 inches	0.0500	0.703	0.17408

The nitrates did not attain a greater height than thirty inches, while the chlorin reached the limit, forty inches. The quantity of nitrate decreased with the height of the column, the chlorid varied, but showed a maximum in the sixth five-inch section from the bottom. The nitric nitrogen in the seventh and eighth five-inch sections from the bottom contained no more or even less than the soil contained when introduced into the tube. Again the question is evidently less simple than it might at first appear, but it seems very probable that the distribution of the nitric nitrogen is the same that we would find in a soil in which the nitrates had been washed from the surface into the ground-water by a moderate application of water to the surface. The section of this soil as it was taken from the field showed the following distribution of nitric nitrogen down to the depth of 60 inches: one to six inches 109.0 p. p. m.; seven to twelve inches 14.0 p. p. m.; thirteen to twenty-two inches 11.0 p. p. m.; twenty-three to thirty-two inches 6.0 p. p. m.; thirty-three to forty-two inches 2.6 p. p. m.; from this point downward to a depth of sixty inches the nitric nitrogen was constant at 2.0 p. p. m. It does not seem probable that this nitric nitrogen was involved in an upward movement.

DISCUSSION.

We have given the results obtained with the samples as taken without comment, in order that the reader may consider them in detail for himself, but even so it is quite impossible for him to make any reliable interpretation without a knowledge of the varied conditions that obtained at the different places, and at the same place from time to time, and particularly of the conditions which obtained at the time the samples were taken. I have already stated that these conditions in 1912 were decidedly less intense than in the years of 1910 and 1911. While this staement is intended as a general one, it applies specifically to three out of the four places given and to the fourth place, too, with the important modification that in preceding years no nitre spots could be recognized by us, but one spot was definitely located in this year. While this general statement is true, there were a number of places where this condition was much worse than in former years. In fact, it appeared in this year, 1912, in places where it had not previously appeared, or if previously present it had not become sufficiently intense to produce noticeable injury. In one section of the State the trouble etxended very greatly, I call to mind one piece of land which in 1911 showed very little of this trouble, but the conditions in 1912 were very bad. In fact, the garden stuff planted on it was, to a large extent, a failure. The water-plane in this land was from 5 to 8 feet below the surface. The soil was a fine, sandy loam.

The first place chosen was, prior to 1909, an apple orchard. The trees had attained the age of 27 or 28 years, were large, and apparently healthy. There was but little premonitory burning which was not recognized as such until after the fatal attack which destroyed the orchard, that is, killed the trees in a few weeks. The following year it was planted to corn, the next year to cantaloupes, and last year, 1912, to oats. These crops have all been failures. The character of this soil, the location of the land, and its drainage, are all that can possibly be desired. The development of this trouble has ruined it, for the present at least. Samples taken from the surface of this land have shown the presence of from 864 to 3,861 p. p. m. nitric nitrogen. These samples were not taken immediately after irrigation, and were taken in the summer season. The samples of soils presented were taken, those of the vertical section in October, and show that the top six inches of soil contain approximately 218 parts of nitric nitrogen, while the remaining fifty-four-inches sampled contained 106 parts. The surface portion is rich in chlorin. The surface six inches carry 1,863 parts of chlorin, the remaining fifty-four inches carry 8,749 parts. The surface section of soil was taken to a depth of six inches. This is too deep to get the highest amounts of nitric nitrogen and chlorin in parts per million. This would undoubtedly have been found within an inch, perhaps within the surface one-half-inch, still we find that there is a little more than twice as much nitric nitrogen in the top six inches of soil as there is in the succeeding 54 inches. The ratio of nitric nitrogen to chlorin in the surface six inches of soil is 1:8.5; in the remaining 54 inches it is 1:82.5. In the bottom 28 inches of this section we find that the soil carries only two parts per million of nitric nitrogen and an average of 396.5 p. p. m. of chlorin. The ratio of nitric nitrogen to chlorin in this section of the soil, i. e. for the bottom 28 inches, is practically 1:188. On 10 December, 1911, three sets of samples, each representing the surface nine inches, were taken. There were twenty-two samples in each set and these were united to form a composite sample. These composite samples show that the surface three inches contained one and one-half times as much nitric nitrogen as the succeeding six inches and the second three inches contained three times as much nitric nitrogen as the third three inches, but the chlorin in the second and third three inches was exactly the same. It is in this connection that the interesting question of the movement of salts in the soil, and to what extent their movement may be affected by the capillary movement of the water on the one hand and the power of the soil particles to retain the salts on the other hand, has presented itself. This soil is a fine, sandy loam underlaid by gravel which gives free drainage to the river and is so open that the water-plane under this land rises and falls with the rise and fall of the river, so that any nitrates that may find their way into the ground-water have direct drainage into the river.

I have pointed out that in studying the composition of the ground-waters we found this to depend quite directly upon the height of the water-plane and that we had been convinced that this composition came very nearly to representing the soil solutions at that level. This statement pertained only to narrow wells. We found the waters obtained from newly opened wells growing decidedly poorer in dissolved mineral matter as we attained more depth, but I have found no record of any attempt to determine the movement of different classes of salts under these conditions nor how they mutually modify one another's movements.

The soil here considered was all in bad condition; in fact, the nitrates had become so abundant as to make the land for the present time, at least, useless. There were spots in which this action was intense and we find a maximum for the samples given of 1,722

p. p. m. nitric nitrogen and 19,832 p. p. m. chlorin. There was no sample taken below the surface in this case, but the next set of general samples serves to indicate the condition in such intense cases, for they approach the preceding conditions in spite of the irrigations and rains that we happened to find in progress, or which had recently taken place. We found in these general samples 487 p. p. m. nitric nitrogen in the surface three inches with more than 12,000 p. p. m. chlorin; in the next four inches only 20 p. p. m. nitric nitrogen and 1,443 p. p. m. chlorin. There is an abundance of chlorin in the underlying soil to permit of an explanation for the large amounts of it found on the surface by a process of concentration; not so with the nitrates. In what way and to what extent the presence of calcic and magnesic nitrates or their chlorids formed at or near the surface, would affect the movement of the other salts in the soil is not clear and would probably depend upon moisture conditions. In this case we have the rainfalls, the irrigations and even the backing up of the river water in the field, perhaps we should say damming back of the ground-waters, as disturbing factors.

The second place chosen has not been in a desirable condition for more than six years. Some persons think that drainage would reclaim this land. I think that drainage might benefit it, but I doubt most seriously whether this land can now be profitably reclaimed. I have already given my reasons with the full knowledge that some, perhaps many, will call my conclusions into question. My conclusions are based upon somewhat extended observations and, while I wish that I could truthfully state an opposite opinion, I am convinced that drainage is in the first place so difficult as to be infeasible, and, in the second place, I am convinced that the results obtained would be very disappointing. This place is strongly alkalized and in part seeped. We have in this land, both on the surface and in deeper sections, comparatively small amounts of nitric nitrogen and large amounts of chlorin. The ratio of nitric nitrogen to chlorin varies from 1:598 to 1:3,216. In six years' observation of this place, we have never been able to locate but one nitre-spot and that was in 1912. In this case we have a very strongly alkalized area and no nitre. A part of this area is badly seeped in other parts this is not the case; on the contrary, water may not be met with until one attains a depth of nine feet or more. The alkalization and seepage of this land is not something of recent date, but is of long standing, more than six years, at least, and a part of this tract was entirely barren at the beginning of this period. If the nitre and the alkali had a common origin, as a somewhat current, popular view would assert, we should, at all times within the six years during which we have had this land under observation, have found excessive quantities of nitrates. This has not been the case and is not now the case. I have in previous publications stated that land may be so wet as to preclude the occurrence of nitrates, at least such occurences as we have made the subjects of our study. This statement does not apply to the greater part of this land, if it does to any of it. A portion, that is spots here and there in this land, is certainly in bad condiion at the present time. This is not due to nitrates but to water. Within half a mile of this land, however, occur some bad and persistent nitre-spots where there is no excess of water or alkali. Alkalied land and nitre-spots are not synonomous terms, a fact which I have frequently stated. One might think that the surface portion of this soil is the portion richest in soluble salts; this is not the case, at least not necessarily so, for we have found the soil at a depth of two and three feet, richer in soluble matter than the first foot, but so good as free from nitrates. In this land we have a very great concentration of the chlorids in the surface-soil without nitrates, showing that this concentration may be entirely independent of the nitrates. In other cases, we have the nitric nitrogen present in excess of the chlorin. Large amounts of chlorin occur generally with excessive nitrates. This seems accidental and not necessary.

The third place selected was land in a portion of which the nitrates had quite recently developed in very deleterious quantities. In 1909 there was some burning, in 1910 a few trees died, in 1911 a portion of the orchard was destroyed. I counted at one time thirty-five successive trees in a row that had died within two weeks. These were not small, weak trees, but well grown, and previous to this time, healthy appearing trees. "Brown spots" were very marked in portions of this third piece of land selected; in others there was nothing noticeable, but in the greater portion, the whole surface showed by its general color the presence and activity of the Azotobacter. This section of the land, particularly in 1911, was puffed up and oily looking. I do not recall having at any time seen an incrustation of alkali on it. This may have been due to the careful cultivation that it received. I think that this is probable, for adjoining land, similarly located and separated from this by a wire fence, did show such incrustation where it was not occupied by a good stand of alfalfa. We took a large number of samples from this third place, representing the alkali ground in the alfalfa field, the surface soil of one acre of the orchard land to a depth of seven inches, the top three inches being taken as one sample and the succeeding four inches being taken as a second sample. We also made in all nineteen sections of this acre of land, digging in each till we encountered water. From these sections samples were taken forming a continuous section, usually to a depth of fifty-five inches, but the maximum depth to which any set of samples was taken was sixty-seven inches. There were also other samples taken. especially samples within the "brown spots" mentioned as occurring as distinct spots in some portions of this land; and others taken just outside of these spots; also some of the ground-water. The conditions in 1912 were better than in 1911, and we found only moderate quantities of nitrates in 1912 in sections of this land in which they were very evident in 1911.

I raised the question in Bulletin 155 in regard to the amount of nitric nitrogen that we may expect to meet with in good, cultivated soils. especially in the surface portions. We concluded that in general from five to eight parts per million would be found to be a usual maximum, but that 30. 40. and 50 are not unusual amounts to find in our lands, particularly if fallow. We also found like quantities in cropped land absolutely free from seepage. In cultivated fields we have found 120 to 160 and 200, and have shown that the amount may vary in a cultivated field up to 330 p. p. m. I do not think that the finding of from 30 to 50 or more p. p. m. of nitric nitrogen in alkali incrustations, which usually means the soil and effloresced alkali scraped up together off of the surface of the land, is at all significant of the association of the nitric nitrogen and alkali, for we find such amounts in land which we would consider entirely free from alkali.

The distribution of the nitre in the surface-portions of the land is set forth by series of composite samples, each composite sample consisting of 60 sub-samples. The sample from the alfalfa field was likewise a composite sample of about 20 sub-samples, but these were taken from the surface with a shovel and not with a soil tube. These samples give a section of the land selected beginning with the alfalfa field and crossing the area of active fixation and nitrification, to a section where. in 1912, it was very moderate, perhaps no more than normal, for our lands.

This section, beginning with the alfalfa field, shows 20 to 8c p. p. m. of nitric nitrogen. reaches a maximum of 367 p. p. m., and then passes to a minimum of 3 p. p. m. We find that the surface three inches carry by far the larger part of these nitrates. The alfalfa land sampled was free from vegetation, but was quite strongly alkalized. The orchard land was not strongly alkalized, but the brown color, due to the Azotobacter pigmentation, could be traced with the greatest ease and detail in 1911 throughout this land. In 1912 this was the case only in portions of it, and these portions are as clearly designated by the analytical results as the brown areas were distinct to the eye. I have no doubt that I could have collected samples, taken to a depth of three inches, in any one of these six sections, which would have shown either very low or very high results. and if I had sampled the acre of land in the direction at right angles to that in which I did sample it, I could have shown that the whole acre of land was exceedingly uniform in its content of nitric nitrogen. and all very rich or moderately poor. according to what state of things I wished to prove. We will illustrate this in later paragraphs. We content ourselves. for the present, with showing that the distribution of the nitric nitrogen in the surface-soil is exceedingly irregular and is independent of the distribution of the alkali, and with the observation that portions of this land which were very bad in 1911 were by no means bad in 1912.

In regard to the vertical distribution of the nitrates. the samples taken in December, 1911, a few weeks, six to eight weeks, after the fall irrigation, indicate, in the main. that the nitrates had been washed down into the soil and the ground-water.

This land is not drained. It has never been considered wet enough to require draining. An important question in this connection, is that regarding the lateral movement of the ground-water, if there be any. I think that any lateral movement that there may be is comparatively slow. This. however, is merely an opinion at which I have arrived from observation and is not proven by direct experiment. I do not think that I have at any time found the water-plane, even in the lowest-lying hole that we dug, less than four feet, six inches below the surface. In a hole dug at another point I found water near the surface. but at this particular point the trees were still in good condition. It is just to state in this connection that I thought, at the time that the water-plane in this instance was temporarily higher than usual. Be that as it may, the water was high and the trees were well grown and healthy. I am strongly of the opinion that the ground-water found in any given hole in this land, belongs, for the most part, just where we find it. That there may be some lateral movement is possible. but I think that this is very small, if it exists at all.

We find that in holes 2, 4 and 5, opened in December, 1911, that the nitrates increase with depth till we reach the water-plane, but that the amounts, compared with some of our results, are not very remarkable, the maximum being 80 p. p. m. I believe that this is due to the fact that the nitrates were washed from the surface into the soil, and had these localities had a little more water applied, we would have found the surface and succeeding portions still poorer, but possibly in the same order that we now find them. In holes 1 and 6 we find the reverse to be the case. This is shown very markedly in the results obtained with the samples taken in Hole No. 1. in which we have 422.7 p. p. m. in the top three inches and only 0.1 p. p. m. at a depth of 4½ feet. Hole No. 6 shows the same facts. but the amounts of nitric nitrogen involved are so small, 24 p. p. m., being the maximum, that it, for our present purposes, may be neglected. The spot where Hole No. 1 was dug, had probably failed to receive any considerable irrigation and the whole summer's formation had probably remained at the surface. This is suggested by the fact that the sample of ground-water taken from this hole at this time, contained only 4 p. p. m. nitric nitrogen, a quantity less than is found in some deep wells. The total solids in this water, however. was nearly 10.000 p. p. m. The hole dug close to this at the next sampling showed the same facts quite as strikingly as this one. In these samples we determined the water-soluble to see if there could be discovered any relation between this factor and the nitrates. We obtained for the surface three inches of soil the following results: Water-soluble. 13.475 p. p. m.; nitric nitrogen, 237.4 p. p. m.; for the twelve inches from 44 to 55 inches inclusive, water-soluble 17,925 p. p. m.; nitric nitrogen 6.0 p. p. m. We find the nitric nitrogen to diminish very rapidly with even slight depths, unless it has been carried down by rain or irrigating water, and in this land we nowhere find excessive quantities of nitrates. except where we can readily and with certainty recognize the brown pigmentation of the Azotobacter. The nitric nitrogen found in the surface section, three inches, is less than is found for the composite sample made up of 60 samples representing a sixth of an acre.

The extremely variable results obtained by taking such sections of soil is well shown by these 19 sections, as the numbers in each set have the same significance. The three sections numbered 1 were taken as close together as I deemed advisable, so of number 2 and the succeeding ones. I fear lest I erred in taking them a little too close together. Holes 1 and 4 were only about 55 feet from one another and yet we find altogether different conditions, and the same is true of holes 2 and 5, which were the same distance apart. The same may be said of these taken in pairs the other way, i. e., 1 and 2, 4 and 5. We observe the same irregularity on the surface of the soil and we can, using the brown color as a guide, pick out these irregularities with all certainty. Hole No. 6 was located in ground that was bad in 1911 but showed no injury in 1912, while the Hole No. 7 was located in territory that has never shown any trouble. We find the nitric nitrogen in the samples taken from these vertical sections, decreasing rapidly with depth, and in case of number 7, surprisingly low for our soils.

In regard to the ground-waters collected from these various holes, we find a very great variation, indeed, just as great as we find in the vertical or lateral distribution of the nitrates and other salts. I have already stated the chief features of the ground-water obtained from Hole No. 1. The second sample of ground-water taken from this sixth of an acre was taken from Hole No. 4. The water-plane was 4 feet 2 inches below the surface. The three-inch-sample of surface-soil contained 52.9 p. p. m. nitric nitrogen. The foot terminating at the water-plane, contained 57.0 p. p. m., while the intervening sections varied 3.5, 12 and 32 p. p. m. The total solids in this ground-water were 18,557 p. p. m. and the nitric nitrogen 318.8 p. p. m. The other sample of ground-water carried 13,-258.0 p. p. m. water-soluble with 441.5 p. p. m. nitric nitrogen, while the surface-three-inches of soil carried 18.0 p. p. m. nitric nitrogen, which at a depth of 55 inches had fallen to 1.5 p. p. m. The water-plane at this time was 8 feet 7 inches below the surface. This same land was brown in 1911 and the trees died. These facts even do not convey a full idea of the uneven distribution of the nitrates in this soil. We have seen that we can pick areas of one sixth of an acre, so that they will show wide variations. We have further shown in this single piece of land the same thing that we have used other individual pieces to show, i. e., that there is no connection between the ordinary alkali and the nitrates. The vertical distribution of the nitrates, as exhibited by the nineteen vertical sections made of this land, is certainly perplexing. We find a large amount in the surface-soil of one section with the water-plane four feet nine inches below the surface. The nitric nitrogen decreases rapidly in this section from 423 p. p. m. of the air-dried soil to less than one part. This difference is very great as becomes more apparent on calculating this nitric nitrogen to the sodic salt. When we find 2,538 p. p. m. in the surface three inches and less than one part in the lowest foot taken. The ground-water taken 12 hours after the trench was dug contained only 4 p. p. m. of nitric nitrogen or as sodic nitrate 24 p. p. m. This sample of water should have been taken when the hole was first opened and should not have been allowed to stand. We have in the surface-portions of this soil large amounts of nitrates and in the ground-waters only small amounts and in the intervening soil still less, in fact, as good as none. These facts may be remarkable, but this is the way we found them. There was no incrustation on this soil. The ground-water carried 9,788 p. p. m. of total solids. If we assume that these 2,538 parts of nitrates, calculated as sodic nitrate for convenience.

owe their origin to the evaporation of this ground-water brought to the surface by capillarity, we have to answer the following questions: How long has it taken to do this? What has become of the associated salts which we know are readily moved through the soil by capillarity? In regard to the first question, we have only the testimony of the trees. They lived and grew healthily till the season of 1911. A few of them showed distress in 1910. These nitrates were not present in deleterious quantities at this place till the season of 1911, so the concentration must have taken place very rapidly. To furnish the amount of nitrates in the surface three inches of this land per acre would require the evaporation of 40.4 acre feet of water, which we found four feet nine inches below the surface. Can this be done in this time? Our actual evaporation is less than 60 inches *per annum* from a free water surface (it is 41 inches at Fort Collins) and the evaporation of 40 acre feet of water from the surface of this land would require about eight years, provided it presented a free water surface, but we found this free water 4¾ feet below the surface. Further, what has become of the million pounds of other salts which this water holds in solution? This is not the only trouble. We find within 60 feet of this, entirely different conditions. The ground-water is practically the same distance below the surface, if there be any difference the water is a little nearer the surface in the second case; but there on the same date, so that there is no question of weather conditions, we find 2 p. p. m. in the surface three inches which at a depth of 54 inches reaches 80 p. p. m. and the ground-water contains 318 p. p. m. of nitric nitrogen and 18,557 p. p. m. of total solids. Why is the surface portion so poor in nitric nitrogen and why do the nitrates increase with depth till we find the ground-water much richer than the soil? The answer that I offer is that the late irrigation had washed these nitrates into the deeper portions of the soil and into the ground-water. While our conditions are involved and our data difficult to interpret, there is nothing to indicate that, in fact, these nitrates ever moved back to the surface. My conviction is that in the case of the first hole dug we selected a spot which had escaped with a light irrigation or without any. There was no reason why the people should be careful about the distribution of the water, as the trees were already dead. The nitrates found were those that had been formed there during the preceding season. The fact that these trenches had to be dug in slightly different places for the different sectional samples is unfortunate because a difference of two or four feet may make every difference as our surface samples, taken only a few feet part, fully demonstrate.

We have given samples taken from alkalized land showing respectively 0, 40, 80, 20 and 25 p. p. m. nitric nitrogen associated with 7,693.4; 18,554.0; 19,024.0; 18,743.0 and even 261,000.0 p. p. m. of chlorin. We also selected surface samples from brown spots which showed but slight or no incrustations of white lakali. Very pronounced brown spots gave 8,970.9; 1,229.7; 15,275.0 and 5,231.5 p. p. m. nitric nitrogen. The chlorin in these cases was high, but without any definite relation to the amount of nitric nitrogen. We have for instance in the white alkali 20 p. p. m. nitric nitrogen with 19,024 p. p. m. of chlorin. In a very extreme brown spot we have 15,275.0 p. p. m. nitric nitrogen and 18,908 p. p. m. chlorin. We have before now tested such spots and found no living bacteria in the surface, but they were alive a few inches below it and at the edges.

The surface soils of sections 4 and 5 gave respectively 117.0 and 24.0 p. p. m. nitric nitrogen. A brown spot lying just between these sections gave 7,076.0 p. p. m., while a sample taken just outside of the brown spot showed only 16.0 p. p. m. of nitric nitrogen. At another time the inner portion of this spot gave 10,000.5 p. p. m. nitric nitrogen This ground is about equidistant from holes No. 1 and 2, probably a little nearer to hole No. 2. These facts are general. I have elsewhere stated that the Azotobacter pigments are not the cause of all brown spots any more than nitre is the cause of the death of all trees. I recall stating that one dark colored piece of land owed its color to the presence of calcic chlorid and others to the presence of salt, and others simply to organic matter. But usually we can recognize the brown spots due to the Azotobacter pigments. I selected another place to make observations similar to those just recorded, but we were so unfortunate in taking our samples, mostly due to the weather, that I have given the samples taken the weight of miscellaneous samples, though they are really members of a sadly broken series. The nitrates developed for the first time in this section of the country about 1909. Previous to that if present, as I suppose they really were, their development was not prominent enough to attract attention. There is an abundance of alkali all over this mesa, which was apparent the first time that I saw the section. Samples of soil rich in alkali gave 14 p. p. m. nitric nitrogen, ordinary white alkali soil, surface, 40 p. p. m. nitric nitrogen, and 235,584 p. p. m. chlorin, while a very brown spot showed 5,498.0 p. p. m. nitric nitrogen with 17,016.0 p. p. m. chlorin. This spot was exceedingly sharply defined. A sample taken almost at the edge of this carried 12 p. p. m. Some spots at this place that were very bad in 1911 had entirely disappeared in 1912. These spots do not by any means always occur in unfavorably located land.

The only condition that seems indispensible to their development is a constant and fairly abundant supply of moisture and a chemically alkaline soil. We have recorded samples taken from a cultivated field on the same date which showed the presence of from 5.0 to 150 p. p. m., and again samples taken from the same field on different dates which gave from 65 to 100 and even 333 p. p. m. of nitric nitrogen.

RÉSUMÉ

The occurrence of "brown spots" has been complained of from time to time for years past. The first ones that I saw, to recognize as being rich in nitrates, were in uncultivated land in the extreme southern part of the state. These were round or eliptical spots, smooth and shining on the surface, and had an almost black color. They were wholly destitute of vegetation. The rocks forming the neighboring mountains were granites and schists. The strata underlying this soil were sands and clays of lacustrine origin. The waters of this section are exceptionally pure and are acid in character, i. e. the most of them, surface waters excepted, contain more acids than are necessary to combine with the bases; silicic acid is usually in marked excess. Other occurrences are in Cretaceous and still others in Triassic areas. Some of these brown spots are small and isolated, in other cases they have coalesced and cover comparatively large areas—twenty, thirty or more acres from which the vegetation has, in many cases, been exterminated. The barrenness of these spots has not in all cases been permanent, in other cases it has been very persistent. These spots in 1910 and 1911 were very common in some sections of the state, and but few cultivated sections in the state, with which I am familiar, are entirely free from them. We have some marked cases of their occurrence in this immediate neighborhood which is within forty miles of the northern boundary of the state, and I have seen them almost on the southern boundary line. They also occur in the extreme eastern and western parts and at various altitudes up to 7500 feet.

Their appearance is peculiar, usually the soil is mealy and from a light brown to almost black in color, varying somewhat with the soil. That they have spread during the past seven years is evident from the statements made concerning the damage done. Lands that were considered desirable five years ago are now of little value and where four years ago, only an acre or two was known to be affected, many acres are now involved. These spots are not confined to any particular variety of soil or to any particular geological horizon. They occur on well drained land as well as on land that contains an abundance of water. In some cases the muddy condition of the land seems to be a result rather than the cause of this condition.

These spots are characterized by their brown color. In some instances they appear smooth and shining, but usually they are soft under the foot, mealy, and at a little distance give the impression that they are moist. In orchards where oil has been used for heating one might readily take small spots as due to spilled oil or contrariwise, an oil spot for a nitre spot. The amount of water-soluble salts in the surface portions of these spots, varies exceedingly. By surface portion, I mean all depths up to three inches. These spots do not, as a rule, show efflorescences which is characteristic of alkali spots. There is sometimes an incrustation. The maximum amount of water-soluble found in a selected sample of this brown surface incrustation amounted to 22.5 percent, of which 29.1

percent was sodic nitrate, 12.0 percent was sodic chlorid and the other salts were sulfates. Another exceedingly rich sample yielded 13.4 percent of water-soluble, of which 41.86 percent was nitrates, 10.0 percent chlorids and the rest sulfates. The occurrence of very small amounts of sodic carbonate in the aqueous extracts of soils from these spots is noticeable, in fact the carbonates are more frequently absent than present. Calcic carbonate, however, is always present, and usually abundantly so, in these soils. It should also be stated that our common alkalis seldom contain large amounts of carbonates. There does not appear to be any relation between the amount of nitrates and that of any other class of salts present. Our alkalis consist of sulfates and chlorids, the carbonates being very subordinate in quantity. Sometimes the sulfates, sometimes the chlorids, and at other times the nitrates are the predominating salts in the water-soluble portions of these brown spots. For example we have sulfates 90.0, nitrates 8.2 and chlorids 1.5 percent; again nitrates 50.2, chlorids 38.2, and sulfates 9.9 percent; again nitrates 35.6, chlorids 33.6, sulfates 28.3 percent; again chlorids 67.4, nitrates 15.4, sulfates 15.1 percent; again sulfates 46.9, nitrates 41.9, chlorids 10.0 percent; again sulfates 80.4, nitrates 15.1 and chlorids 4.1 percent. The last sample given is the extract from a gypsiferous, clay soil, and calcic sufate was the only sulfate present. Our ordinary white alkali is essentially a mixture of sulfates, but occasionally is very rich in chlorin. It seldom carries more than a trace of nitric acid and is often entirely free from it. I have, when possible, given the nitric acid as sodic nitrate. This, as elsewhere stated, has been done as a matter of convenience. The nitrates present in some cases are certainly those of calcium and magnesium and these salts are probably always present but not necessarily to the exclusion of other nitrates.

The fact of the existence of these spots is no longer in question, nor are the results due to their formation. The extermination of vegetation in these areas, involving the killing of many acres of old, well established apple orchards, has been observed in many places, and there is no question but that the nitrates are the cause of this. This question was naturally the first one suggesting itself. Neither the sulfates nor the chlorids produce the changes in the trees observed in these cases and nitrates do. The trouble complained of is characteristic and is common to all the cases that we have observed.

The origin of these nitrates, however, may be questioned. The first explanation offering itself was that of concentration. In this event water seemed to be the only possible carrier. Our irrigating waters do not carry nitrates, for the most part they are snow-waters; our ground-waters do not carry greater quantities of nitrates than may be found in drain-waters from other lands, the same is true of our drain-waters unless they be from badly affected areas. Our well waters are not richer in nitrates than it is usual to find such waters. I have given in Bulletin 178 analyses of two most extraordinary well waters which contain nitrates. Our soils are not rich in organic matter or as a rule in nitrogen so that ordinary nitrification and leaching cannot account for it. Seepage and ground-waters may be very heavily charged with alkalis but ordinarily contain only small amounts of, or no, nitrates. We mentioned nitrate areas in locations surrounded on three sides by alkali and seeped lands, but these locations themselves are well drained. The nitrates in these locations are not derived from the alkalis and seepage water from these adjacent lands for the following reasons: These adjacent lands contain only such quantities of nitric nitrogen as soils in general may contain. The alkalis, even the efflorescent ones, taken together with the surface portion of the soil, contain no nitrates; the ground-water underlying this seeped section contained no nitrates, therefore this land, though rich in alkalis and seeped, could not be the source of the nitrates found in the nitre areas. Further the drain-waters flowing from a drain laid through a portion of this land, but not under a nitre area, while comparatively rich in alkalis, carrying some 9,000 parts total solids per million, carried only 0.1 p. p. m. of nitric nitrogen. The nitrates found in these spots could not have been derived ready formed from these outside sources. The land was well drained; three out of five drains laid in this land drew no water except after irrigation. There is no unusual amount of the ordinary alkalis in this soil. Vegetation does well in this land except in these spots. The soil itself, except in these spots, is not rich in nitrogen and here it seems to be largely in the form of nitrates. The evaporation of the ground-water that underlies this land would yield large amounts of the ordinary alkalis but no nitrates, or very small amounts, and as the land is level and uniform in character and texture, there is no reason why the deposition should not be general over the surface and not confined to spots. The fact is that the nitrates are confined to the brown spots. All of these considerations were weighed before Bulletin 155 was written, and the question asked, whence comes the nitrogen. Our investigations had shown that it did not come from the adjoining lands, nor from below and the land itself does not ordinarily contain it, but still there is no question of its presence. It was not always there, for the beginning and cause of this trouble had been observed and unsuccessfully combated. In 1904 this land was free from this trouble, in 1909 apple trees and garden vegetables could not maintain themselves against its influence. Besides, the spots were extending their boundaries. It was not a stationary thing, but was growing. The adjacent land had in the meantime not changed materially; it continued to be barren of nitrates, but the seepage condition was growing worse; this, however, did not, and does not now affect this land. Between 1906 and 1908 the trouble began to be recognized here and there without knowledge of its cause, but in 1909 it began to destroy orchards over larger areas, and the nitrates were recognized as the direct cause of this. From 1909 on, the annual loss of trees due to this cause, has been great. This trouble has varied in intensity, having been apparently most sever in 1910 and 1911. The distribution of these "brown spots" in any given piece of land is very erratic and the "brown spots" are often, one may say usually, sharply defined. Such considerations eliminate the waters, the alkalis and the neighboring lands as sources of the nitrates or of the nitrogen contained therein. In Bulletin 155 of this Station, I suggested the atmosphere as the source of this nitrogen and fixation as the means of transferring it from the atmosphere to the soil. The most probable agency having the power to accomplish this seemed to be the Azotobacter. Examination of these soils proved these organisms to be present in great abundance, except in areas too rich in soluble salts, but they were abundant at the edges of such areas, and below the surface. The Azotobacter form a brown to an almost black pigment. The formation of this pigment has been shown by Professor Sackett to be conditioned by the presence of the nitrates. The "brown spots" are rich in Azotobacter, either throughout or at their edges and below the surface, the nitrates are present in exceptional quantities and the spots are recognized by their brown color. Our soils when incubated without the addition of any carbohydrate, show a marked fixation of nitrogen. My own results showed a fixation of 10.54 milligrams for each 100 grams of soil in 27 days and the moist soil kept at the room temperature showed an increase of 4.82 milligrams in the same time for each 100 grams of soil. It is usual to add glucose or mannite to furnish energy but an ordinary cultivated soil fixed these quantities without any addition of any kind except boiled, distilled water. That energy was necessary there can be no doubt, that it was not added in the form of glucose or mannite is also certain. If it was used, as we agree it must have been, it must have been derived from the soil itself, but our soils are not remarkably rich in organic matter. The total nitrogen was found to be 0.1075 percent at the beginning of the experiment. Other analyses of this soil gave the total nitrogen as 0.147, humus 0.426 and ignition 5.072 percent. These are facts which we have recorded in Bulletin 178. My experiments do not stand uncorroborated. Professor Sackett obtained very similar results with other soils. I do not know the conditions in our soils which may possibly limit this ability to fix the atmospheric nitrogen. The conditions of my experiments seem to give rise to a strong development of Azotobacter. This soil at the beginning of the experiment gave a very moderate culture of Azotobacter, but after thirteen days another sample gave a remarkably strong one which developed the brown pigment within nine days. This soil, as are all of our soils, with almost no exceptions, is alkaline in reaction. The nitrification, too, in these samples without the addition of anything except distilled water which had been boiled to expel any traces of ammonia that might be present, was very marked. We found a maximum gain equal to 138 percent of the nitric nitrogen present at the beginning of the experiment which was 35.0 p. p. m. Professor Sackett has studied this subject more thoroughly and systematcally with interesting results, one of which, with his permission, I use, i. e. some of our soils show a nitrifying efficiency 173 times greater than an Iowa soil which I understand was a typical one. The increase in the nitric nitrogen present in this soil in six weeks was 1040 fold. I have personally done nothing with the ammonifying efficiency of our soils, but Professor Sackett has presented the results of his investigations of this subject in Bulletin 184 of this Station, from which it appears that the ammonifying efficiency of our soils is from two to three times greater than average soils from other localities for which we have comparable data. Two of Professor Sackett's conclusions are as follows:

"Soils in the incipient stage of the nitre trouble appear to surpass our normal soils in ammonifying efficiency.' "Compared with soils from other localities, our nitre soils excel in ammonifying efficiency."

It has been stated and emphasized that our soil conditions seem exceedingly favorable to the development of bacteria, especially such as require an alkaline medium for their development.

It is stated in Bulletin 178, p. 90, that quite a vigorous development of algae and diatoms took place on the soil that I used in my incubation experiments when it was exposed to the light in a culture dish. I have since that tested other samples of soil and found that they all yielded an abundant growth of algae. Mr. W. W. Robbins has taken up the subject systematically and has published some of his observations in Bulletin 184. Out of twenty-two samples of soil taken for experiment, only two failed to give a growth of algae, and one of these was a sample of raw, uncultivated, adobe soil. This abundant presence of algae has been mentioned as a possible source of energy.

SUMMARY AND CONCLUSIONS.

Our soils, as is shown by numerous analyses, are not unusually rich in nitrogen. They are only moderately well supplied with it and the unusual amounts of nitrates found cannot be produced by the nitrification of the supply already in the soil, but this supply must be supplemented by nitrogen from some other source, we believe that this other source is the atmosphere.

The nitric-nitrogen does not owe its origin to the same sources that furnish our ordinary white alkalis which, beyond question are decomposition products of our common minerals, but principally of the feldspars, by agencies now at work.

The distribution of the nitrates in our soils cannot be consistently accounted for by any theory of concentration of pre-existing nitrates. Their distribution is wholly independent of that of the alkalis—the latter being practically free from nitrates, as much so as a great many of our soils, while the aqueous extract of our soils, especially those showing the brown color due to Azotobacter, are extremely rich in calcic and magnesic nitrates.

The ratio of the nitric to the total nitrogen in many of our soils, particularly in the surface portion of the brown spots, is very high due to fixation and nitrifcation.

The deeper portions of the soil under these brown spots are usually poor in nitrates, but irrigation or rainfall may carry the nitrates on the surface downward, even into the ground water. While the solutions of potassic and sodic nitrates show capillary action, it is doubtful whether the calcic and magnesic nitrates do not move downward, especially in soils that are quite moist, rather than upward. The calcic and magnesic nitrates do not show capillary movement exposed in glass vessels, as do sodic chlorid and nitrate, ammonic chlorid and many other salts.

The solubility of the nitrates contributes to their easy and rapid removal by downward moving waters. The soil seems to have but little or no power to retain these salts, nitrates, so they pass readily into the drainage waters of the country, but our ground and drainage waters are rich in nitrates only when they come from nitre areas. Of the many ordinary and artesian well waters that I have examined, I have found but two that contain unusual quantities of nitrates. I have described these in Bulletin 178.

The shales and sandstone do not furnish these nitrates or else all of our well waters would be rich in nitrates, but they are not richer in nitrates than well waters usually are. These well waters, both from ordinary and artesian wells, are usually quite rich in the so-called alkali salts, but not in nitrates.

These nitre spots occur in sections where these shales and sandstones do not occur, and consequently cannot be derived from them. These facts were known to us before we published anything upon the subject, and this process of elimination led us to the views adopted before we had any results of bacteriological experimentation at our disposal. If the alkalis and nitrates have a common origin they should have a common distribution, but this is not the case even for very limited areas. If they owed their origin to leaching then the ground-waters found beneath these lands should contain notable quantities of nitrates, but this is not true and the nitrates are localized in the brown spots to such an extent that the people have made this characteristic the distinguishing one in their complaints.

The nitrates might make the soil more hygroscopic but there is nothing in them *per se* to produce a color, but Azotobacter in the presence of nitrates, do produce a brown, almost black, color. The brown, often almost black, color is characteristic of these spots and samples of soil taken only a little way, a few feet, from these brown spots, contain no unusual amounts of nitrates. This is true to such an extent that I believe it quite possible to collect samples within a few inches of one another, one of which may show only ordinary amounts of nitric nitrogen and the other from hundreds to thousands of parts per million.

The burden of the complaints made is of "brown spots on which nothing will grow." These spots have appeared in cultivated land, much of it otherwise very good land, not seeped nor saturated with alkali and not deficient in drainage.