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RAILROAD VALLEY COMPANY

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E. E. Free

Railroad Valley Company

POTASH

REPORT OF

E. E. FREE

Railroad Valley Company

ORGANIZED UNDER LAWS OF
STATE OF NEVADA

Capital $1,000,000—One Million Shares—$1.00 Each
Fully paid and non-assessable

MAIN OFFICE

308-9 State Bank Building, Tonopah, Nevada

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Railroad Valley Land & Water Co.

ORGANIZED UNDER THE LAWS OF
THE STATE OF NEVADA

Capital $500,000—500,000 Shares—$1.00 Each

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INTRODUCTION.

The main object of the Railroad Valley Company is to discover valuable potash salt deposits. We are drilling in the Railroad Valley (Nye County, Nevada) basin for a potash salt or brine deposit supposed to exist in the lowest depression in the bottom of a former lake, now buried. The present well is 1200 feet deep and results to date are inconclusive but strengthen the general theory. It is possible that three wells may be required to locate the potash body.

We have also started a comprehensive research in other localities of the Great Basin, where geological and former lake conditions are favorable. This research is under charge of Mr. E. E. Free, formerly of U. S. Bureau of Soils in charge of Desert Basin Potash Research of the United States Government.

Incidental to its main object the Railroad Valley Company will develop any agricultural possibilities indicated by its potash explorations. Any basin that indicates buried potash bodies is almost sure to be an artesian water basin as well, as both possibilities depend upon similar topographic conditions. These basins usually contain large areas of fertile land, which artesian water will make very valuable.

In Railroad Valley the drilling to date has already established an important agricultural possibility. The Railroad Valley Land and Water Company, a subsidiary corporation operated in the interests of the Railroad Valley Company, has acquired this artesian basin, and in the judgment of experts should in time develop a land value great enough to make the shares of the Railroad Valley Company worth par.

The following discussion by Mr. Free upon the subject of potash and the possibility of its discovery under the "Dry Lake Theory," and interpretation of the development record in Railroad Valley, is published to meet requests of stockholders and other interested parties for details of the scientific evidence upon which we base our undertakings.

RAILROAD VALLEY COMPANY.

August 22, 1912.

Potash and the Dry Lake Theory.

POTASH, USES AND SOURCES.

Outside of museums the metal potassium is known only through its soluble compounds or "salts," for any or all of which the term potash is the common designation. The salts of potassium have many and varied uses, by far the greatest of which is in the manufacture of artificial or "commercial" fertilizers. Such fertilizers are of various types, but the so-called "complete fertilizer" contains three essential ingredients—potash, phosphate and nitrogen. The use of such fertilizers—and hence the use of potash—is very rapidly on the increase, not so much because soils are "wearing out" as because the increasing scarcity of land is making necessary a greater soil productivity and more and more intensive forms of agriculture. In the United States this intensification of agriculture has scarcely more than begun, but it must both persist and increase if we are to feed our rapidly growing population. And intensive agriculture means fertilization, *regardless of the richness or poorness of the soil.* Indeed, it is the universal experience that fertilizers yield the greatest increase and are most worth while not on the poorest soils but on the best. Artificial fertilization is not so much a remedy for poor or mistreated soils as it is a necessary and universal accompaniment to the cultivation of all soils. There is every reason to expect a continued and very rapid increase in the use of fertilizers and, since potash is nearly always an essential constituent, this means a large and increasing use of potash.

A half century ago, when potash was made entirely from wood ashes, there was a flourishing potash industry in the United States, but under the competition of the cheaper German salts this industry has declined almost to nothing, and practically all the potash now consumed is imported. The volume of these imports is indicated in the following table:

Importation of all forms of potash salts.*

Year.	Short Tons.	Value.
1900	358,736	$5,237,560
1905	568,979	8,639,039
1910	899,196	11,615.134
1911	1,074,172	16,269,408

*This table is compiled from Phalen—Potash salts, their uses and occurence in the United States, U. S. Geol. Survey, advance chapter from Mineral Resources for 1910; and from Phalen—Potash salts, Summary for 1911, same, 1911.

In this table figures for calendar year and fiscal year have been added together without distinction, the error thus introduced having no effect on the general meaning of the table. Of the potash imported probably three-fourths or more goes into the manufacture of fertilizers, and it is this use that is so greatly increasing and is responsible for the recent rapid rise in potash imports. At the present time on the Atlantic seaboard crude potassium nitrate (niter) is worth about $65.00 per short ton, potassium sulphate about $45.00, and potassium chloride (or "muriate") about $35.00. There is every prospect that these prices will rise rather than fall.

THE GERMAN POTASH SALTS.

Practically all the potash of the world now comes from the mines at Stassfurt, Germany, controlled by the German potash monopoly or Kali Syndicate. At this locality various soluble potash salts occur in solid form and associated with large amounts of common salt and gypsum and with various salts of magnesium.

The potash was discovered by accident. From very early times brine springs and wells had been known in the Stassfurt region, and common salt had been manufactured there for centuries. About 1845 the German Government undertook to increase the supply of brine for common salt manufacture by drilling a well into the brine bodies supposed to lie below. This well tapped brines carrying such large quantities of potassium and magnesium salts as to be bitter and useless for salt manufacture. The value of these bitter salts in themselves was not recognized and the well was considered a failure. A few years later the Government sunk a shaft which, after passing through considerable bodies of "bitter" potash and magnesia salts, reached the main body of common salt. From this and other similar shafts the salt was extensively mined, the potash overburden (then believed worthless) being removed when necessary and thrown away as waste or "abraumsalze." This continued until von Liebig suggested the possible usefulness of this material as fertilizer. About 1870 it was tried, its value proven, and the waste heaps of the mines became their greatest assets. At the present time the potash material is mined by deep workings of the usual type, brought to the surface and put through such chemical or mechanical refining as may be necessary.

The potash salts are seldom pure, but are associated with various compounds of sodium, calcium and magnesium. The deposit contains 30 or 40 more or less complex minerals, the more important of which are the following:

Sylvite (or sylvan), chloride of potassium, KCl.

Carnallite, a hydrous double chloride of magnesium and potassium, $KMgCl_3$, $6H_2O$.

Halite, or rock salt, chloride of sodium, $NaCl$.

Kainite, a combination of potassium chloride and magnesium sulphate with 3 molecules of water, $MgSO_4$, KCl, $3H_2O$.

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

Kieserite, hydrous magnesium sulphate, $MgSO_4$, H_2O.

Gypsum, hydrous sulphate of calcium, $CaSO_4$, $2H_2O$.

Anhydrite, anhydrous sulphate of calcium, $CaSO_4$.

Sylvanite is an indefinite mixture of sylvite and halite (rock salt). "Hartsalz" is a mixture of sylvite, halite and kieserite.

At one time considerable quantities of sylvite, carnallite and kainite were mined directly in reasonably pure form, but this is believed not to be now the case, the potash salts being obtained in a variable mixture somewhat lower in grade. As it comes to the market the potash is mainly in four forms:

1. Sulphate of potassium, K_2SO_4, usually containing 70 to 90 per cent of pure potassium sulphate.

2. Chloride (or "muriate") of potassium, KCl, usually containing 80 to 90 per cent of pure potassium chloride. Both sulphate and chloride are produced by the more or less complete refining of the original salts.

3. Kainite (not necessarily the same as the *mineral* kainite noted above), a variable mixture of the mineral kainite, sylvite, halite, kieserite, etc., containing 12 to 15 per cent of potash (K_2O), the other materials being chlorides and sulphates of sodium and magnesium. Kainite usually comes to the market directly from the mine without chemical treatment.

4. "Manure salts," a similar mixture, usually resulting from partial refining and divided into grades containing 20, 30 and 40 per cent potash (K_2O).

There is also a mine classification into "carnallite salts" and "kainite salts," the difference being that the former consist essentially of carnellite, the latter of kainite (mineral), Hartsaltz and sylvinite. The carnallite salts are not now exported to America.

THE GEOLOGY OF THE STASSFURT DEPOSITS.

The section of the Stassfurt deposits is somewhat variable in different mines, but usually includes the following main divisions:

1. Drift, shales, sandstones, etc., variable thickness.
2. Younger rock salt, variable thickness.
3. Anhydrite, 100 to 250 feet thick.
4. Salt clay, 15 to 30 feet thick.
5. Carnallite zone, consisting of carnallite, halite, kieserite, etc., 50 to 125 feet thick.
6. Kieserite zone, consisting of rock salt with kieserite and kainite, variable thickness.
7. Polyhalite zone, consisting of rock salt, with polyhalite and other magnesium salts, variable thickness.
8. Older rock salt, 400 to 3000 feet thick.
9. Anhydrite and gypsum.

The depth of the potash-bearing horizon is usually 800 to 1000 feet. The various divisions are seldom sharply separated from each other and some are occasionally lacking. In particular the so-called carnallite, kieserite and polyhalite zones are sometimes considerably confused and divided into sub-zones of variable character. The lower rock salt contains many thin (¼-inch) layers of anhydrite alternating with slightly thicker layers of rock salt.

According to the theory first developed by Ochsenius and now generally accepted, the Stassfurt salts resulted from the evaporation of a large body of sea water which had been cut off in some way from connection with the ocean. In its progressive concentration this sea water deposited first the lower gypsum and anhydrite, then the lower or "older" rock salt, and finally its remaining mother liquors or "bitterns" laid down the magnesium and potassium salts of the polyhalite, kieserite and carnallite zones. Following this some geologic change caused an inwash of clay, which formed the salty clay bed noted in the section and sealed the previously deposited salts against subsequent solution and removal. A new body of sea water or of brine from leaching of the earlier deposited salt seems then to have been supplied and concentrated, thereby producing the upper anhydrite zone and the upper or "younger" rock salt. Either this second concentration was interrupted before it had gone far enough for the deposition of the magnesium and potassium salts, or such of these salts as were deposited were removed by subsequent erosion. At the present time the later deposited clays and shales rest directly upon the younger rock salt.

The total amount of potash available in the Stassfurt deposits is unknown, but is undoubtedly very large. It is rumored, however, that the high grade material is approaching exhaustion, though the secrecy which surrounds the operations of the Kali Syndicate makes it impossible to verify this report. In his first report above noted Phalen gives figures for the production of the German mines in 1908 as 7,372,144 short tons, worth $32,965,856. No later figures are known to the writer. Phalen also quotes financial figures for twenty-one of the mines in 1906, indicating that during that year these mines earned a total of $3,747,570 in net profits on a total capitalization of $23,502,625, or an average profit of 15.9 per cent.

No salt deposit similar to the Stassfurt body is known elsewhere, and, so far as known, none of the other rock salt bodies of the world carries significant amounts of potash. The United States Geological Survey and the United States Bureau of Soils have devoted some effort to a study of brines from the various North American salt bodies,* but no indications of potash have been discovered. It is not impossible that a potash deposit of essentially the Stassfurt type may exist somewhere in the United States or in the world, but the writer is acquainted with no criteria by which its presence or location could be inferred in advance of discovery.

THE AMERICAN POTASH SEARCH.

The recent rapid increase in the consumption of potash in the United States and the absolute dependence of this country upon the German supply have stimulated both private and Governmental agencies to a very active search for American de-

*A preliminary report has been published by Phalen,—U. S. Geological Survey, Bulletin 530B (1911).

posits or sources. As a result there have been many suggestions not only of favorable localities for prospecting but of materials known to be available and from which potash might be extracted. For instance, a considerable proportion of potash is contained in orthoclase feldspar, and many processes have been suggested for its extraction and utilization. Leucite, muscovite and other silicate minerals also contain significant quantities of potash, and alunite, a basic sulphate of potassium and aluminum, has actually been used as a source of potash alum. So far, none of these minerals looks very promising as a commercial source of potash. To have fertilizing value it seems necessary that the potash be added to the soil in soluble form. It does little or no good to use the potash silicates directly on the soil, and as yet no practicable process has been developed for the preparation of soluble potash salts from them. Alunite, though it yields soluble potash more easily, is not known in the United States except in small deposits or as a comparatively minor constituent of certain rocks.

Perhaps a little greater promise is offered by the kelps or giant sea weeds of the Pacific Coast. These carry considerable amounts of potash salts—amounting to 3 to 5 per cent of the wet material—and the nitrogenous substances which make up nearly all the remaining solids are also very beneficial to the soil. There is little question of the quantity of kelp available or of its considerable value as a fertilizer, but some very difficult problems of gathering and drying stand in the way of its commercial utilization. It is quite possible that these problems will be solved, as it is quite possible that methods will be devised for the extraction of potash from silicate minerals, but potash from either source will probably have to carry a considerable cost of production and will compete with difficulty with potash directly obtained in soluble form. Both kelp and silicates constitute large potential sources of potash and form a reserve upon which we can confidently expect to be able to draw if all other supplies should fail.

It is, however, the judgment of the present writer that the only hope of immediate competition against the German supply lies in the discovery of American deposits of the soluble salts. Mention has already been made of the lack of indication of other deposits of the Stassfurt type, and it seems that the best and almost the only chance of developing immediately available American sources lies in the basins or "dry lakes" of the Great Basin and other arid regions.

THE "DRY LAKE" POTASH THEORY.

By the natural processes of weathering all rocks and minerals give up certain of their constituents in the form of soluble salts of sodium, potassium and other elements. These salts are dissolved by rain and ground water and pass into the streams. All natural waters contain in solution more or less material thus derived and hence tend to correspond in chemical character to the rocks of the country, from which they drain. The high lime content of limestone waters is a well-known example.

In ordinary regions the salts of the drainage waters are carried from stream to river and finally to the sea. Indeed, geologists are agreed that the salinity of ocean water has been thus acquired. There are, however, regions from which the drainage has no seaward egress, but concentrates in a lake or "sink" and then suffers evaporation. In such cases the salts derived from rock decay are locally accumulated where the waters evaporate, and form either a bed of salt, as in Death Valley, or the salinity of a bottom lake like, for instance, the Great Salt Lake of Utah.

Now nearly all rocks and soils contain some potash-bearing minerals, and these, on weathering, set free soluble salts of potash. It follows, therefore, that all normal drainage waters contain more or less of these potash salts. Ordinarily, however, the potash is in small amounts and is far surpassed by the quantities of sodium salts present. In normal waters the potassium salts vary between 1 per cent and 4 per cent of the total dissolved materials. Only very rarely do they exceed the latter value. Even 4 per cent of potash in a salt body is ordinarily far too low to be commercially utilizable, and if a valuable potash body is to be formed there must be not only salt accumulation by the concentration of enclosed drainage waters, but also some sort of natural *segregation* of the potash from at least a part of the other salts which are present.

Whether a workable potash deposit can have been formed by the concentration of drainage in enclosed basins depends upon two considerations: (1) Are there any places where the evaporation of natural drainage waters has accumulated potash in sufficiently large amounts? (2) Has there been possible in any of these places a sufficiently complete segregation of the potash from the much larger amounts of sodium salts which must have accumulated with it? The first of these questions can be answered at once in the affirmative. There are a number of enclosed basins in North America, where very large amounts of drainage water have evaporated for very long times, and for many of these basins there is ample evidence that the drainage waters were normal or above normal in their content of potash. The question of possible segregation of the potash is less certain and its consideration must be prefaced by a brief discussion of the recent geologic history of the regions of present enclosed drainage.

This historical discussion need not be complete. It is sufficient to note that at a time geologically recent though historically remote the deepest depressions of many of the enclosed basins of North America were filled with great lakes. This lake period is generally regarded as synchronous with the Glacial Period and is due to similar climatic causes—an increase of rainfall or a lowering of mean temperature, or both. The lakes which characterized this period have disappeared or shrunk to tiny remnants, but their previous size and persistence is attested by innumerable sand bars, wave-cut terraces and similar topographic records which it is impossible to mistake. The lakes seem to have been characterized by frequent and extreme fluctuations of level, and there is good evidence that the lake period was at least double, two periods of expansion being separated by a period of contraction and desiccation, probably to entire dryness. The second expansion was followed by contraction to the present condition of desiccation.

A number of these ancient lakes overflowed at their greatest expansion, and most of the salts which they contained escaped to the sea. Others, however, never attained an overflow and must have retained all salts derived from their drainage basins. At their higher stages the lakes must all have been fresh, but as they began to evaporate and contract they must have become increasingly brackish and finally more and more saline, paralleling the present condition of the Great Salt Lake of Utah and of Owens and Mono Lakes in California. This may have furnished an opportunity for the segregation of the potash. It is reasonably certain that some, at least, of the lakes contained normal proportions of this material. Potash salts are more soluble than those of sodium. It is probable, therefore, that when the concentrating, potash-containing lakes came finally to the point of precipitating their dissolved salts, the sodium and calcium salts would be the first to go, and the salts of potassium would be retained and concentrated in the mother liquors. Finally, when these mother liquors came to be evaporated they would deposit a body of salts relatively high in potash. Essentially this is just what is supposed to have happened in the Stassfurt concentration above described, though there the original water was that of the sea. The sodium chloride was thrown out first as rock salt and the more soluble magnesium and potassium salts came down later in fairly concentrated form.

Were it certain that the ancient lakes had undergone their concentration continuously and uniformly, there would be little question of this theory. Unfortunately, however, this is far from being the case. There is good evidence that the lakes were subject to many fluctuations both up and down. Their evaporation, instead of being a slow and steady downward movement, was almost certainly a series of relatively sudden expansions and contractions, relieved by considerable periods of nearly constant level, and having a general net tendency toward contraction. This detailed history is so complex and so little known that its effect on the segregation of the potash can scarcely be predicted. It is conceivable, though scarcely probable, that the continual and wide fluctuations of the lakes may have prevented any important segregation of their contained salts.

In summary this theory reduces to rather simple terms:

1. In certain enclosed basins of North America (now dry) there were once great lakes, some of which never possessed an outlet.

2. These lakes must have come to contain large amounts of salts, and, in some cases at least, these salts must have included large total amounts and not insignificant proportions of potash.

3. On the evaporation of these lakes their salts must have been deposited in their basins and it is possible that natural processes may have produced a more or less complete segregation of the potash from the other saline materials.

When we come to test this theory by application to the actual salt deposits of the desert basins, we are immediately confronted by the fact that the floors of the desert valleys are seldom especially saline. The writer knows only three or four

American basins where the salt deposits visible on the floor could account for more than a small fraction of the salt that must have been present in the lake which the basin once contained. This surprising fact became patent very early in the investigation of the desert basin regions, and Gilbert and Russell, who were the scientific pioneers in this field, developed in explanation the theory of "freshening by desiccation." According to this theory, the salt body formed by the complete desiccation of a lake might be gradually covered by clay or sand washed or blown in from its surroundings, and thus protected against solution even though later covered by another persistent lake. There seems little question of the reality of this process. It has actually been observed taking place at present, and a similar phenomenon in the Stassfurt deposits was noted above. There is every reason to believe that the present non-saline floors of the old lake basins conceal somewhere beneath them the missing salts of the early lakes.

But this theory itself suggests another process which may possibly have interfered with segregation of potash. If alluvium has been added since the complete evaporation of the lakes, it was doubtless added in even greater quantity during that evaporation, and it is not impossible that this, joined to the irregular fluctuations of the lakes, may have caused the salts (including the potash) to have been deposited with the added alluvium as saline clay beds, rather than as beds of actual salt. How far this suggestion may have had reality is absolutely unknown.

The above theory, though entirely general, rests on much that is concrete and specific, and may fairly be said to lead to the conclusion that segregated potash deposits may have been formed in some of the undrained basins. Thus stated, the theory has received ample vindication from the actual discovery of such a segregated potash deposit at Searles Lake, San Bernardino County, California. At this place the potash is contained in a brine or mother liquor which permeates the mass of a considerable body of crystalline salts of sodium. Progressive evaporation has thrown out a large part of these other salts from the original solution, leaving the potash segregated in the mother liquor. The general theory is borne out in every way. It is true that the Searles Lake salt body is at the surface instead of buried, but the surroundings of the deposit are such as to greatly strengthen rather than weaken the general theory of burial of salt beds. Not only is the failure of the Searles Lake deposit to have become entirely covered easily explainable by a local and unusual topography, but the process of covering has actually been at work. The edges of the salt body are already covered by encroaching alluvium and a few hundred more years of the present conditions would doubtless have covered the deposit entirely. As a whole, the Searles deposit offers nothing to weaken the general theory and much to support it.

It does not necessarily follow that other similar deposits exist. It is perhaps justifiable to say that Searles sufficiently confirms the general theory, but the general theory may be perfectly sound and yet may have failed of exact and complete realization elsewhere. The chances of the occurrence of a potash body in any particular basin are matters determinable, if at all, only by the local and particular character and history of the basin. Probably the criteria applicable, and the general chances, favorable and unfavorable, will sufficiently appear in the following discussion of the Railroad Valley.

The Railroad Valley is an enclosed basin lying just southeast of the geographical center of Nevada. Several adjoining valleys are and have been tributary to it, and its drainage area during the great lake period was about 6400 square miles. Some of the former tributaries have been cut off by dams of recent alluvium or by the desiccation of the streams which once drained them, but these changes are recent and unimportant. The passes leading out of the drainage basin are all ancient and fairly high and there is no doubt that the basin has been for a long time an enclosed one and has never overflowed. A series of old wave bars, beaches, etc., surround the valley and indicate the existence of an ancient lake which seems to have had the usual history. The exposed rocks and soils of the valley carry rather more than the normal proportion of potash-bearing minerals and there is every reason to believe that the early Railroad Valley Lake had its full share of potash and that that potash is now within the valley. The questions are two: (1) Was the potash segregated? (2) Can it be located?

Investigations to date have not sufficed for the definite answering of either of these questions. The present surface of the valley contains no large salt body. The deepest depression is a mud flat or "playa," very nearly level and not particularly saline. About its borders, at both north and south ends, are a number of smaller mud flats or "pans," which are much more saline and in which the superficial ground waters are usually concentrated brines. These brines, rising to the surface by capillarity, evaporate to produce thin surface crusts of white salt. The salts of both brines and crusts frequently carry 5 to 12 per cent of potash, but the quantity of the brine is not believed to be large and it seems to occur in separate local pockets, showing considerable chemical differences. Both the origin and the amount of these surface brines well deserve the investigation which they are now receiving on the ground, but it is the provisional opinion of the writer that the material will prove small in quantity and not particularly important. The interest of these superficial high-potash brines to the present prospecting in the valley is two-fold—they first directed attention to the valley as a possible potash locality and they indicate that potash accumulation and segregation, on a small scale at least, has actually occurred in the basin.

It is not believed that the amount of salt contained in these surface brines is nearly large enough to account for the salt which must have been in the early lake. The theory of burial seems to apply in every detail and there is every reason to believe that large quantities of salts are buried somewhere in the basin and that these salts contain a significant proportion of potash.

As to the possible segregation of the potash from the other salts, there is no specific data, and opinion must rest upon the general theoretical considerations above discussed. These theoretical considerations do not warrant any final conclusion for or against the segregation of the potash, but they indicate that such a segregation is quite possible. In the opinion of the writer the chances of such a segregation having occurred are ample to warrant an attempt to locate the hypothetical buried salt bed in the hope that this bed may contain one or more horizons of useful potash material. Of course, it is quite possible that the potash may not have been sufficiently separated from other salts, or that both potash and other salts were deposited with alluvium in the form of saline clays. These are uncertainties which cannot be removed except by actual investigation.

The location of the hypothetical buried bed is not a matter of extreme ease. The inwash of recent alluvium, the movement of dune sand, etc., have considerably changed the minor topography of the basin. It is quite possible that the point of deepest depression has been shifted by these agencies, and that the place which was deepest at the time of the original lake concentration, and which contains the hypothetical salt bed is not now directly under the present mud flat. It is not possible, therefore, to so locate a single drill hole that it would be certain to find the salt bed if it exists. Any hole, located without knowledge of underground conditions and of the ancient topography, might easily miss the edge of the saline beds and fail to show their existence. Indeed, a number of holes might have to be drilled before the bed was located or its existence disproved. It is the opinion of the writer that a maximum of four holes would probably be sufficient. It is probable that the records of lake expansion and desiccation can be identified even in holes which miss the central salt body, and the comparative study of such records from three properly placed holes would make possible the reconstruction of the ancient topography of the basin with sufficient accuracy to enable the placing of the fourth hole where its record would be conclusive. Good fortune might make the first or the second or the third hole conclusive, but this really could not be expected.

There is also no complete assurance that a hole could be drilled deep enough to reach the saline beds. The Railroad Valley, like most of the enclosed basins, is filled with alluvial material to a very great depth—probably many thousands of feet. Undoubtedly much of this filling antedates the lake period and does not concern us, but there is absolutely no way of knowing how much *later* alluvium may have been deposited or how deeply the significant beds have been buried. The writer knows of no well record in any basin sufficiently complete, accurate and deep to enable the identification of the horizon of the early lake. There is, therfore, no scale by which can be measured the amount of alluvial deposition subsequent to the lake period.

As a matter of fact, the depth of the saline "desiccation beds" will probably prove to be widely different in different basins, the depth in any particular basin depending upon the local topographic conditions which have controlled the supply of alluvium. It is the opinion of the writer that the alluvial fill in the Railroad Valley is comparatively shallow and that the critical strata will be encountered inside of 1500 feet or only slightly below that level. This opinion, however, is admittedly little better than a guess, and is entirely unsupported by any direct evidence.

However, evidence on this point is being rapidly acquired. The drill hole being sunk by the Railroad Valley Company is now nearly 1200 feet deep and is going down rapidly. A full and careful record has been kept and a very complete series of samples has been preserved. The record of the hole to August 19, 1912, is given in the following table:

LOG OF RAILROAD VALLEY HOLE.

Feet.		
1-32	Sand with occasional clay layers.	
32-103	Quicksand.	
103-132	Alternations of quicksand and clay.	Artesian water, especially at 128 ft.
132-136	White clay with small seams of fine gravel or coarse quicksand.	
136-178	Heavy clay.	
178-214	Quicksand.	Artesian water.
214-285	Alternations of clay and sand, layers 1 ft. to 10 ft. thick.	Artesian water in most of the sands, especially at 220 and 250 ft.
285-305	Sand, coarser in upper part. Pebbles 3-4 in. in dia. at 285 ft.	Artesian water.
305-336	Tough clay.	
336-340	Quicksand with some clay and some small gravel.	Artesian water.
340-365	Clay, with occasional streaks of quicksand.	
365-375	Quicksand with very small streaks of clay.	Artesian water.
375-390	Tough gray clay.	
390-391	Quicksand.	Small artesian flow.
391-418	Tough gray clay.	

418-419	Quicksand.	Small artesian flow.
419-429	Brown clay.	
429-430	Quicksand.	Small artesian flow.
430-460	Clay, gray in lower part, changing to brown in upper.	
460-461	Quicksand.	Artesian water.
462-470	Blue-green clay, with a white layer on top.	
470-471	Quicksand.	Artesian water.
471-478	Lead-colored clay.	
478-479	Very fine sand.	
479-500	White and blue-green clays.	
500-504	Blue-green clay with some coarse sand.	
504-519	White and blue-green clays.	
519-520	Quicksand.	Artesian flow smelling of sulphuretted hydrogen.
519-529	Gray clay with occasional sand streaks.	Small artesian flows in sands. All smell of sulphuretted hydrogen.
529-533	Gray clay.	
533-534	Very fine quicksand.	
534-539	Blue-green clay.	
539-541	Quicksand with some light colored clay and some coarse gravel.	Strong artesian flow.
541-560	Yellowish, white and blue-green clays.	
560-561	Quicksand.	Artesian water.
561-586	Blue-green and white clays.	

586-587	Quicksand.	Small artesian flow.
587-596	Clay.	
596-609	Alternations of sand and clay, the proportion of sand increasing downward.	Small artesian flow at 605 ft.
609-637	Clay, whiter in upper part.	
637-638	Quicksand.	
638-676	Tough clay, white and greenish in color.	
676-677	Quicksand.	Small artesian flow.
677-680	Alternations of clay and sand.	
680-691	White clay.	
691-700	Alternations of clay and sand.	
700-719	Clay, brownish on top.	
719-720	Sand.	
720-738	Brownish clay.	
738-746	Clay and quicksand mixed. Some coarse gravel.	Very small artesian flows.
746-759	Tough brownish clay.	
759-771	Sand alternating with very tough brownish clay.	Very small artesian flows in the sands.
771-785	Tough brownish clay.	
785-786	Quicksand.	Artesian flow.
786-790	Clay.	
790-791	Sandy streak in clay.	Small artesian flow.
791-798	Brownish clay.	
798-805	Alternations of clay and sand.	
805-816	Clay, hard and brown in lower part.	

816-822	Quicksand and gravel.	Artesian water.
822-824	Hard white clay.	
824-846	Clay and sand alternating every 2 to 6 inches. Proportion of clay increases with depth.	Strong artesian flows in all sand strata.
846-850	Brownish clay.	
850-855	Sand and gravel.	
855-865	Rapid alternations of clay and sand.	
865-876	Gray clay.	
876-878	Coarse gravel.	Artesian water
878-882	Fine sand.	
882-899	Alternations of clay and sand.	
899-908	Gray clay.	
908-924	Sand and gravel.	Strong artesian flows.
924-934	Light gray clay.	
934-941	Fine sand.	
941-945	Gray clay.	
945-947	Sand.	
947-967	Clay, yellow on top, gray below.	
967-968	Sand and gravel.	Small artesian flow.
968-1088	Hard, dry clay.	
1088-1089	Dry sand.	
1089-1175	Hard, dry clay.	

This record falls without violence into five main divisions:

I. 1-103 feet—Sand with thin layers of clay.

II. 104-375 feet—Alternate sand and clay.

III. 375-596 feet—Clay with occasional thin streaks of sand.

IV. 596-968 feet—Alternate sand and clay.

V. 968-1175 feet—Solid clay.

In the interpretation of records of this character certain general principles are of service. Solid clay beds mean permanent lake conditions over the site of the drill hole. Alternations of sand and clay usually mean the recurring expansion and contraction of a shallow lake, the sand layers being produced by stream wash or dune movement when the site was outside the lake or at its shore, while the clay layers indicate periods when the lake advanced and covered the site for a longer or shorter time. Sand unmixed with clay probably indicates conditions of intense aridity, complete desiccation, and extensive movement of dune sand. Applying these principles to the record as given in the condensed table, it is apparent that division I probably corresponds to a period of intense aridity and dune movement in the recent past. The reality of such a period is indicated by much evidence from other regions, and may be considered fairly well established. Divisions II and IV obviously correspond to intermittent lake conditions, and division V to a persistent lake, the deposits of which are not yet bored through. The interpretation of division III is less certain. Over 95 per cent of this division is clay, yet the recurrence of thin sand streaks seems to negative the existence of a permanent lake. The writer is inclined to interpret it as the record of a fairly permanent but shallow lake, the shore line of which stood not far from the site of the drill hole—close enough that sand could occasionally be washed outward to cover the site.

In its influence on the potash theories two interpretations of this record are possible. It will be recalled that the early lake period was apparently double, a first and a second expansion being separated by a period of contraction. Applying this to the well record, it is possible either to correlate division III of the condensed record with the second lake expansion and division V with the first, or to correlate division V with the second expansion, assuming that the record of the first expansion is still below, and that divisions I to IV correspond to minor fluctuations subsequent to the second expansion. The writer has not personally examined the samples from below 916 feet, and before doing so he cannot express a final opinion as to which of these alternative correlations is correct. He inclines, however, to the second, not only because division III is scarcely a typical record of persistent lake conditions, but because division IV when examined in detail shows no indication of the long and intense arid period which is believed to have intervened between the two lake expansions.

There is reason to believe that the second lake expansion was considerably shorter than the first, and this has two consequences: (1) The clay beds corresponding to this lake will be relatively thin, and (2) the greater salt body will have been produced by the concentration of the *first* lake and will be under these clay beds. If all this is right, and if the writer is correct in his very tentative interpretation of the well record, saline waters are to be expected in the well so soon as the clay beds now being traversed by the drill have been penetrated. It is to be expected, further, that these clay beds will not be too thick for their penetration to be possible. On this interpretation the salt accumulated during the *second* lake expansion is represented by that now found in the surface and sub-surface beds of the mud flat, there being very probably areas of local accumulation, not deeply buried but unknown, and not cut by the present drill hole.

Of course, this interpretation of the record is very uncertain and provisional and the writer does not feel willing to hazard any definite predictions. He would not be surprised, however, to see saline beds or saline artesian brines encountered not very far below the heavy clay beds in which the drill is now working. Whether these saline materials, if found, will contain workable quantities of potash remains, as before, an open question.

In summary, all information so far obtained, though not at all conclusive, tends to confirm the general theory outlined above. A commercially valuable potash deposit in the Railroad Valley is distinctly possible. If it fails to be found, it will almost certainly be because of one or more of the following reasons:

1. The general theory may be wrong in some essential detail, the error having remained undetected.

2. The hypothetical salt body may be too deep to be reached.

3. The potash associated with it may have failed to segregate sufficiently to be of value.

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