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[ALKALI SERIES, VI.]

Alkali Lakes and Deposits.

By W. C. KNIGHT AND E. E. SLOSSON.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyo.
Wyoming Agricultural Experiment Station.

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Introduction.

This bulletin is one of the alkali series published by this station. An attempt is being made to work out thoroughly the origin, constitution and distribution of alkali in Wyoming, and if possible to find some means by which its accumulation can be retarded or greatly diminished, and also some method of successfully redeeming the soils that are too rich in these salts to be of agricultural importance. These problems are extremely difficult, and have been receiving a considerable attention from the government as well as individual stations, and after spending a great deal of time it may be ascertained that even in the present light of science it will be impossible to improve the present conditions with economy. However, the problem is worthy of the greatest consideration, for if any assistance can be given the agriculturist whereby he can increase the amount of tillable land or redeem areas already ruined by alkali a great work will have been accomplished. In undertaking these problems it has been found advisable to consider three special topics: 1st, the deposits of alkali that have been made by nature, their origin and chemical constitution. 2nd, the distribution of the alkali in the soils and geological formations. 3rd, the occurrence of the salts in the natural waters, showing how they are stored upon the land and giving information that will be beneficial in handling the detrimental waters by irrigators. In the present bulletin will be found a discussion in a general way of the occurrence of alkali in Wyoming and also a special treatise on the nature of the deposits, which will discuss problems relating to their chemistry, geology, mineralogy and origin.
HISTORY.

In the year 1835 Rev. Samuel Parker commenced his journey across the Rocky mountains, and in his narrative he mentions the lakes near Independence Rock; but calls them Epsom salts.* This is the first note published, so far as I am aware, of the soda deposits of Wyoming. Many of the early explorers between the years 1835 and 1850 did not refer to deposits along the Sweetwater. In Captain Stanbury's report on his expedition to Great Salt Lake, which started in 1849, he mentions the saline deposits of the Sweetwater valley and reports the first analysis. This he refers to as saleratus from a native saleratus deposit on the Sweetwater river, and stated that it was composed of sodium sesquicarbonate and chloride and sulphate of sodium.†

Among the early explorers who gave us some idea of the soda deposits, no one is more worthy of quotation than Sir Richard Burton.‡ The following is an extract: "After about 20 miles we passed to the west of the road, a curious feature, to which the Mormon exodus first, on dit, gave the name Saleratus Lake. It lies to the west of the road and is only one of a chain of alkaline waters and springs whose fetor without exaggeration, taints the land. Cattle drinking the fluid are

*See Parker's Exploring Tour Beyond the Rocky Mountains, 2nd edition, p. 74.
†See Stansbury's Expedition to Great Salt Lake. p. 420.
‡The City of the Saints, R. F. Burton, pp. 147-148.
nearly sure to die; even those who eat the *herbe salee*, or salt grass growing upon its borders, and known by its reddish-yellow and sometimes bluish tinge, will suffer from a disease called ‘alkali’ which not unfrequently kills them. The appearance of Saleratus Lake startles the traveler who, in the full blaze of midday upon this arid waste, where the mirage mocks him at every turn, suddenly sees outstretched before his eyes a kind of Wendham Lake solidly overfrozen. This illusion is so perfect that I was completely deceived, nor could the loud guffaws of the driver bring me at once to the conclusion that seeing in this case was not believing. On a near inspection the icy surface turns out to be a dust of carbonate of soda, concealing beneath it masses of the same material, washed out of the adjacent soil, and solidified by evaporation. The Later-Day saints were charmed with their *trouvaille*, and laid in stores of the fetid alkali matter, as though it had been manna, for their bread and pastry. It is still transported westward, and declared to be purer than the saleratus of the shops."

There have been several statements made, but upon what authority I am unable to learn, that the Mormons for years after their settlement of the Salt Lake valley made annual journeys to the Saleratus Lake and hauled large quantities of the natural soda with horses and oxen to supply the needs of the rapidly settling valley.

From the time that Burton visited the Sweetwater valley up to the year 1883 nothing was published so far as known concerning the soda deposits of the state. During this period the Union Pacific railroad had been built across the southern part of the state, and the deposits of soda in Albany and Carbon counties had been discovered and large blocks from these had been displayed at Philadelphia, New Orleans and Denver, where they attracted a great deal of attention.

In the report of the U. S. G. S. Mineral Resources for the year 1883 there is a brief reference to some of the soda deposits of Wyoming and a few analyses given. One of these
from near Independence Rock was in all probability taken from
the Omaha soda mine. On pages 602 and 603 of this report
there are some very serious mistakes. The statement made
by Mr. Bailey, then Territorial Geologist for Wyoming, is very
wide of the mark. No such number of soda lakes exist in the
region referred to by him, nor have the deposits been found to
be 45 feet in thickness. The block of soda exhibited by the
Union Pacific railroad in Denver in 1882 was a sulphate of
soda, and did not contain any carbonate.

In the report of the U. S. G. S., Mineral Resources for
the year 1885 Mr. Weeks gives a very brief article upon all
the deposits known at that time in the state. In this he dis-
cusses the manufacture of soda at Laramie, notes the vari-
ous deposits and gives analyses of the salts. This is the most
complete description of the natural soda deposits published up
to this time.

L. D. Ricketts, Territorial Geologist for Wyoming, pub-
lished in his annual report for the year 1888 an article of con-
siderable length on the natural soda deposits, and discussed
several locations that had been hitherto unmentioned.

The writer has published three articles on this subject,
as follows: Bulletin 14 Wyoming Experiment Station, 1893,
page 179; The Mineral Industry, 1897, page 612; Mining Re-
porter in 1898; but exact date not known.

Pemberton and Tucker gave a description of the U. P.
deposits and analyses in “Chemistry News” Vol. 68 pp. 19-20
—1893.
Alkali Lakes and Deposits.

Alkali.

There are several compounds and mixtures of compounds that are known as alkali to the people of the west. The term has such a universal application that any white efflorescence or deposit falls under this head.

These salts are widely distributed and occur in the hills, upon table lands, valleys and plains. Occasionally there are deposits or lakes with waters rich in salts; but more often they are formed as thin efflorescent crusts, covering sandstones, shales and clays, or in slight depressions in the soil. Springs are also a source of alkali and the various salts contained in the water sometimes amount to several per cent. Wells in many localities are seriously contaminated with various salts under this head. At Green River there is a well that contains nearly a saturated solution of sodium carbonate.

The most ordinary occurrence of alkali is its association with the soils of the state. Prior to irrigation vast bodies of land support a scanty stand of grass and, in very many instances, are covered with typical sage brush and there is no appearance of alkali. As soon as the land is watered artificially, alkali commences to rise from capillary attraction from a subterranean source and, in many instances, completely destroys nearly all kinds of vegetation. The depth of the soil along water courses is often very great and the rise of the salts appears to be a problem with which we are wholly unable to successfully cope, at the present time. In Wyoming the question of the percentage of salts at various depths in the soil has not received much attention; but from several observations it has been ascertained that in many places wells sunk from 8 to 20 feet in the soil, the water contains too much alkali to be utilized for domestic purposes, and are wholly abandoned, and the ranchman secures his water supply from the nearest stream.
As soon as the irrigation season is over the alkali forms a pul- 
verent crust upon the surface and the fall winds distribute 
this over vast areas, and often leave the irrigated tract appar-
etly free from the salt. This to some extent is beneficial for 
the irrigated tracts; but the process is altogether too slow to 
have any beneficial results.

In regions where there are exposures of clays, shales and sandstones, where the soils do not exist, there are also annual accumulations of the various salts. These arise from rock in place, there being sufficient moisture to bring the alkali to the surface. In cases of this kind its source is traceable to the original sedimentary rocks, and these are constantly adding a storage of alkali to the soils that already have too much for agricultural purposes. No study has been made of the percentage of the salts in various geological horizons; but it has been observed that they vary greatly in richness and that all of the formations from Triassic to Tertiary inclusive contain more or less of these various compounds. The fact that these salts are so universally distributed throughout the various formations ought to cause the careful investigation of them, to determine, if possible, the supply being annually added to the tillable areas, and also to prevent, if possible, accumulation. There is a vast amount of necessary investigation to be carried out along this line, and it is highly probable that by ditching and the proper handling of rain water coming from areas of this sort, a great deal of alkali could be impounded or carried to some stream where its presence would not be serious on account of the great dilution.

These exposed banks of clay, shale and sandstone are the present source of these very detrimental compounds and in or-
der to battle with the ravages of alkali successfully this source must be considered, for so long as these exist and are tributary to the soils, so long the accumulation must increase, unless per-
chance there is a greater percentage leached out of the soils than is carried in.
In some localities the amount of alkali stored in clays and shales is enormous. In the midst of the Red Desert there are clay beds of a dull red color, with rather pulverent surface during dry weather. Only a few inches below the surface the alkali often amounts to 30 or 40 per cent of the mass. When there is a slight rainfall the clay forms a protective covering and none of the alkali escapes. With heavy rains, which rarely occur, the water often finds its way through the mantel and following the alkali surface carries away all of the salts that will pass into solution. In cases of this kind the water draining from these places and entering the soils are nearly saturated with salts.

Spring water should also be very carefully examined. These waters contain a higher percentage of alkali than is usually supposed. Often water is considered unfit for domestic purposes when it is used for irrigation and is the means of ruining a piece of land. For example, there is a spring some six miles east of Beaver Creek, on the old Lander-Casper trail, that contains 10 per cent of sodium carbonate. There are many others which contain an unusual amount of salts; but examples can not be given, since analyses have not been completed. All waters of this nature should be turned into natural depressions to evaporate or ponds should be made to impound them. In this way the water supply would be curtailed, but decrease in salts would more than recompense this loss.

In view of these facts, alkali is the greatest enemy to the agricultural districts of the arid west, and is one that appears to be gaining ground, while there is little advancement made in coping with it. To be sure the salts can be washed out with an excess of water, but this causes the salts to rise from lower zones. Subterranean drainage put in with tile is very successful, but this is so expensive as to absolutely prevent its use for ordinary crops and hay. It is advisable under these conditions to attack the problem from all sides, and attempt to decrease
the storage of salts in the soils, as well as to eliminate the alkali they contain.

There are many minerals included under the name alkali and on this account a description of them seems necessary, before considering their occurrence. The following is a list of the most important ones together with a brief description and also some notes on how they may be distinguished.

White Alkali, Mirabilite \((\text{Na}_2\text{SO}_4 + 10\text{H}_2\text{O})\), Hydrous sodium sulphate. When newly deposited it is a crystalline mass nearly transparent; but upon exposure to the atmosphere loses its water and becomes a pulverent white powder. The typical mineral dissolves in its water of crystallization at 90 degs. F. and if soap is added to any solution of this salt it will produce a curdly precipitate. This is the most common alkali in Wyoming and is found in every county in the state.

Thenardite \((\text{Na}_2\text{SO}_4)\), Anhydrous sodium sulphate. When Mirabilite loses its water of crystallization it becomes Thenardite. Otherwise this salt has not been found in this state. This mineral is only known as a white or drab powder. It is soluble in water, when it will answer the tests for Mirabilite. This and the previous salt have a slightly disagreeable taste.

Black Alkali, Thermonatrite \((\text{Na}_2\text{CO}_3 + \text{H}_2\text{O})\). This is a white efflorescent crust or may be mixed with other salts in deposits. Taste alkaline and gives an alkaline reaction. Associated with this salt there are two others that are included under the heading of Black alkali.

Natron \((\text{Na}_2\text{CO}_3 + 10\text{H}_2\text{O})\) found mixed with other carbonates of soda and about which very little is known.

Trona \((\text{Na}_2\text{CO}_3 \cdot \text{HNaCO}_3)\) Found as an efflorescent crust and also in deposits along the Sweetwater river. Taste alkaline, and although mixed with other salts as sulphates and chlorides has been utilized for bread making. When taken from the deposit it is nearly transparent, seriously affects the hands. Upon drying becomes a pulverent white powder.
Gay-lussite, \((\text{CaCO}_3 \cdot \text{Na}_2\text{CO}_3 \cdot 5\text{H}_2\text{O})\) Found as small transparent crystals associated with deposits of carbonate of soda in the Sweetwater valley. It has an alkaline reaction, is soluble in water; but is of little importance as an alkali.

Halite, common salt, \((\text{NaCl})\) found associated with nearly all of the alkali of the state; but seldom in sufficient quantities or pure enough to be of importance. While this is included with the alkali it is the least detrimental of all of the white incrustations found in this state.

Epsomite, epsom salts \((\text{MgSO}_4 \cdot 7\text{H}_2\text{O})\) found associated with nearly all of the alkali, and occasionally in large quantities. Also found nearly pure in this incrustations and also in deposits. It has a very bitter taste and is very soluble in water.

Bischofite \((\text{MgCl}_2 \cdot \text{H}_2\text{O})\) Found associated with other alkali; but not known as a mineral. All that is known of this compound has been reported by the chemists who have analyzed the various alkali salts from this state.

Alunogen, native alum, \((\text{Al}_2(\text{SO}_4)\cdot 18\text{H}_2\text{O})\) found as an efflorescent coating on shale, often in coal mines and occasionally in deposits. It is a white or yellowish salt, with an alum taste and is very soluble in water.
General Discussion of Alkali Deposits.

The alkali deposits of Wyoming have a common origin, although they are located at various elevations above the sea, in depressions that occur in various kinds of soil and also in various geological formations. The depressions are of very modern origin and have been made by water and wind. Wind seems to have played a prominent part in their development, and all of them are provided with an inlet but no outlet. Even at spring tide there are few if any depressions which contain soda that overflow.

Geologically they are found in various formations extending from the Triassic to the soil of the present time, having been dependent upon undrained depressions for their origin. It was also necessary for the surrounding country to have been alkali producing. While all of the deposits are in undrained depressions, we have undrained depressions in the Paleozoic rocks and also in the Mesozoic that do not contain enough alkali to speak of: For example, St. James lake and Cooper lake are remarkable undrained depressions receiving a large water supply annually, and often drying up during the early fall; but leaving little or no deposit of salt. This is due to one or two influences. 1st, the territory draining into these depressions contain little or no alkali. 2nd, possibly there may be an underground drainage through which the salts may pass with the water. Which of these suggestions will be applicable will have to be determined by experiment.

Until very recently it has been advocated that all of the alkali of the arid west has been formed by the decomposition of the granitic rocks. That is, by the oxidization of the feldspars of the granite the alkali was changed into a soluble compound and washed into the natural depressions. Upon
taking up the study of the origin of the alkali in Wyoming
special attention has been given to the source of the salts, and
the following observations have been recorded. Some ten
years ago my attention was first called to the origin of the so-
dium salts, and at that time I commenced my investigations,
and have been making field observations ever since. Upon
visiting the granitic areas I realized that they were not the
source of the alkali stored in the valleys below. In the first
place I could not find that any of the deposits, with one possible
exception, were connected in any way with the water courses
of the mountains. Small depressions were noticed in the
granitic masses; but none of these had alkali associated with
them. Granitic soils were also found to be practically free
from alkali. In examining the granites it was found that the
feldspars were not undergoing rapid decay. In places where
disintegration was taking place and the granite was so loose
that it could be shoveled up with a steam shovel there was lit-
tle or no kaolinization. Weathering of the granites along the
mountain ranges in arid regions results in the separation of
the quartz and feldspar, and the oxidization of the mica and
hornblende. Consequently but little alkali is being formed an-
nually, and all of the salts appear to be washed into the streams
and in no instance stored upon land. It is also a fact worth
recording that nearly all of the granites of Wyoming have
orthoclase as the dominant feldspar, and the alkali produced
should be potassium; but all of the deposits in Wyoming are
almost free from any of the potassium salts.

After examining the most of the granite areas of the state
and finding the above conditions practically universal I came
to the conclusion that none of the alkali of the west has been
formed from the direct decomposition of the granitic masses
in the vicinity of the deposits.

Realizing that there are numerous questions as to the
distribution of the alkali formed by the decomposition of gran-
ite, for it is an assured fact that there must be a gradual pro-
duction from any granitic mass, some might consider that the salts found their way by subterranean means to the soils and deposits. Upon examining the structure of the regions associated with the granitic rocks, it has been found that with one exception all of the granite exposures occur along the axes of the mountain ranges, and that flanking these ranges are the sedimentary rocks dipping at various degrees away from the crests. In case any salts are formed and are leached out of the rocks they would enter the soils and finally reach the water courses or be carried by subterranean waters into porous bands resting on the granites. Thus the product forming today would be carried into the various lower formations resting upon the primordial rocks. Since the thickness of the formations flanking the mountains is very great none of the alkali resulting from the decomposition of granite could possibly reach the Mesozoic or Cenozoic formations, since the various strata over which it would have to flow in order to reach the upper rocks would more than absorb it. Salts carried into artesian basins in this manner may reach the surface through a fracture; but as a rule these basins are unbroken.

From the Archean rocks the formations resting upon them were studied. There was no evidence of alkali found in any of the Algonkian exposures, nor in basins or valleys made in these rocks. In the Paleozoic formations, Cambrian, Ordovician, Carboniferous and Permian strata were examined; but no alkali was found associated with any of these. In localities where these rocks were comparatively level and where natural conditions favored the accumulation of various salts none were found. In the majority of cases all of the mountain waters have to travel over or through these formations to reach the valley. It is a notable fact, that soils derived from these formations and the formations themselves are free from the efflorescent crust of alkali that is so abundant in the Mesozoic and Tertiary areas.

Upon crossing the line of contact between the Mesozoic and
Paleozoic, conditions change immediately, alkali crusts are found in abundance and deposits occasionally. In fact it is the rule to find an alkaline crust forming about all depressions and ponds above the Paleozoic. Analyses of soils derived from Mesozoic and Cenozoic formations contain many times as much alkali as those derived from lower rocks, and the waters contain vastly more salts. There is much valuable information to be obtained by a careful examination of the soils and waters of the many formations in this state. Thus far there has been only enough done to give one an inkling of the true conditions of the distribution of the various salts.

After having abandoned the theory that the alkali which causes so much trouble in the west, was derived from other sources than the decomposition of the alkali-bearing rocks such as granites and other eruptive rocks in the vicinity of the efflorescent crusts or deposits, other possible theories were examined.

It has been argued that the alkali found in the deposits has been largely derived from springs that are found in their immediate vicinity. Ricketts in his report for 1888 has given special attention to the spring theory; but has not given very much convincing evidence.

Ricketts' argument is as follows: "It was first generally supposed that the soda arose simply by the evaporation of surface waters that had drained through the soil into the lakes and in this way had dissolved the soda salts. For many reasons this supposition was doubted, and is now proved to be incorrect. While it is true that soda deposits occur in basins with lakes or ponds in them which contain only alkali waters, or when dry, but a thin crust of the alkalis or alkaline earths. The true soda deposit on the other hand, though the basins in which they occur are of abnormal area, always contains exceedingly large quantities of salts peculiar to them, and these are pure and are not, as a rule, a mixture of sodium, magnesium, and
calcium salts which would be present if they were the result of the evaporation of surface waters. Mr. Arthur L. Stone, of Laramie City, has found the Union Pacific lakes near Laramie are fed by springs whose waters are highly charged with sodium sulphate. Finally at Rock Creek there are in one and the same basin some lakes containing pure sulphate of magnesium, others which contain with the latter also large quantities of sulphate of sodium, and still others which contain no deposit whatever. For these reasons it seems very certain that all of the large deposits of soda in Wyoming arises from the evaporation of the waters of springs which feed the lakes, and which are highly charged with soda.”

Ricketts in giving his views on the origin of the deposits of soda was led astray by several mistakes made by others. In the first place none of the deposits are pure soda. See analyses recently made by Prof. Slosson in this bulletin. The salts stored in the basins either in solution or as a solid compare in chemical constitution with the salts found in the soils and as efflorescent crusts. To be sure the sulphate of lime is quite insoluble and in consequence is very rapidly precipitated when concentrated in depressions. The difference in the salts found in the same basin, but in different depressions, is very interesting; but is accounted for in several ways. In the first place there is no deposit of pure Epsom salt; for it always contains sodium sulphate, unless one selects pure crystals for analysis. The relations between these deposits with varying composition should be considered in discussing their origin. The deposit rich in Epsom salt occupies the lowest point in the basin. Magnesium sulphate is more soluble than sodium sulphate at ordinary temperature, and in the case of a heavy rain when the soda had been deposited in the small depressions above the large ones, the freshet would carry away the magnesium sulphate to the lowest depression, where it is found. The magnesium sulphate being much more soluble, would also tend to store, the Epsom salts in the lowest depression on ac-
count of the percolation of the water, rich in these salts, to the lower level.

While it is possible that considerable alkali is being brought to the surface with spring water, the amount is insignificant as compared with the supply that is constantly being derived from the soils and other formations.

In looking into the "spring" theory careful observations were made at nearly all of the deposits of note in the state. In no instance were springs found on a level with or above the deposit or water line. In five instances deposits were found without any appearance of moisture, and in digging into the mass no water was found. In other places the deposits were underlaid with a saturated solution of sodium sulphate and other salts, while in other localities the soda is always in solution. In the latter instance I believe that there are springs that feed the lakes; but whether or not the waters are rich in sodium or other salts has not been determined. There are many instances where the water came up and filled an opening made, when blocks of the salt were being removed, and following this the opening was immediately filled with crystallized salts. This was in all probability due to the water below the deposit and the superincumbent weight was sufficient to force it to the surface. In one instance of this kind when the cube of soda was taken out for the World's fair the bed of salt was pierced several times with an inch bar, and through this opening the water came in at the rate of 450 gallons per hour. This solution had a gravity of 31 Baume, and an analysis made for sulphur trioxide proved it to contain 19 per cent $SO_3$ corresponding to 76 per cent of Glauber salts or 57 per cent of Epsom salts. Both these salts were present. While the springs play some part in the accumulation of the soda deposits, they must be considered of minor importance as compared with other factors.

From personal observations, it is my opinion that the alkalis have been derived from the soils and the strata which sur-
round the deposit or drain into them. In localities where there are vast beds of shale and clay with undrained depressions we always find alkali being stored. There is no exception to this statement so far as I am aware. In hundreds of places there are slight depressions at the present time, where there is an accumulation of salts going on; but no one has pretended to measure the amount that accumulates annually. This explanation was given by me in an article entitled "The Soda Deposits of Wyoming" and published in the spring or early summer of 1898, in the Mineral Industry, edited by R. P. Rothwell of New York, p. 631. In the fall of the same year Whitney and Means arrived at the same conclusion which was published in Alkali Soils of the Yellowstone, U. S. Department of Agriculture, Washington, D. C., 1898.

In summing up the evidence relating to the origin of the so called alkali salts of Wyoming I have arrived at the following conclusion: Primarily the alkali has been produced by the decomposition of the various rocks containing these elements. These salts appear to have been formed extensively during the Mesozoic and Cenozoic eras, but in place of being stored in deposits were carried down with the sediments. Later through the mountain making agencies these formations were brought to the surface and through the influences of decomposition and erosion have been converted into soil. The salts have remained in the soils so formed, since there has not been sufficient water to leach them out. The decomposition of the rocks is still in progress and from this source and the storage already accumulated in the soils the deposits of alkali have been formed and are being increased.

There are hundreds of places in Wyoming where sodium salts are being accumulated; but as a rule they do not form beds of much consequence. Upon the Laramie plains alone there are no less than 100 slight depressions containing more or less alkali. In the majority of cases the alkali is found in the fall of the year in a thin crust upon the bottom of small
ponds which have recently dried up. The deposits which are
to be discussed under the above heading are those where there
has been a considerable storage of alkali, and where it forms
masses of sodium sulphate and associated salts to a thickness
of one or more feet.

Since the alkali deposits look very much alike and have
been deposited under similar conditions a general discussion
of the beds will not be out of place at this point. In many
instances the name alkali lake has been applied to the soda de-
posits, since in the early spring and often into late summer the
deposits are covered with water. The water accumulates through
the melting snows and rain and is often a foot or two in depth:
but beneath this one can find a solid bed of crystallized alkali.
Later in the season these so-called “lakes” are deposits of snow
white alkali, which when seen from a distance resembles a snow
covered basin.

The deposits vary in size from a few to one hundred acres,
and in thickness from a few inches to ten or possibly fifteen
feet. The salts are always found resting upon a muddy bed,
which is usually very soft and without difficulty one can force
a pole to five or six feet below the hardened deposit. The mud
varies in color from almost black to bluish, and contains many
crystals of sodium sulphate. When it is removed from the bed
it has a strong odor of sulphuretted hydrogen, and often one is
conscious of an odor resembling that rising from dissolving
sodium hyposulphite. This mud always contains quite a per-
centage of salts found in the deposits.

For many years it was supposed that all of the alkali deposits
were of crystalline purity, and for commercial purposes they
could be quarried, dried and made ready for the market. Up-
on making a careful section of several deposits it was found
that none of the beds were pure; but were alternating layers
of salts, sand and mud. The thickness of the sodium sulphate
bands depends upon the rapidity with which the salts were
washed into the depression. It appears that at the close of each
season, or during the fall, all of the water was evaporated, and upon the alkali deposit the winter's wind carried the usual amount of sand. On the following spring the melting snow and rains carried into the depression not only the salts, but also muddy water which settled to the bottom and made a stratum of mud or muddy deposit. In some instances the accumulations of alkali of one or more previous seasons might have been dissolved, and all of the sand and mud concentrated at the bottom of the deposit or stratum. It is a rule that the deposits are mixtures of the various salts arranged in bands of varying thicknesses and alternating with other bands containing large percentages of sand or mud.

From a distance one would judge that the surface of any of these deposits was hard and smooth; but upon walking upon them they prove to be very irregular, and are covered with small conical depressions. These usually contain mud and water in case the surface is not entirely dry, and are about two feet in diameter and a foot or so in depth. No explanation can be offered for the formation of these at the present time.

For convenience the various deposits have been grouped under eight headings, as follows: Downey, Union Pacific, Rock Creek, Rankin, Bothwell, Morgan, Independence and Gill. These are all located in the southeastern part of Wyoming and are confined to Albany, Carbon and Natrona counties.

THE DOWNEY DEPOSITS.

These are located some 21 or 22 miles southwest of Laramie on the Laramie Plains, in a depression lying just west of Alkali creek. This depression has a northwest and southeast trend and originally drained into Sand creek, but has been dammed up, probably through the agency of wind driving the fine particles of clay from the great clay exposures along the bluff to the west. To the south of the deposits there appears to have been another dam formed by the wind which changed the drainage from Steamboat lake, from this depression, to Alkali
creek on the east. There are three deposits arranged one below the other, with only a short distance between them. Along the east side there is quite a prominent ridge along which one can see the outcropping Triassic red sandstone, which dips to the westward and passes beneath the beds. Only a few hundred yards west of the deposits the Jurassic clays and marls with alternating strata of light colored sandstone form gentle slopes for a distance of nearly a mile. The beds have a total area of about 100 acres. The lowest or the one furthest to the north and the middle one contain the greatest amount of alkali. The upper one is usually soft and miry and does not contain any large beds of hard soda. Along the edges of these depressions the salts are usually very thin; but the beds thicken rapidly
toward the center where they have a maximum thickness of about ten feet. The deposits have been derived from the formations in the immediate vicinity. The Triassic red sandstone and also the Jurassic clays are rich in these salts. The clays are especially so, and although this depression does not drain over four square miles, and at no time in its history could it have drained more than ten times this amount, from this limited area enough alkali has been released from the sandstones, clays and shales to have filled these depressions. In the fall of the year, when the surface becomes a pulverent mass the westerly winds carry it away in huge clouds. When at a distance of four or five miles from these beds I have seen the air so filled with these desiccated salts that one unacquainted with the conditions would have pronounced the dense white clouds the result of some terrible conflagration. Often in the fall of the year I have been upon the slope of the Laramie mountains, when the wind was blowing from 40 to 60 miles per hour, and from every dry alkali pond there was a cloud of alkali dust rising to a height of from 50 to 100 feet and extending for some distance beyond the course. In this way the annual supply of alkali washed into these depressions is to a certain extent disposed of; but this disposition is not equal to the storage, and in consequence the deposits are on the increase.

THE UNION PACIFIC DEPOSITS.

These are located some thirteen miles southwest of Laramie and until a few years ago were supplied with a branch line of railroad from the Union Pacific. There are four of these deposits, having a combined area of sixty acres. Being in the very heart of the Laramie Plains there are no natural water courses nearer than the Big Laramie river, which is fifty or more feet below at a point opposite the deposits. In this section of the country the plains form a broad, gently sloping surface having only a few feet fall per mile for a dis-
tance of twenty-five or thirty miles. This is rather deeply covered with river wash, with occasional depressions, which are seldom connected. These depressions vary from an acre to two hundred acres in extent and have been formed in the underlying Benton shales. In this vicinity one can find no less than a hundred of these and in every one there is alkaline water or more or less salts. Only a few of them are considered to be of any importance, and the Union Pacific are by far the largest and most valuable. Prior to the completion of the Pioneer irrigating canal which passes above the alkali deposits they were alternating lakes and soda deposits. Since the completion they are usually under water, which varies from a foot to two or three feet in depth. Some fifteen years ago an attempt was made to utilize these deposits. An alkali factory was erected at Laramie and equipped to manufacture carbonate and caustic soda out of the natural material. The salts were quarried or scraped from the surface, transferred to cars and shipped to the plant. After a long experimental existence the plant was compelled to close down, since with the high price of labor they could not compete with alkali manufactures of the east.

Later the salt was dried and utilized for glass making and was shipped to some extent to glass plants in the east. Recently nothing has been done with the crude material.

The quantity of alkali in these deposits is very great; but there are no data on which a reliable estimate can be based. Blocks of soda as large as eight feet square have been taken from the mass, and in places it has been reported to be upwards of fifteen feet in thickness.

It has been argued by some that since the Downey and the Union Pacific deposits were supposed to be identical, that they had a common source and that they were connected. Since they have been proven to be very different by Prof. Slosson's analyses it is scarcely necessary to recall this suggestion. The fact that they occur in different geological formations
and that the Downey are 100 feet above the Union Pacific would be sufficient to consider them wholly independent.

The origin of these deposits can be traced directly to the shales of the Benton formation which encloses them. Wherever the shales are exposed there is an encrustation of alkali. The river wash lying upon the shales, and which is often covered with considerable soil, is quite free from any soluble salts. Farming is going on in this region and alkali has not seriously interfered with raising any kind of grain or hay.

THE ROCK CREEK DEPOSITS.

These are located twelve miles northwest from the old Rock Creek station on the Union Pacific railway. Since this part of the road has been abandoned the nearest point by road is Rock River, which is some twenty-two miles via Rock Creek. Medicine Bow station is about the same distance, being a little south of west from the beds. The country about the group is composed of Triassic sandstone, and there has been a very large depression cut out of these rocks. At the lowest point this basin has a width of upwards of a mile and is two miles in length north and south. From this there is a broad gently sloping valley leading to the northwest. The upper portion of the valley is covered with soil and there are patches where greasewood and some coarse grasses seem to thrive. In the midst of this broad shallow valley there are many small depressions, the most of them being in soil. In these there are deposits of alkali; but the quality is quite variable. Near the upper depressions the salt is almost pure sodium sulphate; but as one follows the valley toward the great depression at its end the sodium salts decrease, and the magnesium salts increase. From these deposits there are all kinds of analyses published ranging from pure sodium sulphate to pure magnesium sulphate. The occurrence of these salts in the same valley has long been a puzzle, especially on account of the various beds having varying proportions of the two salts. It can be ac-
counted for by the greater solubility of the magnesium sulphate. These two salts accumulate together as they are derived from the soils and rocks. The sodium sulphate being less soluble precipitates first. This will often leave a bed covered with a concentrated solution of magnesium sulphate. In case a freshet happens to come, at such a time, the magnesium salts would be washed into the lower depression if not carried into the lowest one. In this way there has been going on in nature a gradual differentiation of these salts until today there are at either end of the valley almost pure salts of the two kinds; sodium being above and magnesium below. In the same way concentration of the magnesium salts has been going on by the solutions seeping through the soils to the lower levels.

No attempt will be made to describe in detail the deposits in this group. There are several small ones ranging from a quarter to a mile and a half north of the largest bed. In these there are in places, several acres of alkali, and they graduate down to mere ponds in which there is only a very slight deposit. The purest sodium salts are found farthest to the north. Intermediate the alkali is a mixture of sodium and magnesium that can not be relied upon since it is continually changing as the years go by.

The large bed in the lowest point of the depression covers an area of 90 acres. On the east, west and south there is a very high bluff of Triassic sandstone. For the greater part of the year this basin is covered with water; but in August it usually dries up, and one can walk about upon solid alkali, which in this case is almost pure Epsom salt. The entire surface of this was not examined; but a good many acres were examined about the northern end. At one of my visits there was a hole dug to a depth of three feet in the epsomite. Just how much of this salt there is in this basin has never been determined; but it is safe to say that the quantity is very great, and that there is ample to supply the United States with Epsom salts for many years to come.
The origin of the deposits in this basin is the same as those associated with the Downey group. The salts have been derived from the soils and from the decomposition of the Triassic and Jurassic formations, and are entirely cut off from any other source.

THE RANKIN DEPOSITS.

Under this heading will be included the Dillon, which is not far distant. The Rankin is located some three miles north-east of Brown's canon up on the great alkali flat that extends from the Union Pacific railroad west of Fort Steele northward nearly to Whiskey Gap. This great flat is from four to six miles in width and is bounded on the east by a huge escarpment of Cretaceous rocks, and on the west by a hilly country made up of the lower groups of the Rocky mountain Cretaceous. Through the central portion of this flat there is a series of depressions, which often contain water and form small ponds or lakes. All of these are more or less alkaline. The source of this water is the Red desert, the most of it being brought in by Separation creek, and passes very near the Bothwell deposit. Consequently the water contains a large percentage of alkali and the salts are being concentrated in the basins along the alkali flat. The Rankin deposit is usually under water; but occasionally it becomes dry and there are several acres of sodium sulphate scattered over the numerous small depressions. This is very likely a young deposit and we may expect to see it increase in size during our day, since it has such a desirable region to draw from. The exact geological position of the beds could not be determined on account of the very thick accumulation of soil that covers the flat. However, it is safe to place it either in the upper Benton or Lower Niobrara. The salts in this deposit as in the Bothwell are derived from the Cretaceous rocks and all other sources are barred. The drainage from the Red desert brings in a vast amount of alkali and the Benton shales and clays lying above the deposits are also rich in salts.
The Dillon deposit is located some six or seven miles northeast of Rawlins in a slight depression. Samples of the purest salt were obtained from Mr. Dillon for analysis; but no further information was secured and the deposit was not visited. It is located westward from the Alkali Flat in the Cretaceous rocks and is probably in the Benton formation.

THE BOTHWELL DEPOSITS.

These are located thirty miles northwest of Rawlins and to the right of the Rawlins and Lander trail, just east of the old Bull Springs stage station, on Secs. 23 and 26, T. 25, R. 39. The country about is a desert and in reality is a portion of the Red desert, clothed with greasewood and occasional patches of sage brush together with the salt sage and a few stunted grasses. There are no streams in this section. Separation creek, as it is called, passes through this region, but it is only a gully, carrying water occasionally and then never in any great amount. To the northeast are the mountain ranges which are fifteen or twenty miles away. To the south is the Rawlins uplift and to the northwest there is a prominent Tertiary bluff that rises between 500 and 1,000 feet above the desert. Between the Tertiary bluff and the Rawlins uplift there is a broad stretch of comparatively level country which drains to the eastward toward the Seminoe mountains. The soils of this region as well as the formations themselves are rich in alkali, and it is seen everywhere. A slight rain or snow melting brings a considerable to the surface and it is found in slight pools upon the surface of the soils and the exposed strata. In no place in Wyoming have I seen more alkali upon the surface. Undrained depressions are few; but wherever found contain alkali. The Bothwell deposit appears to be a wind-made depression in the Laramie shales and clays and drains quite an area of country. The depression is small as compared with the others of the state, and the alkali covers by far the greater portion of it. To the south and west there are several lesser
alkali deposits which drain into the large one, which is 250 by 515 yards in extent.

When I examined this deposit in the fall of 1899, it was a solid bed of salt; but in all probability it is often covered with water during the spring. A hole was dug to the depth of over two feet and the accumulation was found to be about the same as in the other deposits of the state. No attempt was made to ascertain the thickness of the bed; but judging from observations made on other masses it will prove to have a maximum thickness of not less than 15 feet.

The origin of the salts in this deposit can be traced to the decomposition of the Tertiary and Laramie formations, which are the only ones that could supply them. There are no springs to bring salts from beneath, and no rocks older than the Laramie that could contribute to the soil making, unless the material would be brought in by the wind. This instance illustrates very nicely my idea of the origin of the deposits of the entire state, for here we have none of the other possible sources to consider, and at the same time have one of the largest deposits in Wyoming.

THE MORGAN DEPOSIT.

This is the most northern of any of the important deposits along the Sweetwater river. It is located in the southwestern corner of Natrona county and about six or seven miles below Split Rock P. O. on the south side of the river. In this vicinity the valley of the river is quite wide. There is a broad lower flat that is irrigated, and from this the country rises gradually to the high and arid plains. Occasionally there is a secondary valley paralleling the present river channel and in one of these the Morgan deposit is located; it being separated from the river by a well marked divide. This long narrow depression has been cut out of Tertiary rocks, and to some extent refilled with mud and debris brought in by a small gulch which enters the basin from the southwest, and the wind.
This gulch carries considerable water during the early spring; but is usually dry. It does, however, drain quite an area of the valley and small gulches reach out nearly if not to the Ferris mountains. South of the mouth of the gulch there is a small marshy place where there is usually a little water. The area known as the alkali deposit contains about 100 acres; but of this there is only a slight amount that contains any solid deposit. In the summer of 1885 I examined this so-called soda lake and in August found it under water, and a small walk built out to the solid alkali. In 1894 I made another examination in the month of September and found the depression a great soft mud deposit with the exception of a small acreage in the southeast corner. The mud was, however, highly charged with soda; but no deposit except the intermixture of crystals which would amount to only a few percent of the mass. I did not make an estimate of the alkali; but later Mr. Attfield of London made a survey and announced that there were six acres of alkali.

The origin of this deposit has not been satisfactorily worked out. There are no granitic rocks associated with this depression, and there are no Mesozoic rocks exposed in the valley. Consequently one must look for the origin in the Tertiary beds. Here there is another question to be solved. The alkali in the Morgan deposit is nearly all sodium sulphate, and in the Independence group, which are in the same formation, there is a large percentage of sodium carbonate. If they have a common origin it would appear that they should be of the same chemical nature. In my opinion the salts are brought in from the soils covering the Tertiary rocks and the Tertiary beds; but I have no evidence to support this theory, more than that they occur in Tertiary basins and can not draw their salts from other sources.
THE INDEPENDENCE GROUP OF DEPOSITS.

This is the largest group in the state, and is located in the Sweetwater valley near Independence Rock, from which the group takes its name. The topography of this region is different from any other part of the state. The Sweetwater valley, which includes all of the territory between the Ferris mountains on the south and the Rattlesnake on the north has an approximate width of thirty miles. This was at one time a level stretch of country covered with Tertiary rocks. The Sweetwater river in its meanderings has cut a broad irregular valley in the midst of this region. At the present time it is a comparatively level rolling country studded with low hills of granite, which are known as the Sweetwater mountains. These irregular masses of granite appear to have projected above the Tertiary seas, and at the present vary from one hundred to one thousand feet above the surrounding country. They are very smooth, nearly barren slopes, with occasional scrubby pine trees. Near Devil's Gate, which is just above the alkali deposits, the granitic mass is the largest, and crosses the river at this point in its southern course, and forms what has been known for years as Fort Ridge. From Fort Ridge to the northward the valley is quite wide, and there are numerous places where one can see the old river bed far to the north of the present stream. While the country about is composed solely of Tertiary light colored beds with the projecting knobs of granite, in the valley of the stream these are not visible. The surface of the valley is extremely sandy and there are small dunes scattered along the north side of the channel. Between the river and the alkali deposits, which are from one-half of a mile to a mile north of the river there is a prominent divide that is covered with river gravel and sand. This divide extends for a distance of ten or twelve miles; but varies in prominence. Near Devil's Gate, this ridge terminates and the country is slightly higher than the valley to the south. It appears that the Sweetwater river at some early date occupied the depression north of the ridge; but has not used it for a
very long period of time. On account of the accumulation of sand, this old channel has numerous barriers across it, but as a rule one can trace the gradual descent to the eastward. At the present time none of the depressions have any connection with each other, and it is hardly probable that salts are carried from one to the other unless it is by underground drainage; which would be very natural in a sandy region of this sort. Along this old channel are scattered the alkali deposits. There is a very large one at the very head of the valley, and there are many small depressions that contain a crust of salt, or in a few instances some solid deposit to the depth of two or three inches. Where ever there is a depression, alkali is found to a greater or less degree. From the edge of the basins toward the north or south there are the typical coarse alkali grasses which graduate into the more nutritive forms on the sandy soil above. The depressions are apparently in a muddy layer, and above this there is quite a thickness of gravel and sand. Apparently the river cut this long channel out of the horizontal Tertiary rocks, and then partially refilled it with mud and sand. Later the stream abandoned it for the channel to the southward, and it was materially changed by the wind carrying sand, and also cutting away quite a volume from the various dry exposures. It looks very reasonable to believe that the wind has played a very important part in the development of the beds in which the alkali has been deposited. As has been found in all of the alkali deposits, the beds beneath the solid crust are made up of a dark mud which is highly charged with the salts. Within the channel are located many of the most celebrated alkali deposits in the west.

North of this depression there is a second one, in which the Bertheton beds are located, that does not appear to have any connection with the one just described. It extends east and west for a distance of three or four miles, and in it there are numerous alkali ponds. It is probable that this also represents an old channel of the Sweetwater river; but the topography was not worked out in detail and this cannot be given as
The alkali deposits in the first channel are as follows: New York, Philadelphia, Wilmington, Wilkesbarre and Omaha, besides many lesser ones of little importance.

The New York and Philadelphia claims are located on Sec. 12, T. 29, R. 87, and are very near the granitic exposures that extend north from Devil's Gate. These claims are located upon one basin, which according to survey of the owners of these claims contain 110 acres of deposit. On the north the Sweetwater mountains rise to a height of about 800 feet. Otherwise the country is comparatively level. There is a marked outlet to the east and in case there is ever very much water in the depression there would be an overflow, into the numerous depressions along this old channel. The amount of alkali in this the largest deposit known in Wyoming was not estimated. In walking over the surface, which was in places covered with mud, a solid mass was found everywhere, and since it was nearly a mile in length and from one-fourth to one-half a mile in width it would necessarily have to be quite thick in the center, probably from 15 to 20 feet, and the entire deposit would average not less than four feet in thickness.

There are greater problems in connection with the origin of these deposits than any other in the state, and on this account it is best to make reference to some observations in connection with this great deposit. Wherever there are depressions in this vicinity, and about the large deposit, the alkali was found along the eastern sides and reaching up to the grass roots, while along the western slopes alkali was scarce or practically absent. In one place a spring of water was noticed to the westward of the old channel, and it was freely used by cattle and did not taste strongly of alkali. There was no marked amount of alkali collected along the north side of the large deposit, which was nearest the granite. From what could be seen, it was evident that the alkali was being drawn from the north; but the source was not determined.
East of the New York and Philadelphia claims five miles are the Wilmington and Wilkesbarre, which are very near Independence Rock. These are located in sections 2, 3, 10 and 11, T. 29, R. 86, being on a section line. The Wilmington claim contains 160 acres, and is a lake that has never been known to dry up. The water is highly charged with alkali, and possibly there may be salts forming in the bottom of the depression. The soil about is highly charged with alkali; but as in the beds above there is much more found to the north than the south. The Wilkesbarre claim is only a short distance east of the Wilmington, and separated from it by a narrow ridge which is quite low. At the time of my examination the midst of this claim was partially wet and not being provided with waders I could not examine into the conditions beyond the limits of solid shore. The shore was covered with a thin efflorescent crust; but no deposit of any consequence was observed. As compared with the other deposits or claims this one is very small, and should there be a considerable deposit in the middle the very small area would prevent it from being valuable.

About a mile and a half northeast of the Wilkesbarre claim is the Omaha; a very remarkable alkali deposit, although it is very small, containing only between three and four acres. The depression in which this claim is located is of considerable size and from the west and to some extent from the north there are efflorescent crusts of alkali leading down to the deposit. While the base of this depression is at least 50 feet above the Sweetwater river, the depression is nearly surrounded with a rim that is from 20 to 50 feet above the surface of the solid alkali. All of the surrounding surface could have been transported by the wind; in fact the soils are largely dune sands. The solid alkali looks like a pond of glistening snow as one approaches it. The surface is comparatively level and the salts are as solid as a lake of ice. A drill hole put down in the middle of the deposit proved it to be four and one-half feet in thickness. Owing to this deposit containing a large percentage of sodium carbonate and also some bi-carbon-
ate it has long been utilized for cleansing purposes and to some extent for raising bread, and it must have been from this bed that the Mormons in early days mined the alkali and transported it to Salt Lake.

From this place the surface of the valley falls very gently to the eastward, and there are many places where the soil is so completely saturated with the salts as to prevent the growth of any kind of vegetation. Even in the most favored places the only grass seen was the coarse, harsh variety that will grow upon alkali soil; but which the stock will not eat unless they are compelled to. These conditions extend as far down the stream as the Sweetwater bridge; here ditches are furnishing water for irrigation, and portions of the valley are being successfully tilled.

North and east of the Omaha claim three miles are the Berthaton claims that have attracted considerable attention, and which are now held by some Chicago gentlemen. Some years ago they erected a soda plant and commenced to manufacture the bicarbonate of soda. For unknown reasons the plant was shut down. These claims embrace 640 acres of ground that is scattered along what appears to be an old channel of the Sweetwater river. It is about three or four miles in length and drains into the river. The most of the depressions are covered with water and when making the examination one could not tell whether there was any solid soda deposited or not. The depressions were not separated by marked barriers as those to the southwest, and when any considerable water would flow into this valley there is no question but they would drain one into the other and finally into the river. On this account there has never been an opportunity for any great accumulations of alkali. About this depression there was an abundance of alkali efflorescence, much of the ground was barren, and the remainder supported typical alkaline vegetation.

The origin of the alkali in the Independence group has not been satisfactorily accounted for. If there is any alkali being produced by the decomposition of granitic rocks, and stor-
ed in the soils, this appears to be an ideal place. The granitic hills are numerous and are often not far removed from the deposits. The river gravel is largely feldspatic granite and it appears that the decomposition of the feldspar in this should add a considerable alkali to the soils. On the other hand there was no evidence that the granite in place was feeding any of the depressions, and often a bank of river gravel was exposed and no trace of alkali upon the surface. A vast amount of money has been spent in prospecting for supposed beds that many have contended were covered up, but without success. Holes dug to the depth of 20 feet, in the various depressions have universally proven to be devoid of any alkali, and often the water seeping into these prospect shafts has been fit to drink. Springs also occur in the vicinity of several of the deposits and usually the water is quite pure. In the vicinity of the Berthaton claims are numerous springs of very good water. All of the water used by the company developing these deposits was obtained from wells that were dug near by the soda deposits or lakes. This water was better than the average found in the Cretaceous rocks in Wyoming. Springs feed the lakes; but in my opinion they do not carry any considerable quantity of salts annually into the depressions. Judging from the fact that in the group nearest the river the efflorescent crust was found in abundance upon the soils and clays on the east side of the depressions and only sparingly if at all on the western slopes, leads me to believe that the alkali is being brought in from the north by the seeping of water from rain or snow. It is clearly demonstrated that the salts are superficial, or they would be found in the many test pits that have been sunk. Whether or not they are found in any considerable quantity in the Tertiary strata has not been determined; but I surmise that this is the case, and that they are being concentrated at the present time in the undrained depressions. The large amount of sodium carbonate present is a question that deserves attention; but since its occurrence has not been accounted for, it will not be taken up in this connection.
THE GILL DEPOSITS.

The Gill deposits are located in the desert region north-east of Casper some six or eight miles. The country about is rolling upland with sandy surface, on which grows the average desert vegetation, which makes such excellent winter sheep range. The drainage of the region is toward the North Platte river; but there are no streams and only a few dry gulches. All of the water of this region comes from rain or snow.

The deposits are four in number, and are located in the same basin on section 26, township 35, range 78. The geology of this part of Natrona county is very simple. Along the Laramie mountains in the vicinity of Casper mountain the Carboniferous rocks lie highly inclined against the Archean. To the northward are the following formations outcropping: Triassic, Jurassic, Cretaceous. The Cretaceous groups present are as follows: Dakota, Benton, Niobrara, Fort Pierre, Fox Hills and Laramie. The Laramie outcrops a few miles east of Casper and from this point extends to the northward. The Fox Hills underlies Casper and also extends for many miles to the north. These deposits are located in what appears to be wind-made depressions in the Fox Hills formation. The deposits are usually solid, and it is only in early spring that they are covered with water. The amount of solid deposit has been placed at about 80 acres, and it is claimed to be of unusual thickness. The origin of these deposits has been the same as others in the Cretaceous rocks. This depression drains a small area of clay and shale formations, and the alkali brought to the surface by the decomposition of these strata together with that which is in the soil has been sufficient to furnish the alkali found in these ponds. These are of unusual importance since they are very near the Fremont, Elkhorn and Missouri Valley railroad and could be worked for the sulphate, which when dried makes an excellent glass, and if not utilized at home could be shipped to eastern glass plants.
In the present bulletin only those deposits where the alkali is of considerable depth and purity are considered. Analyses of many of the alkali-bearing waters of the state were reported in Bulletin No. 24, and some analyses of common alkali surface crusts are given in Alkali Studies, IV, published in the Ninth Annual Report of Wyoming Agricultural Experiment Station. Samples of alkali from the large deposits were reserved for publication till all the large deposits in the state could be reported together in this bulletin.

The alkali deposits, or "soda lakes" as they are commonly called, can be divided into two classes, those that contain carbonates in quantity and those that do not. The principal salts in the former class are sodium carbonate, sodium sulphate and sodium chloride. Lakes of the latter class contain sodium sulphate, sodium chloride and magnesium sulphate. Besides these there are also often traces of potassium, lithium, iron, aluminium, manganese, borates, nitrates, sulphides, and phosphates. In most of the following analyses only the three principal salts were determined and calculated to 100 per cent, the results being checked by duplicate determinations and by sufficiently close agreement with the total weight of dried salts. This method of analysis was complete enough for the purpose of the bulletin, which was to determine the character of the deposits as a whole. Samples taken from any two points of a lake or
from the same point at different times are quite unlike in composition, and analyses of the heterogeneous mass of crystals and adhering solution like those given here raise more questions than they answer as to the mineral species present and the method of their formation. The complete analysis of selected crystals and the determination of the order of crystallization of the salts from saturated solutions will be carried on for a future bulletin of the University Geological Survey of the State.

The salts found in the soda lakes are the same as those which occur in the soil of the surrounding region and form alkali crusts as they are drawn up from below with the water and left on the surface as this evaporates. Of these salts, the most abundant in Wyoming is sodium sulphate. This exists in two forms: with water of crystallization and without. The former has the chemical symbol \( \text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O} \) and is called mirabilite in mineralogy and Glauber's salt in medicine. The pure crystals contain 55.91 per cent of water and 44.09 per cent of the dry sulphate. It forms large, transparent crystals which when exposed to the air lose all their water of crystallization and fall into a fine white powder (\( \text{Na}_2\text{SO}_4 \)), known as thenardite.

Magnesium sulphate (\( \text{MgSO}_4 \cdot 7\text{H}_2\text{O} \)) epsomite, or Epsom salts, is found as long, needle-shaped crystals or short, thick crystals about a quarter of an inch thick, and contains 51.2 per cent water of crystallization which it loses in part when exposed to dry air.

Sodium carbonate (\( \text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O} \)), sal soda, or natron, contains 62.9 per cent water of crystallization when fully hydrated, but will lose from a half to nine-tenths of it to dry air.

Sodium chloride (\( \text{NaCl} \)), common salt, or halite, contains no water of crystallization.

Besides these forms there are an immense number of salts which must be formed under the constantly varying conditions of temperature, concentration and composition which prevail in the soda lakes. Besides other salts of the bases and acids pres-
ent, such as magnesium chloride, there are an unknown num-
ber of double salts of different degrees of hydration which
could exist within the range of actual conditions. To work
these out as Van't Hoff is doing with the similar Stassfurt salts
is a task that will require years.

In taking these samples, in most cases the effort has been
to get an average sample representative of the deposit as a
whole and not to select the best crystals, as has usually been
done for the analyses previously published. Consequently the
analyses here reported will be a disappointment to many who
have put faith in the exaggerated accounts of the purity and
extent of the deposits. The variation in composition is, how-
ever, so great that it would require sampling on a large scale to
an accurate idea of the average composition.

The samples were usually bottled on the spot, so very little
of the water was lost. As the analyses show, the crystals from
beneath the surface have nearly the theoretical percentage of
water of crystallization, and sometimes more, owing to the ad-
hering water. The matter insoluble in water is clay, mud and
sand, sometimes also containing precipitated calcium and mag-
nesia carbonates and often gypsum. Since the insoluble
matter and the water are so variable and accidental, the analyti-
cal results are recalculated on the basis of the dry salts. From
the relations between these, however, no conclusion can be
drawn as to the existence of double salts of definite composition.

DANGER TO STOCK FROM THE SODA LAKES.

The two principal salts in the alkali deposits of Wyoming,
Glauber's salt and Epsom salt, are used in medicine as purga-
tives and are poisonous in large doses. Cattle, horses and sheep
gradually become immune to the alkali of the amounts con-
tained in most of the surface water of the state, and even when
kept in the vicinity of alkali lakes if supplied with a sufficiency
of good water they do not drink that of the lakes. It has
frequently happened, however, that sheep driven some dis-
tance have come to the alkali lakes very thirsty and have perished in large numbers from drinking the water. In 1889 Professor Nelson saw about 500 sheep around the Howell lakes which had been killed in this way, and a similar accident happened near Laramie a few months ago. Very likely some of the numerous supposed cases of malicious sheep poisoning are to be accounted for in this way. It is, however, difficult to determine whether death in any particular case is due to the poisonous effects of alkali or merely to drinking too much water when overheated by hard driving.

THE DOWNEY DEPOSITS.

The Downey soda deposits were visited by E. E. Slosson and H. M. Derr on Oct. 5, 1901. There are three lakes in this group, extending in a line from the southwest toward the northeast. The most southern of the lakes was filled with water only a few inches in depth in most places. Beneath this and around the lake for some thirty to fifty feet is a thick bed of soft mud into which the feet slowly sink as in quicksand. The mud is in distinct layers, yellow on top, then greenish and very black. A strong odor of hydrogen sulphide is given off when it is stirred. Analysis of the water from this lake (No. 173) shows it to be a very strong solution of sodium and magnesium sulphates, with a little sodium chloride. Its specific gravity is 1.261. There is a little sodium carbonate, but the solution is so strong with neutral salts that it does not give an alkaline reaction with phenol-phthalein until diluted.* The water contains sulphides and very likely also other reduced sulphur acids, although these were not detected. There is a trace of bromides but no borates.

A ditch leads out of this lake for a short distance and in this some of the water had evaporated, leaving a bed of clean crystals from which sample No. 175 was selected. This con-

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*This was first observed and explained in the case of Great Salt Lake, Utah, by Dr. Cameron of the Department of Agriculture. [Report No. 64, 1899, p. 106.]
Alkali Lakes and Deposits.

109

contains more magnesium sulphate than sodium sulphate and beautiful crystals of both salts can be picked out by hand.

The middle Downey lake is the largest and most important and is almost solid, although in walking over it one frequently breaks through the thin upper crust into pools a few inches deep. There are also pools of water standing on top of the soda in many places, formed by the melting of the salt in its own water of crystallization by the sun. As the air cools these again become solid and it is interesting to watch the long, transparent crystals of sodium sulphate shooting rapidly across the surface of the water. The salts are distinctly pink in some places, which is due to a trace of some manganese salt.

The upper crust is nearly pure white and one to three inches deep. Beneath this is a layer of black mud, then crystals embedded in mud. Near the center of this lake a hole was drilled to a depth of about six feet, when the drill dropped through the crust into the soft mud and water below. Water seeps in from the sides as the hole is dug. A blast placed in this threw out a mass of large, clear crystals mixed with mud and water from which Sample No. 178 was selected by picking out chiefly the larger and cleaner crystals. As the analysis shows, the salt is mostly sodium sulphate with some five per cent of magnesium sulphate and smaller amounts of sodium chloride and gypsum. The water which fills up the hole is of course a saturated solution of the salts (No. 176) and has a specific gravity of 1.307. In this the magnesium salts and chlorides are in larger proportion than in the salts deposited from it and there is a little carbonate. On evaporating the solution to dryness and treating repeatedly with small amounts of water there is left a slight insoluble residue consisting of magnesium, aluminum and iron hydroxides, the quantities being in this order. Sulphates are present but no borates. Since in these solutions the water present is not much more than the water of crystallization of the accompanying salts, the analyses are also reported in percentage by weight.
Samples Nos. 162 and 163 are salts and solution taken from the same lake in 1899. They contain a much larger proportion of magnesium sulphate, which in the salt is nearly equal in amount to the sodium sulphate and in the water is nearly three times as great.

The northern Downey lake is smaller than the middle but the salts are purer and there is less mud. A sample of good clean crystals from the surface gives over 95 per cent sodium sulphate, with about 4 per cent magnesium sulphate and a trace of chloride (No. 182).

### Percentage Composition of the Downey Deposit, Albany County, Wyo.

<table>
<thead>
<tr>
<th>Laboratory No.</th>
<th>162</th>
<th>178</th>
<th>163</th>
<th>176</th>
<th>173</th>
<th>175</th>
<th>182</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>44.41</td>
<td>55.43</td>
<td>74.60</td>
<td>72.79</td>
<td>75.89</td>
<td>49.29</td>
<td>55.94</td>
</tr>
<tr>
<td>Insoluble</td>
<td>.11</td>
<td>2.24</td>
<td>.13</td>
<td>.02</td>
<td>.02</td>
<td>.51</td>
<td>.10</td>
</tr>
<tr>
<td>Sodium Sulphate (Na$_2$SO$_4$)</td>
<td>.28</td>
<td>24.17</td>
<td>6.93</td>
<td>12.77</td>
<td>11.50</td>
<td>19.67</td>
<td>41.02</td>
</tr>
<tr>
<td>Sodium Chloride (NaCl)</td>
<td>.28</td>
<td>.12</td>
<td>1.16</td>
<td>.86</td>
<td>.45</td>
<td>.50</td>
<td>.12</td>
</tr>
<tr>
<td>Magnesium Sulphate (MgSO$_4$)</td>
<td>.26</td>
<td>2.34</td>
<td>17.31</td>
<td>13.40</td>
<td>12.08</td>
<td>30.33</td>
<td>1.82</td>
</tr>
<tr>
<td>Sodium Carbonate (Na$_2$CO$_3$)</td>
<td>.80</td>
<td>.65</td>
<td>.06</td>
<td>.06</td>
<td>.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium Sulphate (CaSO$_4$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculated as dry salts:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium Sulphate (Na$_2$SO$_4$)</td>
<td>.50</td>
<td>92.54</td>
<td>25.61</td>
<td>47.18</td>
<td>47.74</td>
<td>39.18</td>
<td>95.46</td>
</tr>
<tr>
<td>Sodium Chloride (NaCl)</td>
<td>.50</td>
<td>.28</td>
<td>5.28</td>
<td>3.17</td>
<td>1.86</td>
<td>1.00</td>
<td>.28</td>
</tr>
<tr>
<td>Magnesium Sulphate (MgSO$_4$)</td>
<td>.48</td>
<td>.29</td>
<td>70.11</td>
<td>49.47</td>
<td>50.16</td>
<td>59.82</td>
<td>4.26</td>
</tr>
<tr>
<td>Sodium Carbonate (Na$_2$CO$_3$)</td>
<td>.80</td>
<td>.18</td>
<td>.24</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium Sulphate (CaSO$_4$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No. 162 is a sample of the crystallized salts from under water in the middle Downey lake and was obtained by W. C. Knight Nov. 22, 1899.

No. 178 is from the same lake and consists of large, clear crystals of mirabilite mixed with mud and water. It was obtained by blasting through the crust to the depth of about six feet near the middle of the lake. Collected by E. E. Slosson, Oct. 5, 1901.

No. 163 is a sample of the solution standing above the salts represented by No. 162. Collected by W. C. Knight, Nov. 22, 1899.

No. 176 is the solution which filled in the blast hole when No. 178 was taken.
No. 173 is the water from the southern Downey lake. Collected by E. E. Slosson, Oct. 5, 1901.

No. 175 is a sample of crystallized salts found in a small ditch leading out of the southern Downey lake. Collected by E. E. Slosson, Oct. 5, 1901.

No. 182 is a sample of the purest crystals obtainable from the extreme northern end of the northern Downey lake. Collected by E. E. Slosson, Oct. 5, 1901.

THE UNION PACIFIC DEPOSITS.

These soda deposits have received more attention than any others because of their accessibility and commercial importance and it therefore will not be necessary to devote much space to them here. For shipping to the Laramie Soda and Glass Works the purest soda crystals from the surface were scraped up when the lake was dry and kept in large heaps in the open air while being worked up. The outer layer of such a heap loses, of course, its water of crystallization and becomes white powder, but at a depth of an inch or two the crystals are entirely unchanged. Good crystals are even to be found in the interior of a small heap of soda that had been exposed to the weather for over six years. The average composition of the salts is represented by the analyses here given, but large crystals of pure sodium sulphate can be easily picked out. The chief impurities are magnesium and calcium salts and chlorides. The average output is, however, as pure as the commercial "saltcake," made by the LeBlanc process, which contains usually 93-95 per cent of sodium sulphate. The sulphate from the lakes contains more magnesium salts than the Le Blanc sulphate, but on the other hand it is freer from iron and therefore better suited for glass making. In the works at Laramie the soda was dried by methods in imitation of the old Le Blanc process, which involved useless labor and expense. According to analyses made in 1891 in this laboratory the final product was less pure than when it was put into the calcining furnace.
It is not at all necessary to use such high heat, because the water of crystallization is entirely driven off at a temperature a little above 212° F., or the sodium sulphate can be precipitated anhydrous from a hot solution without difficulty. The application of a few elementary chemical principles to the problem would have saved many thousand dollars wasted in the attempt to utilize the soda deposits of the Laramie Plains.

**Chemical Composition of the Union Pacific Deposits, Albany County.**

<table>
<thead>
<tr>
<th></th>
<th>Laboratory number, 172</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>55.55</td>
<td>46.87</td>
</tr>
<tr>
<td>Insoluble matter</td>
<td>.09</td>
<td>13.86</td>
</tr>
<tr>
<td>Sodium sulphate (Na$_2$SO$_4$)</td>
<td>42.75</td>
<td>34.85</td>
</tr>
<tr>
<td>Sodium chloride (NaCl)</td>
<td>.70</td>
<td>1.16</td>
</tr>
<tr>
<td>Calcium sulphate (CaSO$_4$)</td>
<td>--</td>
<td>1.45</td>
</tr>
<tr>
<td>Magnesium sulphate (MgSO$_4$)</td>
<td>.91</td>
<td>.97</td>
</tr>
</tbody>
</table>

Calculated as dry alkali salts:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium sulphate (Na$_2$SO$_4$)</td>
<td>96.37</td>
<td>94.23</td>
</tr>
<tr>
<td>Sodium chloride (NaCl)</td>
<td>1.58</td>
<td>3.14</td>
</tr>
<tr>
<td>Magnesium sulphate (MgSO$_4$)</td>
<td>2.05</td>
<td>2.63</td>
</tr>
</tbody>
</table>

Sample No. 172 was taken from the Soda Works at Laramie in 1891. It represents the dried soda as it was then being put on the market, prepared from the purest crystals of the lake. To bring them into the form in which they exist in nature, the water of crystallization has been calculated and added to the first report of the analysis.

In the column marked A is an analysis of an average sample from the Union Pacific lakes made by H. Pemberton and G. P. Tucker and published in Chemical News, vol. 68, p. 19 (Abstract in Journal of the Chemical Society, 1893, p. 535). To bring this into form comparable with the other analyses of this bulletin, the magnesium which they report as chloride has been recalculated to sulphate. In a solution it would be a matter of indifference which way it is reported, because a solution of magnesium chloride and sodium sulphate would be identical with a solution of magnesium sulphate and sodium chloride in equivalent proportions, but since crystals of magnesium sulphate can be picked out of the mass in many of these lakes,
while the chloride has not been distinguished, it was thought better to report the magnesium as sulphate in all cases.

Pemberton and Tucker, in the same article, report the following analyses of the supernatant liquid of the Union Pacific lakes. Probably what they report as borax and which they determined merely by titration with standard acid, is really sodium carbonate, because borates are very rare in the Wyoming lakes, while sodium carbonate could easily be present in such a solution in spite of the presence of calcium and magnesium. See analysis of the water from the Downey lakes, which are similar to these.

**Analysis of the Water from the Union Pacific Lakes.**

Calculated in grams per liter (parts per 1000).

<table>
<thead>
<tr>
<th></th>
<th>Big Track Lake</th>
<th>Red Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>1.0487</td>
<td>1.0725</td>
</tr>
<tr>
<td>Sodium sulphate (Na$_2$SO$_4$)</td>
<td>44.90</td>
<td>75.63</td>
</tr>
<tr>
<td>Calcium sulphate (CaSO$_4$)</td>
<td>1.75</td>
<td>1.46</td>
</tr>
<tr>
<td>Magnesium sulphate (MgSO$_4$)</td>
<td>.60</td>
<td>.70</td>
</tr>
<tr>
<td>Magnesium chloride (MgCl$_2$)</td>
<td>6.43</td>
<td>3.00</td>
</tr>
<tr>
<td>Sodium borate (Na$_2$B$_4$O$_7$)</td>
<td>1.46</td>
<td>1.21</td>
</tr>
<tr>
<td>Total solids</td>
<td>55.14</td>
<td>82.00</td>
</tr>
</tbody>
</table>

In comparison of the composition of the water with the salts crystallized from it the greater purity of the latter will be noted here and in all other cases. The magnesium salts and chlorides remain in solution while nearly pure crystals of sodium sulphate are deposited.

**THE ROCK CREEK DEPOSIT.**

These deposits differ from the other deposits in the large proportion of magnesium sulphate or Epsom salt they contain, amounting in two of the samples to over 77 per cent of the dry salts. Beautiful crystals of epsomite can be easily selected which are of large size with well developed faces and nearly chemically pure. The amount of sodium chloride is small, but an average of the mass of salts shows that there is a large
quantity of sodium sulphate, much more than has been commonly understood.

No. 88 is from the surface of the largest of the Epsom lakes.

No. 89 is from a depression in a small lake about a quarter of a mile north of the largest.

No. 90 is from a large deposit about a mile north of the largest lake.

No. 91 is from a deposit just north of No. 90. In this sample the sodium sulphate is between four and five times greater than the magnesium sulphate and it corresponds therefore rather with the ordinary Wyoming soda deposit than with the rest of the deposits of this group.

No. 92 is the mud from beneath No. 89. The salts contained in it are much the same as in the deposit above, but the proportion of chlorides is much greater.

All these samples were collected by Dr. Knight in February, 1898.

### Chemical Composition of the Rock Creek Deposits, Albany County.

<table>
<thead>
<tr>
<th>Laboratory number</th>
<th>88</th>
<th>89</th>
<th>90</th>
<th>91</th>
<th>92</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>44.50</td>
<td>48.03</td>
<td>51.08</td>
<td>49.66</td>
<td>27.71</td>
</tr>
<tr>
<td>Insoluble</td>
<td>.65</td>
<td>.08</td>
<td>1.13</td>
<td>.58</td>
<td>64.96</td>
</tr>
<tr>
<td>Sodium sulphate (Na₂SO₄)</td>
<td>12.13</td>
<td>24.49</td>
<td>10.22</td>
<td>40.52</td>
<td>1.20</td>
</tr>
<tr>
<td>Sodium chloride (NaCl)</td>
<td>.38</td>
<td>.24</td>
<td>.46</td>
<td>.42</td>
<td>.66</td>
</tr>
<tr>
<td>Magnesium sulphate (MgSO₄)</td>
<td>42.34</td>
<td>27.16</td>
<td>37.11</td>
<td>8.82</td>
<td>5.47</td>
</tr>
</tbody>
</table>

Calculated as dry alkali salts:

| Sodium sulphate (Na₂SO₄) | 22.13 | 47.19 | 21.41 | 81.43 | 16.33 |
| Sodium chloride (NaCl)    | .69   | .46   | .95   | .84   | .906  |
| Magnesium sulphate (MgSO₄) | 77.18 | 52.35 | 77.64 | 17.73 | 74.61 |

### THE BOTHWELL DEPOSIT.

This deposit consists chiefly of sodium sulphate with magnesium sulphate running from a trace to five per cent and sodium chloride from three-tenths of one per cent to three per cent of the dry salts. There is no apparent relation between the depth and composition and the deposit is composed of alternating strata of varying mixtures of the three principal salts.
These samples were all taken by W. C. Knight and P. Paulson in November, 1899, from the Bull Spring lake or Bothwell deposit.

No. 158, from the surface.
No. 159, depth of one foot.
No. 160, depth of two feet.
No. 157, selected crystals.

**Chemical Composition of the Bothwell Deposit, Carbon County.**

<table>
<thead>
<tr>
<th>Laboratory number</th>
<th>158</th>
<th>159</th>
<th>160</th>
<th>157</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>46.99</td>
<td>42.99</td>
<td>17.08</td>
<td>34.11</td>
</tr>
<tr>
<td>Insoluble</td>
<td>4.15</td>
<td>1.79</td>
<td>10.71</td>
<td></td>
</tr>
<tr>
<td>Sodium sulphate (Na₂SO₄)</td>
<td>44.92</td>
<td>55.05</td>
<td>69.16</td>
<td></td>
</tr>
<tr>
<td>Sodium chloride (NaCl)</td>
<td>1.32</td>
<td>.17</td>
<td>.84</td>
<td></td>
</tr>
<tr>
<td>Magnesium sulphate (MgSO₄)</td>
<td>2.62</td>
<td>trace</td>
<td>2.21</td>
<td></td>
</tr>
</tbody>
</table>

Calculated as dry alkali salts:

| Sodium sulphate (Na₂SO₄) | 91.94 | 99.68 | 95.78 |     |
| Sodium chloride (NaCl) | 2.69 | .32 | 1.16 |     |
| Magnesium sulphate (MgSO₄) | 5.37 |     | 3.06 |     |

**THE DILLON DEPOSIT.**

The single sample from this deposit was obtained in 1899 and shows the usual mixture of sodium and magnesium sulphate with a smaller quantity of chloride.

**Composition of the Dillon Deposit, Carbon County.**

<table>
<thead>
<tr>
<th>Laboratory number</th>
<th>168</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>35.18</td>
</tr>
<tr>
<td>Insoluble</td>
<td>8.57</td>
</tr>
<tr>
<td>Sodium sulphate (Na₂SO₄)</td>
<td>38.22</td>
</tr>
<tr>
<td>Sodium chloride (NaCl)</td>
<td>3.75</td>
</tr>
<tr>
<td>Magnesium sulphate (MgSO₄)</td>
<td>1.01</td>
</tr>
<tr>
<td>Calcium sulphate (CaSO₄)</td>
<td>13.27</td>
</tr>
</tbody>
</table>

Calculated as dry alkali salts:

| Sodium sulphate (Na₂SO₄) | 88.92 |
| Sodium chloride (NaCl) | 2.35 |
| Magnesium sulphate (MgSO₄) | 8.73 |

**THE MORGAN DEPOSIT.**

In February, 1891, the Morgan deposit was visited by Dr. D. Harvey Attfield, who surveyed and sounded the lake and
gave a report of his investigations before the London Section of the Society of Chemical Industry which was published in the Journal of the Society in January, 1895. From this paper the following analyses are quoted, together with the accompanying notes: "The 'top crust' of the deposit is effloresced sodium sulphate, each pound containing about one ounce of sodium carbonate. Occasionally, actual crystals of potassium sulphate also could be separated during crystallizations, though there was none in the three samples quantitatively analyzed. By 'new deposit' is meant the crystals of sodium sulphate which form when a hole made in the mass fills up with fluid oozing from its bottom or side, the fluid subsequently solidifying. The sample analyzed is evidently almost commercially pure Glauber's salt. The sample of 'old deposit' had doubtless become effloresced after collection and before analysis for the bulk of the sand-free rock-sulphate yielded 54 to 55 per cent of volatile matter. It is unfortunate that frequent windstorms should so contaminate the sulphate with sand. *Per contra*, most of it is free from more than a trace of iron, and it is quite neutral to litmus paper. This 'dry soda lake' is, clearly, Glauber's salt with 3 or 4 per cent only of crystalline sodium carbonate, for the larger proportion of carbonate in the 'top crust' would be due to concentration, the top layers crystallizing last."

There are two or three statements here made that are of peculiar interest and it is unfortunate that specimens from this lake were not obtainable for their verification. It seems strange that soda salts containing one to six per cent of carbonate should be "quite neutral," since .05 per cent gives a decided alkaline reaction if the solution is not too concentrated. The occurrence of crystals of potassium sulphate is remarkable because it has never before been reported from the state and in the analysis of other soda deposits potassium is rarely found in more than traces detectable with the spectroscope.
Composition of the Morgan Deposit,
Natrona County.

<table>
<thead>
<tr>
<th></th>
<th>Top Crust</th>
<th>New Deposit</th>
<th>Old Deposit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>6.93</td>
<td>53.89</td>
<td>40.70</td>
</tr>
<tr>
<td>Sodium sulphate (Na₂SO₄)</td>
<td>84.86</td>
<td>43.93</td>
<td>32.28</td>
</tr>
<tr>
<td>Sodium carbonate (Na₂CO₃)</td>
<td>6.23</td>
<td>1.00</td>
<td>1.17</td>
</tr>
<tr>
<td>Sodium chloride (NaCl)</td>
<td>1.55</td>
<td>.77</td>
<td>.45</td>
</tr>
<tr>
<td>Sand</td>
<td>.25</td>
<td>.17</td>
<td>24.18</td>
</tr>
<tr>
<td>Chalk, magnesia, alumina, iron (by diff)</td>
<td>.08</td>
<td>.16</td>
<td>1.02</td>
</tr>
<tr>
<td>Soluble silica</td>
<td>.10</td>
<td>.08</td>
<td>.20</td>
</tr>
</tbody>
</table>

Calculated as dry alkali salts:
- Sodium sulphate (Na₂SO₄) 91.60%
- Sodium carbonate (Na₂CO₃) 6.72%
- Sodium chloride (NaCl) 1.68%

No potassium, lithium, bromides, borates or nitrates.

THE INDEPENDENCE GROUP.

OMAHA DEPOSIT.

A series of five samples were taken from this lake from the surface to a depth of about two feet in order to determine if there was any regular change in composition with the depth. The analysis shows no such regularity but on the contrary a great variation in the composition of the samples. The sodium sulphate is in one case nearly equal in amount to the carbonate; in another only one-tenth as much. Chlorides range from one-tenth of one per cent to seven per cent. In one the bicarbonate amounts to five per cent and in others is practically absent. The percentage of water increases with the depth, due to the top crust having lost part of its water of crystallization by efflorescence and the lower layers being not only fully hydrated but also soaked in the solution from which they were deposited. The insoluble matter, which is mostly clay and sand, also increases with the depth.

Samples Nos. 76, 77, 78, 79 were taken from the Omaha deposit in 1897 and No. 148 in 1899 by Dr. W. C. Knight.

No. 72 is a surface sample from the Omaha deposit. It is partly effloresced and contains more sulphate and chloride than the other samples, as would be expected if we consider that it
has been the last to crystallize and so carries the bulk of the impurities. It contains no iron, aluminum, calcium or nitrates, but traces of magnesium, borates and phosphates are present.

No. 78 was taken from just below No. 79, and represents the average mixture of salts to the depth of 10 inches. No aluminum, iron or calcium, but traces of magnesium, phosphates and nitrates are present.

No. 77 is a deeper sample than No. 78 from ten to fourteen inches. It is lowest in sulphates and contains traces of lithium, potassium, magnesium, nitrates and phosphates.

No. 76 was taken from below No. 77, from fourteen to seventeen inches from the surface. The large amount of bicarbonate is remarkable. No iron or aluminum; traces of calcium, lithium, potassium, phosphates and nitrates.

No. 148 was taken from the solid deposit at a depth of about two feet. Iron, aluminum, calcium, magnesium, lithium, nitrates, borates, phosphates were not detectable. Trace of potassium.

BERTHATON DEPOSIT.

The Berthaton deposit consists chiefly of sodium carbonate with a large amount of sodium sulphate and smaller amount of chloride. The composition of the two lakes is much the same, although there is a little bicarbonate in the small lake which does not appear in the larger. The water of the lake has the same salts in nearly the same proportion as the deposit, but the percentage of carbonate and chloride is a little greater.

No. 80 was taken from the surface of the small lake by W. C. Knight in 1897. It is a picked sample of clear crystals. There are traces of lithium, phosphates, nitrates, and magnesium.

No. 81 was taken from the large Yale lake by W. C. Knight in 1897 and was said to be representative of the best product of the deposits. It contains traces of nitrates and phosphates. No. potassium, lithium or magnesium could be detected.
No. 84. The solution from the upper Berthaton lake, taken by W. C. Knight in 1897. Its composition is as follows, stated in grams per liter, which is nearly the same as parts per thousand:

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount (g/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium sulphate (Na₂SO₄)</td>
<td>17.26</td>
</tr>
<tr>
<td>Sodium chloride (NaCl)</td>
<td>11.69</td>
</tr>
<tr>
<td>Sodium carbonate (Na₂CO₃)</td>
<td>55.50</td>
</tr>
<tr>
<td><strong>Total salts</strong></td>
<td><strong>84.45</strong></td>
</tr>
</tbody>
</table>

The carbonic acid is here estimated by calculation, so the bicarbonate which must be present in small amount is omitted.

**THE NEW YORK AND PHILADELPHIA DEPOSIT.**

A series of samples was taken from this deposit by W. C. Knight in November, 1899, ranging from the surface to the depth of a foot, and analyses of these are given in the accompanying table. The salts are predominantly sodium sulphate but with a considerable proportion of sodium carbonate and chloride in nearly the same amount.

No. 149 is a surface sample, No. 150 an average sample from just beneath the surface to a depth of four inches, and No. 151 from four to twelve inches.

**THE WILMINGTON LAKE.**

The deposit along the shore of this lake (No. 152) shows the mixture of sulphate, chloride and carbonate characteristic of this group. A sample taken from the bottom of the lake (No. 153) is on the contrary nearly pure sodium sulphate with only a small quantity of chlorides. The water from the lake is a saturated solution of the salts with a specific gravity of 1.104 and has the following composition (No. 154) in grams per liter, which is approximately the same as parts per thousand:

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount (g/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium sulphate (Na₂SO₄)</td>
<td>29.2</td>
</tr>
<tr>
<td>Sodium chloride (NaCl)</td>
<td>21.2</td>
</tr>
<tr>
<td>Sodium carbonate (Na₂CO₃)</td>
<td>69.3</td>
</tr>
<tr>
<td><strong>Total salts</strong></td>
<td><strong>119.7</strong></td>
</tr>
</tbody>
</table>
From these analyses it appears that the salt solutions that form these lakes deposit first pure crystals of mirabilite ($\text{Na}_2\text{SO}_4\cdot10\text{H}_2\text{O}$), and afterwards a mixture of mirabilite crystals with increasingly greater proportions of sodium carbonate ($\text{Na}_2\text{CO}_3\cdot10\text{H}_2\text{O}$) and sodium chloride. There is no proof of the formation of double salts of definite composition, but further study by experimental fractional crystallization will alone decide this point.

THE GILL LAKES.

We were not able to procure salts from the Gill lakes for analysis, but in order to make this bulletin complete the following description and analysis is copied from the annual report of Dr. Louis D. Ricketts, Territorial Geologist, January, 1890, p. 70:

"This group of lakes are situated in section 26, township 35 N., range 78 W., and is six miles north of the Platte river at the old Fiddleback ranch. I have passed by the latter point twice, and did not then know of the existence of the lakes. They are four in number, and are all located in one claim of 160 acres. Of this area between 80 and 90 acres are covered by the lakes. A number of pits have been sunk to a depth of 12 feet on these lakes, and from one of this depth a hole was bored four feet deeper. The soda has never been pierced. A sample of this soda given me shows it to be very clear and pure. When freshly broken it is clear, almost transparent. The outside rapidly loses water when exposed to the air. An analysis of this soda gave the following results:

<table>
<thead>
<tr>
<th>Salt</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium sulphate ($\text{Na}_2\text{SO}_4$)</td>
<td>94.50</td>
</tr>
<tr>
<td>Magnesium sulphate ($\text{MgSO}_4$)</td>
<td>2.52</td>
</tr>
<tr>
<td>Sodium chloride ($\text{NaCl}$)</td>
<td>0.54</td>
</tr>
<tr>
<td>Water</td>
<td>1.61</td>
</tr>
<tr>
<td>Undetermined and loss</td>
<td>0.83</td>
</tr>
</tbody>
</table>

100.00

"This sample had necessarily been freely exposed to the air for a long time. The Gill lakes are not only important from
### Chemical Composition of the Independence Deposit, Natrona County.

<table>
<thead>
<tr>
<th>Laboratory No.</th>
<th>59</th>
<th>78</th>
<th>77</th>
<th>84</th>
<th>84</th>
<th>148</th>
<th>New York 150</th>
<th>New York 151</th>
<th>Wilmington 152</th>
<th>Wilmington 153</th>
<th>Wilmington 154</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water in solution ((\text{Na}_2\text{SO}_4))</td>
<td>56.47</td>
<td>45.71</td>
<td>49.07</td>
<td>53.34</td>
<td>56.70</td>
<td>43.71</td>
<td>51.98</td>
<td>56.80</td>
<td>42.61</td>
<td>48.51</td>
<td>54.41</td>
</tr>
<tr>
<td>Sodium sulphate ((\text{Na}_2\text{SO}_4))</td>
<td>4.26</td>
<td>6.93</td>
<td>6.95</td>
<td>4.82</td>
<td>4.83</td>
<td>3.11</td>
<td>2.21</td>
<td>2.43</td>
<td>2.31</td>
<td>2.31</td>
<td>2.31</td>
</tr>
<tr>
<td>Sodium chloride ((\text{NaCl}))</td>
<td>1.85</td>
<td>1.05</td>
<td>1.30</td>
<td>1.15</td>
<td>1.05</td>
<td>2.21</td>
<td>2.18</td>
<td>1.85</td>
<td>2.01</td>
<td>2.01</td>
<td>2.01</td>
</tr>
<tr>
<td>Sodium carbonate ((\text{Na}_2\text{CO}_3))</td>
<td>17.51</td>
<td>17.52</td>
<td>17.53</td>
<td>17.54</td>
<td>17.55</td>
<td>17.56</td>
<td>17.57</td>
<td>17.58</td>
<td>17.59</td>
<td>17.60</td>
<td>17.61</td>
</tr>
<tr>
<td>Calculated as dry salts</td>
<td>51.81</td>
<td>48.51</td>
<td>49.87</td>
<td>48.34</td>
<td>47.51</td>
<td>51.51</td>
<td>48.51</td>
<td>51.51</td>
<td>48.51</td>
<td>47.51</td>
<td>48.51</td>
</tr>
<tr>
<td>Chloride ((\text{NaCl}))</td>
<td>72.47</td>
<td>72.47</td>
<td>72.47</td>
<td>72.47</td>
<td>72.47</td>
<td>72.47</td>
<td>72.47</td>
<td>72.47</td>
<td>72.47</td>
<td>72.47</td>
<td>72.47</td>
</tr>
<tr>
<td>Bicarbonate ((\text{Na}_2\text{CO}_3))</td>
<td>3.07</td>
<td>3.07</td>
<td>3.07</td>
<td>3.07</td>
<td>3.07</td>
<td>3.07</td>
<td>3.07</td>
<td>3.07</td>
<td>3.07</td>
<td>3.07</td>
<td>3.07</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

*Note: All values are in percentages.*
the fact that they have very large deposits of sulphate of soda, but also because they are now within seven miles of the railroad grade, which passes up the Platte."

GREEN RIVER SODA.

Though this is not a deposit or lake so far as known, still the occurrence underground of water so heavily charged with alkali salts at Green River should be noted in connection with the similar solutions on the surface.

In 1895, in drilling a prospecting well at Green River, a flow of alkaline water was struck at a depth of 125 feet. A sample of the water was sent to the University and proved to be a nearly saturated solution of sodium carbonate of greater purity than any hitherto found in the state. On standing for a few days a thick deposit of large crystals of hydrous sodium carbonate (sal soda) filled the bottom of the vessels. The salt thus formed was much purer than the commercial product and contained mere traces of chlorides and sulphates. This water contained 8.9 per cent of sodium carbonate or 24 per cent of crystallized sal soda. Those interested were at once notified of the character of the product and were urged to put up evaporating tanks on a small scale and begin marketing the soda at once, but they failed to fully appreciate the value of the product and the cheapness with which it could be worked until some time afterwards. Recently a new company has been formed and it is expected that the property will be developed. Mr. Robert Morris of Cheyenne informs me that sixty thousand gallons pumped in 24 hours only lowered the well an inch or two, and did not appreciably lessen the strength of the soda solution.

There seems to be considerable difference in the composition of the wells. A sample of the product of evaporation from one of the wells later bored, sent me January 20, 1897, had the following composition:
Alkali Lakes and Deposits.

Sodium carbonate, anhydrous .......................... 48.2%
Sodium chloride ........................................ 51.6%
Undetermined ........................................... 0.2%

100.0

With traces of magnesium and sulphates.

Herman Harms of Salt Lake reports that the water has specific gravity of 1.10 and contained 246.2 grams sodium carbonate crystallized and 6.12 grams sodium chloride per liter. G. C. Wheeler, Chicago, reports the following analysis of the Green River soda:

Silica .................................................. 0.51
Iron and aluminum .................................... 0.42
Calcium ................................................ 0.64
Magnesium ............................................. 0.27
Insoluble residue ..................................... 0.23
Water .................................................. 22.57
Anhydrous carbonate of soda ....................... 75.36

100.00

In its freedom from sulphates in appreciable quantity the Green River soda differs markedly from all the other waters and deposits of the state.