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A PRELIMINARY REPORT ON THE POSSIBILITIES OF THE CORRELATION OF GEOCHEMICAL DATA RELATIVE TO OIL WELL WATERS

A REPORT ON THE OIL WELL WATERS OF GREENWOOD COUNTY, KANSAS.

BY

DAVID ANDERSON BASH

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MO.

in partial fulfillment of the work required for the

Degree of

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Approved by

A PRELIMINARY REPORT ON THE POSSIBILITIES OF THE CORRELATION OF GEOCHEMICAL DATA RELATIVE TO OIL WELL WATERS

It is a known condition and a proven fact that vast quantities of oil and gas have been lost by the infiltration and encroachment of water in producing sands. The encroachment of water in the pay horizons has not only trapped underground oil locally and caused a great loss of production, but unless the water problem was successfully combated the amount of water entering the pay may increase to the extent of flooding an entire field. Water in an oil well so increases the lifting cost that many wells are abondoned before the normal recovery is reached. Besides this added expense of the lifting cost, water emulsifies with oil and the treatment necessary to separate the oil from the water is expensive and such a treatment results in the loss of oil. Certain types of oil well waters are vigorous agents of corrosion, whereas other types of these waters actually preserve metal in the wells against corrosion. Corrosive waters are expensive factors in production. Only through the compilation of data on the chemical analysis of these waters can the true constituents of such waters be determined and their detrimental properties studied. To cope with any of the above mentioned water conditions, it is essential that the underground conditions of a field be thoroughly investigated, the date compiled and the results correlated.

Correlation of data has always proven beneficial to any kind of systematic engineering study. Before a problem of any underground nature can be thoroughly understood, it is necessary to study the conditions

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causing the trouble. This study should be thorough and extensive and include both the theoretical and practical sides of the cause of trouble. The results of such an investigation, when carefully correlated, should present the possibilities of cause and the probabilities of solution of the problem in a very concise and concrete manner.

In working with water problems relative to the efficient production of petroleum, it should be emphasized that the cause of most trouble is underground and hidden from sight and any picturization of the trouble would be in the form of graphs or cross sections derived from data compiled and correlated by scientific research through the interpretation of geological and chemical analysis. A certain amount of information can be obtained through geology; equally as much can be had through chemistry (i.e. classification of oil well waters by a complete chemical analysis). The data derived from either source alone is inadequate to furnish enough definite information to formulate logical solutions for most of the complex water troubles. However, if the information gathered from a geological and chemical examination can be worked in together, a plausible solution of most problems can be interpreted from the combined data. Consequently it would seem justifiable to select the various producing fields of Butler, Greenwood, Cowley, Marion and Elk counties for study and collect the scattered information both geological and chemical in substance and correlate the data already at hand and that which is added by the extension of old fields and the development of new ones into a geochemical report for each field individually.

Chemical analysis of oil well waters has proven its worth many times as an aid and guide in solving the intricate problems that arise in the location of petroleum horizons and in the systematic and efficient recovery of petroleum from producing strata. It is suggested that an extensive study of the chemical analysis of oil well waters with respect to the depth at which they are encountered, the rock formations through which they percolate or traverse, the geological stratification of the areas through which such waters may travel, be retarded or repelled by definite formations, may be, when properly correlated, of greater value in explaining water problems that are now confronting the production of petroleum. Such a complete study of the analysis of oil well waters would further the correction of geological correlation and would greatly support and advance the chemical correlation of waters so that a definite "top water" and "bottom water" could be established for each producing horizon, which in turn would classify waters as to their relative position above, between, with or below the producing sands. This systematic ar-arrangement would necessitate the adoption of a nomenclature that would make plain the position of the water stratum with regard to the producing sand or sands.

For such a classification, the one suggested by Swigart and Beecher in their Bulletin 232, "Manual for Oil and Gas Operation," is of particular significance and will be followed in these reports. Swigart and Beecher state:

"Oil field waters may be classified as top water, middle or intermediate water, edge water and bottom water, according to position with respect to the oil sands. Top water is the term usually applied to any water in a stratum above the main oil-producing stratum. Intermediate waters are sometimes called top waters, but in the strict meaning of the term intermediate water is that in a stratum between two oil-bearing strata. Bottom water lies in a stratum below the oil-producing stratum and is separated from it by an impervious layer. In many fields, water in the base of an oil sand is termed bottom water. Strictly speaking, this is edge water, since it occurs in the down-slope parts of an oil or gas sand. As oil or gas is removed, the line of contact or the 'edge-water line' moves up slope."

It may be well at this time to mention some of the possible sources of entrance of top water and bottom water into an oil well. Top water is often the cause of some of the most common troubles in oil fields. Top water may gain access to a well in the following ways:

(a) By the casing being set too high or too low

(b) By the unsystematic casing of wells of a group with respect to one another

(c) By leaks around the shoe of the water string

(d) By improper coupling of the joints of casing by cross threading or insufficient screwing.

(e) By collapsed casing

(f) By split casing

(g) By line worn casing

(h) By corroded casing

In order that upper waters may be shut out effectively, all phases of the upper water problem in any locality must be considered care-

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fully and the information obtained from such a study should greatly aid in the selection of a point suitable for landing the casing at a distance below the deepest top water sand and above the producing sand. A geochemical report so arranged as to show definitely and accurately the locations and formations that bear the troublesome top waters as well as the producing horizons, would greatly aid in picturizing the underground conditions so that good points could be selected, whenever possible, for setting casing.

Bottom water may gain access to a well which has been drilled too deep. The entrance of bottom water in such manner usually indicates that the impervious layer separating a pay sand from the water sand directly below, has been penetrated, thus making an opening for the water to enter the producing horizon. Often times if a neighboring well has been drilled too deep, bottom water may find its way to the well in question through some sand below the water strings in the two wells. Assuming a definition of broader scope for bottom water, it may be stated that water occurring in the base of a producting horizon is bottom water, as it actually is below the oil level but is not separated from the oil level by an impervious layer. Such waters are often termed "base waters" and occur mostly in flat dip fields. Porous limestone formations that are oil-bearing often contain base water. This fact may be explained by the supposition that water moving through rock pore spaces by hydraulic pressure and by capillary action, forces oil before it. Base water may be found in one section and absent in another of the same oil-bearing formation. This may be explained by the irregular porosity of the strata through which the water is migrating. Base water is a troublesome factor in oil production and is very difficult to plug off. Reports based on the geochemical analysis of waters for the various fields by counties should clearly show, when possible, producing horizons that are now or may be troubled with detrimental bottom water conditions. From the laws of accumulation and migration of petroleum it is evident that water is closely associated with all of the phenomena related to the movements of petroleum and plays an important part in its migration and accumulation . This fact alone warrants a thorough study of the characteristics of such waters encountered in petroliferous structures.

A general classification of the types of waters occurring in rock interstices may be primarily divided into two groups, meteoric and magmatic. Meteoric water is derived from the rain that falls on the surface and from the water courses and has descended into the earth in the cavities, fissures, or capillary openings to ascend at suitable places under hydrostatic conditions, or to remain stored in rocks and become almost stagnant. Such waters are known as surface waters. Another type of water assumed to be of meteoric origin, is that water mechanically included in the sediments of ancient oceans and has for geologic periods been a constituent of these strata. Such waters are termed "connate" waters. Connate waters are generally salt or mineral bearing and are usually deep seated, and are those waters associated with petroleum in the natural reservoirs. Magmatic waters existed in the solution constituting an igneous magma. Large quantities of magmatic water are rarely found except in regions of present or recent igneous activity. Magmatic waters

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are rarely found associated with petroleum and will not be considered further.

As most of the petroleum in the Mid-Continent field is produced from sedimentary rocks, the constituents of the waters traversing sedimentary deposits in general may be considered very briefly. As stated by Lindgren--" In all these waters the principal constituents are those of the surrounding sediments--calcium-magnesium carbonates from the limestones and dolomites, brines from the saline formations, calcium sulfate from gypsiferous Triassic formations, sodium sulfate from the Cretacious shales, hydrogen sulfide from the reduction of sulfates by oil or other organic matter often present in the strata, carbon dioxide from reactions between carbonates of calcium and other salts. The presence of connate waters is difficult to prove. It is simply inferred from the occurrance of strong sodium chloride and calcium chloride brines in certain sedimentary rocks. Any marine beds must necessarily have contained occluded sea water, but many geologists doubt whether it would have remained undisturbed during long ages." In summarizing the above statement it may be said that the majority of underground waters contain in solution the salts characteristic of the sediments traversed, the concentration of these salts in solution depending on the solubility of the sediments in water, the presence of dissolved gases such as CO_2 and H_2S in the water and the length of time which they were subjected to water-leaching.

A system of calculation and interpretation for the complete analysis of oil well waters must be adopted so that the characteristics and peculiarities of the various waters may be identified, and by such identification

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be classified as top water or bottom water. The classification of water may be based on a variety of considerations. It may be geologic, correlating the waters with their geologic origin, ancient or modern, or by dividing them into classes according to their derivation from rain water or from sources deep within the earth; it may be physical, drawing a chief distinction between cold and thermal waters; or chemical, in which case differences of composition determine the place which each water shall occupy. To a great extent the three systems of classification overlap, and each one depends more or less upon the others. But for the purposes of the reports to follow, which will deal with the chemical composition of the waters, the chemical interpretation is the most appropriate.

The calculations involved in water analysis are simple and are based upon the analysis as stated in parts per million and in percentages. The quantities in parts per million are multiplied by the reciprocals of the equivalents and called the "reaction coefficients" of the radicles; the product so obtained, the "reacting values" of the radicles. The interpretation of water analysis, then, is founded upon a study of equilibria, and the outcome is the grouping of the positive and negative radicles, found to be present in a water, by hypothetical combination. Such a system of combination is based upon the assumption that the most insoluble compound present by hypothetical combination will precipitate out first from the water analyzed and will be present as the most minute quantity. Palmer states--" Two fundimental properties are recognized, namely, alkalinity and salinity, which are subdivided into groups. Salinity is measured by the sum of the strong acid radicles, SO_4, CL and NO_3 , which balance an equivalent number of basic radicles. If the basic radicles are partly or wholly alkaline, that is, Na or K, their proportion of the salinity is said to be *primary*. The remaining salinty, due to the radicles Ca, Mg, and Fe is called *secondary*. If, however, the acid radicles are in excess of the basic, *tertiary* salinity or *acidity* appears, and hydrogenions must be taken into account. When the alkaline radicles exceed those of the strong acids, their excess is the measure of *primary* alkalinity, which represents hydrolyzed carbonates or bicarbonates. The weak-acid radicles CO_3 and HCO_3 which balance any excess of the alkaline earths over the stronger acids, produce *secondary* alkalinity." Palmer's method of interpretation will be followed closely in the geochemical reports. Considerable attention will also be given the concentration of the individual radicles as reported in parts per million. Palmer's interpretation necessitates a complete analysis for classification. It is thought that after a field is thoroughly studied and a top and bottom water established, that any water coming in from a surrounding territory can be identified and classified by a partial analysis alone. If this can be done a saving in time and material will be the result and the ultimate cost of an analysis greatly reduced.

A general outline of the reports to be written is as follows:

1. *Introduction*
    - a- History
        1. Location and area of field
        2. Age of field
        3. Initial and present condition of field as to water troubles

b- Object of the report

1. The importance of water analysis to oil production
2. The use of water analysis in oil production
3. The classification of oil well waters and the establishing of a distinct top water and bottom water for each field.
4. The attempt to classify waters by the aid of geological and chemical correlation

II. <u>Correlation</u>

- a- Maps showing location of production
- b- Maps showing surface contours
- c- Maps showing underground contours of water and oil horizons
- d- Maps showing structural geology with locations of water, gas and oil "sands"
- e- Maps showing structural geology of producing horizon
- f- Grouping of similar waters by chemical composition with respect to the geological formations containing them.
- g- Average complete analysis for type top and bottom waters

III. <u>Conclusions</u>

- a- Information derived from such a correlation of data.

Respectfully submitted,

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A REPORT ON THE OIL WELL WATERS
OF GREENWOOD COUNTY, KANSAS.

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A REPORT ON THE OIL WELL WATERS
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Introduction

Samples from the various depths at which water is encountered during the drilling of a well are taken and sent to the laboratory. Other samples of water are received from the producing horizon and are representative of the water coming in with production. Occasionally a sample of water is received from a dry hole or "salt water" well, and such a sample is assumed to be a type water for the water expected below the pay sand. In a producing well, such a water may be separated from the pay horizon by an impervious layer. Water samples from all three of the above sources are essential for correlation by comparative data. Too many samples from a new area can not be taken. Often times samples are received with misleading information or with little or no information at all. If the correct and complete history of the samples can not be obtained from the production foreman the samples are discarded. For the correlation of oil well waters by water sands, using the complete chemical analyses of such waters as a guide, it is necessary to have certain definite information. For the purpose of securing this information the Chemical department has arranged a printed tag which shows in tabulated form the log desired for any sample. A tag is tied to each sample jar, the jars arranged in a series of six in a substantial wooden case and sent to the respective leases where drilling is in progress.

Chemical analyses of water from the water-bearing strata of an area will serve to identify the water in one sand from that in another.

Such an identification is made possible by correlation of the chemical constituents of these waters. A type water for each water stratum encountered should be established. This can be done by comparing the chemical analyses of true waters from a know water "sand," A sample of water for analysis is of no value for geo-chemical correlation unless it is representative of the water found in the sand. A sample of water mixed with drilling water is absolutely valueless for any kind of water analysis. A sample is of no value where several water sands are exposed to the hole. In order that the properties of the waters of definite water sands can be established, it is essential that a true sample of the water and not one mixed with drilling water or with water from other sands, be obtained for analysis. The analyses of water samples that are trully representative of the water in the "sands" are important and will prove most beneficial to geo-chemical correlation.

After the water sands in an area have been located and a type water established for each sand, mixed water from these sands should be given attention. It is often difficult to obtain a true water sample from a sand when two or more water sands are close together and exposed to the hole. Most likely if the water sands are close together, one string of casing will be used to shut off both waters. If such is true, then a sample of the mixed waters as they are found in the hole will be typical of the water expected behind the casing. The chemical analysis of such mixtures are important and will prove most beneficial for operating purposes. Mixed water samples containing water from two or more sands, if accompanied with correct and complete information, are analysed and the datum from such an analysis proves valuable in determining the source of similar mixtures from the same area. After a well is drilled in and the casing set, water from two or more sands may mix behind the casing. If such mixtures should prove to be troublesome waters and a sample is taken to determine their source, the sample may be identified by comparing the chemical analysis of this water with those of mixtures sent in while the field was new.

In summarizing, it may be said that samples of water from any depth or of any nature, whether true samples from a sand or mixtures from two or more sands, if the information is complete and accurate accompanying the samples, the analysis of such samples will prove valuable in locating the sources of water and in solving water problems.

It is thought at this time that a complete analysis should be run on all samples from a new area where the various water strata are not definitely established and where the water conditions in general are not known. By comparing the complete chemical analyses of waters from various similar depths, the water strata can be located and the water encountered in these strata can be identified and correlated. By such a correlation, the waters occurring in the strata above production can be recognized by their chemical composition and classed as top waters for that particular field. Water is often found closely associated with oil. Water may be found in the same "sand" with oil as base water, or on the edges of a field as edgewater or it may be separated from the producing horizon by an impervious layer. Such waters that occur with or are below the producing horizon and separated from the production by an impervious layer

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are commonly termed bottom waters.

It is generally true, when considering the waters encountered in deep well drilling, that the chemical composition of top water gradually increases in parts per million of the positive and negative radicles present as the water strata approaches the producing "sand." That is to state, the water stratum directly above and nearest to the producing sand would contain the greatest amount of dissolved salts and in turn would show by analysis the maximum total solid content. There is usually a pronounced difference in the total solid content of any one of the top waters- disregarding surface waters- and bottom water. Bottom water will show a total solid content less than any of the top waters. This in turn indicates a smaller quantity present of the positive and negative radicles expressed as parts per million. It can not be said of all the radicles that their concentration in a water increases directly with the depth at which the water is encountered below the surface, although certain negative radicles like Cl- the chloride content- will increase directly with depth until production is reached and then decrease to a maximum in the water below production or bottom water. Certain other radicles of the positive type as Ca and Mg will follow through with increase in concentration with depth but occasionally the increase is not uniform and the radicles will increase gradually, decrease slightly, then increase to a maximum in the top water directly above the producing horizon. The concentration of the positive radicles depends greatly on the composition of the strata through which the leaching waters traverse. The same applies, of course, to the negative radicles as they furnish the acid radicles necessary for salt formation. The positive radicles are not found in solution as the free metals, but as salts formed by chemical reaction. This reaction is the result of the chemical affinity of the radicles in solution, both positive and negative, for one another, the result being the formation of compounds representative of true salts for such acid radicles as Cl, SO_4, NO_3, the strong acids, and CO_3 and HCO_3, the week acids in chemical combination with the bases as the alkali metals Na and K and the alkaline earth metals Fe, Ca, Mg, and Sr. The cause of such chemical activity in solution is attributed to ionization. In summarizing, it may be said that the majority of underground waters contain in solution the salts characteristic of the sediments traversed, the concentration of these salts in solution depending on the solubility of the sediments in water, the presence of dissolved gases such as CO_2 and H_2S in the water and the length of time which they were subjected to water-leaching.

As an example of what may be expected from a water containing a high concentration of sodium sulphate and carbon dioxide gas traversing a calcium carbonate formation, the traversing water maintaining a comparatively high concentration throughout its path of contact, the following chemical equation is stated:

$$2CaCO_3 + 2Na_2SO_4 + 2CO_2 + 2H_2O = 4NaHCO_3 + 2CaSO_4$$

Such a water will show by analysis a relatively high alkalinity content and a high concentration in alkalinity immediately infers that the water contains soluble salts in solution derived from the chemical action of water on a limestone formation. In this way, water analysis will greatly aid in correcting geological correlation and will serve as a guide in determining the nature of the strata through which the troublesome water travels. It is thought that the correlation of oil well waters and the knowledge to be gained by study of underground water conditions in general can best be obtained through reports that are geo-chemical in substance. In this report only the chemical composition of the waters will be used in correlation.

Purpose

The purpose of this report is to identify as well as classify oil well waters received from drilling and producting wells of the Empire Gas and Fuel Company on their leases in the Greenwood County, Kansas field. The primary purpose is to shown by chemical analysis the similarities of these waters taken at the drilling depths at which the water is or may become a troublesome factor in oil production, and to shown by comparison of the chemical constituents of these waters that they are or may be encountered at specific depths as tabulated by the logs for these wells under study; and by such differentiation classify the waters as "top" or "bottom" waters respectively. An effort is made in this report to estimate the percentage of "top" water in a mixture, (and such estimation is believed to be quite possible) by arrangement, study and interpretation of curves plotted for the chlorides,sulfate and total solid content respectively.

This report is based on the conclusions derived from the complete chemical analyses of seventy-seven oil well waters received at the Oil Hill, Kansas laboratories from the following Empire wells in

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Greenwood County, Kans.

Sec. 11-Twp. 22- Range 11

Kipfer #1
Hind #3

Sec. 14- Twp. 22- Range 11

Fromm #1, #2, #3
Kellison #2, #3
Duby #1

Sec. 15- Twp. 22- Range 11

Pees #2
Bartlett #1

Sec. 5- Twp. 23- Range 11

Seeley #6, #7, #8

Sec. 8- Twp. 23- Range 11

Clopton #4, #5, #6, #7, #8, #9, #10

Sec. 12- Twp. 23- Range 10

Piatt #6, #7, #10

Sec. 14- Twp. 23- Range 10

Winegar #1

After a thorough study and comparison of the chemical analyses of these 77 oil well waters, it is thought advisable to group these waters according to the quantity, in milligrams per liter, of the metals and radicles found to be present in these waters taken at the corresponding logged depths. A complete analysis is found to be necessary to classify and group these waters, although much information can be gotten from the chloride, sulfate and total solid content and from such a partial analysis it is possible to differentiate between a "top" and "bottom" water. It

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may be well to define a "top" and a "bottom" water so that the outstanding significances of such a classification can be more easily detected.

Top water is the term usually applied to any water in a stratum above the main oil-producing stratum.

Bottom water lies in a stratum below the oil-producing stratum and is separated from it by an impervious layer. In many fields, water in the base of the oil sand is termed bottom water. Edge water may also be classed as a bottom water. For this report, any water actually found present below the main oil-producing level, whether it is separated from production by an impervious layer, or whether it exists as a base water or an edge water, is termed bottom water.

Correlation

By comparing the chemical constituents of the waters calculated in milligrams per liter of the positive and negative radicles present with the given logged depths for the definite water sands, it is possible to group the waters according to the following depths:

Group #1-- Includes the waters from a depth of 785' to 935' in the Madison Block and 825' to 975' in the Seeley Pool.

Group #2-- Includes the waters from a depth of 1034' to 1290' in the Madison Block, 1095' to 1260' in the Seeley Pool and the 1148' sand in the Piatt.

Group #3-- Includes the waters from 1305' to 1350' in the Madison Block and 1310' to 1385' in the Seeley Pool. The 1245' sand in the Piatt and Winegar is the same as the "1300'" sand found in the Madison Block and Seeley Pool.

Group #4-- Includes the waters from 1600' to 1635' in the Seeley Pool and from 1730' to 1737' in the Piatt and Vinegar.

Group #5-- Includes the waters from 1823' to 1896'. Such samples were listed as water coming in with production, water from the shot hole and water from the producing sand. The samples included in this group probably represent mixtures of top and bottom water and were typical at the time of sampling of the water accompanying production. Samples used in classifying this group were from the Bartlett #1, Pees #2, Hind #2, Fromm #1 and Fromm #2.

Group #6-- Includes the waters from 1878' to 1924' in the Madison Block and from 1940' to 1996' in the Seeley Pool. This group also includes a few samples marked "coming in with production." The chemical analysis of such samples compared closely with those of true bottom water and were included in this group representing bottom waters.

<u>Depth-- 400'</u>

	Ca	Mg	Na	SO_4	Cl	Sr	Ca/Mg	Ca/Sr	Ca-Sr/ Mg	T.S.
Max. :	1047:	325:	14585:	830:	24660:	125:	3.1:1:	8.8:1:	3.5:1:	40440
Min. :	933:	275:	10630:	793:	18160:	623:	2.7:1:	1.2:1:	5.0:1:	30880
Avg. :	1000;	299:	13307:	825:	22383:	293:	3.7:1:	5.9:1:	4.6:1:	37540

Above is stated the maximum, minimum and average analysis for the water encountered at the approximate depth of 400 ft. The analyses are reported in milligrams per liter of the radicles found present in the waters. The stratum bearing this 400 ft. water is about 1600 ft. above the producing sand and is cased off by two and probably three strings of casing. It is thought that a water at 400 ft. below the surface and 1300 ft. from production and being cased off by at least two strings of casing will never become a troublesome top water. Consequently this water was not grouped with the other top waters.

The following groups are the results of correlating the waters by chemical composition with respect to the depth at which they were sampled. The results are expressed in milligrams per liter of the radicles found present in the waters. An analysis is stated for the maximum, minimum and average water found in each water-bearing stratum.

To select a maximum, minimum and average water for each group of waters, it is necessary to choose as many "variables" as possible from an analysis so that the maximum, minimum and average water selected to represent a specific type would be a true example. The "variables" used in determining the maximum, minimum and average water for each group are the chloride, sulphate and total-solid content of each analysis used for the group. The other radicles and ratios included in the grouping of the maximum, minimum and average water are given to show the composition and concentration by a complete analysis. It is admitted that the maximum waters selected for each group may not contain the highest concentration of each radicle present when compared with the concentration of the same radicle in the average water, but the analysis of the water selected as the maximum water for any of the groups will show a maximum concentration for the "variables," chloride, sulfate and total solids. The maximum and minimum analyses are from actual waters. The average analyses are synthetic and are the results of an average for each radicle and ratio of the waters constituting a group.

Group #1-- 800'-900'

	Ca	Mg	Na	SO_4	Cl	Sr	Ca/Mg	Ca/Sr	Ca-Sr/Mg	T.S.E.
Max.	3998	884	29774	21	55500	689	4.16:1	5.34:1	4.94:1	93690
Min.	3306	590	26271	7	48330	1282	4.6:1	2.1:1	6.9:1	79890
Avg.	3832	903	28079	15	53673	830	3.9:1	4.8:1	4.9:1	90147

Group #2-- 1000'-1200'

	Ca	Mg	Na	SO_4	Cl	Sr	Ca/Mg	Ca/Sr	Ga-Sr/Mg	T.S.E.
Max.	5165	1500	39047	6	73660	1894	2.7:1	2.1:1	3.9:1	122805
Min.	4145	1093	31098	32	58500	1021	3.47:1	3.72:1	4.41:1	97540
Avg.	4340	1188	33961	38	63472	1350	3.2:1	3.0:1	4.5:1	105338

Group #3-- 1300'

	Ca	Mg	Na	SO_4	Cl	Sr	Ca/Mg	Ca/Sr	Ca-Sr/Mg	T.S.E.
Max.	4663	1631	36351	60	69000	1834	2.42:1	2.15:1	3.54:1	114440
Min.	4413	1377	34725	40	65330	1537	2.6:1	2.3:1	3.0:1	107370
Avg.	4451	1465	34770	46	65680	1620	2.6:1	2.4:1	3.7:1	109208

Group #4-- 1600'-1700'

	Ca	Mg	Na	SO_4	Cl	Sr	Ca/Mg	Ca/Sr	Ca-Sr/Mg	T.S.E.
Max.	5561	1201	37458	72	71000	1033	4.2:1	4.8:1	4.6:1	119500
Min.	4421	1212	33112	18	62330	1098	3.2:1	3.5:1	4.1:1	103925
Avg.	4995	1338	36999	29	69720	1214	3.4:1	3.9:1	4.7:1	115650

Group #5—Mixed Waters 1800'-1900'

	Ca	Mg	Na	SO_4	Cl	Sr	Ca/Mg	Ca/Sr	Ca-Sr/Mg	T.S.E.
Max.	4456	1130	33711	172	63000	878	3.6:1	4.6:1	4.4:1	105820
Min.	4378	758	30896	120	57500	936	5.0:1	4.1:1	6.3:1	96000
Avg.	4309	995	31743	172	59340	998	4.3:1	4.7:1	5.3:1	99715

Group #6--Bottom Water 1900'

	Ca	Mg	Na	SO_4	Cl	Sr	Ca/Mg	Ca/Sr	Ca-Sr/Mg	T.S.E.
Max.	4093	632	28629	491	52830	873	5.7:1	4.2:1	7.1:1	89995
Min.	3868	609	27762	463	51000	231	6.1:1	16.0:1	6.5:1	86220
Avg.	3960	684	28174	458	52025	621	5.5:1	10.1:1	6.6:1	88300

Average Analyses for the Groups

	Ca	Mg	Na	SO_4	Cl	Sr	Ca/Mg	Ca/Sr	Ca-Sr/Mg	T.S.E.
400'	1000	299	13307	825	22383	293	3.7:1	5.9:1	4.8:1	37540
Group: #1	3832	903	28079	15	53673	830	3.9:1	4.8:1	4.9:1	90147
Group: #2	4340	1188	33961	38	63472	1350	3.2:1	3.0:1	4.5:1	105338
Group: #3	4451	1465	34770	46	65680	1620	2.6:1	2.4:1	3.7:1	109208
Group: #4	4995	1338	36999	29	69720	1214	3.4:1	3.9:1	4.7:1	115550
Group: #5	4309	995	31743	172	59340	998	4.3:1	4.7:1	5.3:1	99715
Group: #6	3960	684	28174	458	52025	621	5.5:1	10.1:1	6.6:1	88300

Groups 1, 2, 3 and 4 represent the average top waters.

Group 5 represents the average mixtures of top and bottom water encountered with production at the time of sampling.

Group 6 represents the water now assumed to be the true bottom water.

It is evident from the above scheme of average analyses that a "top" and "bottom" water can be identified and, also, if a water is a mixture of bottom and top waters the mixture can be detected by comparing the complete analysis of the water in question with the average analyses of the groups. Group #5 in reality is a classification of waters encountered from the depths of 1823-76' and 1833-98'. As the logs for these wells included in the grouping of group #5 show no water sands or complicated water conditions at the levels of 1823-76' and 1833-98', it is reasonable to assume that the waters coming from these depths are mixed waters and contain chiefly bottom water. This fact is substantiated by the sulphate, chloride and total solid content of these waters particularly, and also by the comparison of the complete analyses with the analyses of the "true" bottom water. Information received with the waters included in Group #5 lists them as waters from the producing sand, coming in with production and, in some instances, as water from the shot hole.

A hypothetical top water must be established for the field. This water must represent in composition an average for the top water groups. It must contain a concentration of the radicles so that it will be similar in chemical constituency to any one of the grouped top waters and still not be identical with any one particular group. It should be typical in chemical composition to the water most expected to cause top water infiltration. To create such a hypothetical water, assume that the top water nearest the producing sand and represented as the water characteristic of group 4, has twice as much chance of becoming a troublesome water as the waters characteristic of groups 3 and 2. This assumption is made by virtue of the position of group 4 waters to the producing sand and by the fact that one string of casing is used to case off these waters. Now multiply the radicles of group 4 expressed in milligrams per liter by 2. Add the radicles expressed in milligrams per liter for groups 3 and 2 to the sum obtained for group 4. Divide the total for each radicle by 4 and the resultant radicles expressed in milligrams per liter will represent the composition of the hypothetical top water established for the Greenwood County field. This hypothetical top water is given below.

<u>Hypothetical Top Water</u>

Radicle	Ca	Mg	Na	SO_4	Cl	Sr	Ca/Mg	Ca/Sr	Ca-Sr/Mg	T.S.E.
Mg/L	4695	1332	35682	36	67148	1350	3.2:1	3.3:1	4.4:1	111412

<u>Assumed Bottom Water</u>

Radicle	Ca	Mg	Na	SO_4	Cl	Sr	Ca/Mg	Ca/Sr	Ca-Sr/Mg	T.S.E.
Mg/L	3960	684	28174	458	52025	621	5.5:1	10.1:1	6.6:1	88300

It is evident by inspection that the composition of the hypothetical top water is greatly different from the bottom water. Such a variance in the concentration of these two waters presents sufficient chemical information to differentiate between them. To estimate the percentage of top water and bottom water existing in a mixture, it is necessary to obtain the chemical composition of mixtures representing various proportions of top and bottom water. In calculating the composition of the following mixtures, the sulfate, chloride and total solid contents of the hypothetical top water and the bottom water were used.

A mixture of water containing 90% top water and 10% bottom water should show by a partial analysis the following composition expressed in milligrams per liter of the radicle tested:

90% - 10%		Group #3		Hypothetical Top Water	
SO_4	88	SO_4	46	SO_4	36
Cl	65638	Cl	65680	Cl	67148
T.S.	109099	T.S.	109208	T.S.	111412

A water containing this compostion greatly resembles the top water classified in group 3. If a water should be sent to the laboratory and by a partial analysis the composition was that expressed for the 90-10 proportion, the question being as to the source of the water sampled, it could be stated with a degree of certainty that the water in question is not all top water, but a mixture. This assertion would be substantiated through the results of comparative data. Considering the concentration of the SO_4 radicle in the above three type waters, it is noted that the SO_4 content of 88 in the 90-10 mixture is slightly more than twice the content expressed for the hypothetical top water and is nearly twice that for group 3. It is readily noticeable that the SO_4 content of the 90-10 mixture is too high to allow the water to be classed as all top water. The chloride and total solid content of the 90-10 mixture agrees closely with the group 3 top water, but they are too low in concentration to agree with the hypothetical top water. This fact shows the established hypothetical top water to be suitable for use in differentiating mixtures high in top water.

75% - 25%		Group #2		Hypothetical Top Water	
SO_4	165	SO_4	38	SO_4	36
Cl	63361	Cl	63472	Cl	67148
T.S.	105639	T.S.	105338	T.S.	111412

A water containing the composition of the 75-25% mixture resembles in chloride and total solid content the type water stated for group #2. The sulfate content of the two waters is sufficiently different to state that the two waters are not identical. The sulfate content of the 75-25% mixture is over four times the quantity found present in the group #2 waters. This increase in sulfate content infers that the water is a mixture of top and bottom water. By comparing the 75-25% mixture with the hypothetical top water, it is easily detected that the concentration of the chloride and total solid content is too weak to be all top water. Comparison of the sulfate concentration of these two type waters shows the 75-25% mixture too strong to be all top water. Consequently, by comparative data a water of the same composition as the 75-25% mixture would be classed as a mixed water containing relatively high percentage of top water.

A mixture of water containing 50% top water and 50% bottom water should show by a partial analysis the following composition expressed in milligrams per liter of the radicles tested.

50% - 50%		Group #5	
SO_4	247	SO_4	172
Cl	59586	Cl	59340
T.S.	99856	T.S.	99715

Such a mixed water agrees closely with the water stated as typical for group #5. This similarity in composition infers that the waters in group #5 are mixtures typical of a 50-50 proportion of top and bottom water.

A mixture of water containing 25% top water and 75% bottom water should show by partial analysis the following composition:

25% - 75%	
SO4	354
Cl	55805
T.S.	94085

A mixture of water containing 10% top water and 90% bottom water should show by a partial analysis the following composition:

10% - 90%	
SO_4	416
Cl	53542
T.S.	90611

Some waters, after the complete analysis was run on them, were reclassified as their chemical constituents did not compare favorably with the average analysis representing the depth at which these waters were sampled. As an example, the Kipfer #1, Lab. No. 53152, listed as water coming from the 825' level---

	Ca	Mg	Na	SO_4	Cl	Sr	Ca/Mg	Ca/Sr	Ca-Sr/Mg	T.S.E.
Kipfer #1	3402	821	25581	41	47830	1116	3.5:1	2.5:1	4.8:1	77930
Group #1	3832	903	28079	15	53673	830	3.9:1	4.8:1	4.9:1	90147
400 ft. Level	1000	299	13307	825	22383	293	3.7:1	5.9:1	4.8:1	37540

By comparing the chemical constituents of Kipfer #1 with average waters from group #1 and from the 400 ft. level, it is evident that this sample is a mixture of waters from the 400' and 800' levels.

Another sample, from the Seeley #8, Lab. No. 52784, was listed as a water from the 1070' level. By comparing the chemical constituents of this water with average waters from the 1070' level, or group #2, and with group #1, it is quite noticeable that this water is from a depth corresponding to waters considered in group #1.

	Ca	Mg	Na	SO	Cl	Sr	Ca/Mg	Ca/Sr	Ca-Sr/Mg	T.S.E.
Seeley #8	4058	980	30708	18	57330	760	3.8:1	4.9:1	4.6:1	96250
Group #2	4340	1188	33961	38	63472	1350	3.2:1	3.0:1	4.5:1	105338
Group #1	3832	903	28079	15	53673	830	3.9:1	4.8:1	4.9:1	90147

On the Winegar, and Piatt #6, a water was encountered at the depths of 2665', 2673' and 2693' that resembles the bottom water of the El Dorado field. Little attention is given to this situation as the pay sand in the Greenwood County field is at present, for this report, between 1878'-1926'. These waters will be classified as soon as conditions warrant their investigation.

Conclusions

This report in attempting to identify and classify water from the various water strata in the Greenwood County, Kansas field, has established six groups which can be used in determining the source of water in a well that is or may be a troublesome water to oil production. Such a grouping of the waters substantiates further the fact that waters occurring at various depths in a well can be identified by their chemical composition. It is possible through the data compiled in this report to recognize by a complete chemical analysis the chemical composition of the top waters and the bottom water for this field. The compiled chemical information on the waters encountered above production in this area has made it possible to establish a hypothetical top water for the field considered in this report. The formulation of the hypothetical top water makes possible the plotting of the curves submitted herewith. By the interpretation of these curves it is possible to estimate closely the percentage of top water occurring in a mixture. As a check on the estimate obtained from the chloride and sulfate curves, a curve is plotted for the total solid content of the waters. It is thought that after a hypothetical top water is established and the true bottom water of a field is known, the source of troublesome waters can be determined by a partial analysis alone and if the water proves by chemical analysis to be a mixture, the percentage of top water in the mixture can be estimated by the use of the accompanying curves. Much time and expense will be saved if the source of a troublesome water is determined by a partial analysis. It is the purpose of this department to shorten the procedure of analysis and lessen the cost of such an

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analysis whenever possible. It is hoped that the contents of this report and the conclusions derived therefrom will greatly aid in presenting a means of determining the source of troublesome water in a most scientific manner and at the least possible expense. The department is in search of new elements that may be found in the oil well waters. The strontium content will be a very valuable lead to classification as soon as the method of determining this element is perfected. Other elements such as potassium, bromine, and iodine, not included in the present scheme of analysis, will be investigated and their content noted for further aid in systematizing a marked difference in top and bottom waters.

In order to test the theory evolved in establishing the hypothetical top water and to try out the curves based on this "top water," it is suggested that a survey be made of the wells "making" water, and that samples be taken and sent to the laboratory for verification as to source.

Respectfully submitted,
David A. Bash.
Correlation Chemist

Oil Hill, Kansas.
June 20, 1925.

GREENWOOD COUNTY SURVEY

LEASE & WELL NO.	CHLORIDES CL	SULPHATES SO_4	TOTAL SOLIDS T.S.E.	REMARKS
Bartlett #1	67,500	49	109,870	Chiefly top water
Bartlett #8	56,670	401	94,630	30% " "
Duby #2	57,330	426	93,790	35% " "
Duby #9	59,500	300	97,850	47% " "
Kellison #6	52,660	456	88,350	Bottom "
Kellison #5	71,500	51	116,830	All top "
Bartlett #3	63,330	165	103,810	71% " "
Bartlett #2	54,660	484	92,770	17% " "
Duby #3	54,000	466	89,600	13% " "
Kellison #2	51,500	425	86,290	Bottom "
Kellison #4	68,000	131	111,400	All top "
Duby #1	53,500	485	87,800	10% " "

Note: Out of 100 producing wells, 12 wells had lost their production due to water trouble. Samples of water from the 12 wells as represented above were taken and sent to the laboratory for analysis. From the analysis the source of the troublesome water in each well was to be determined, and the percentage of top and bottom water of each well was to be estimated from the curves in this report. It was also found that a partial analysis of these waters was all that was necessary to identify them as to source and estimate the percentages of top and bottom water .

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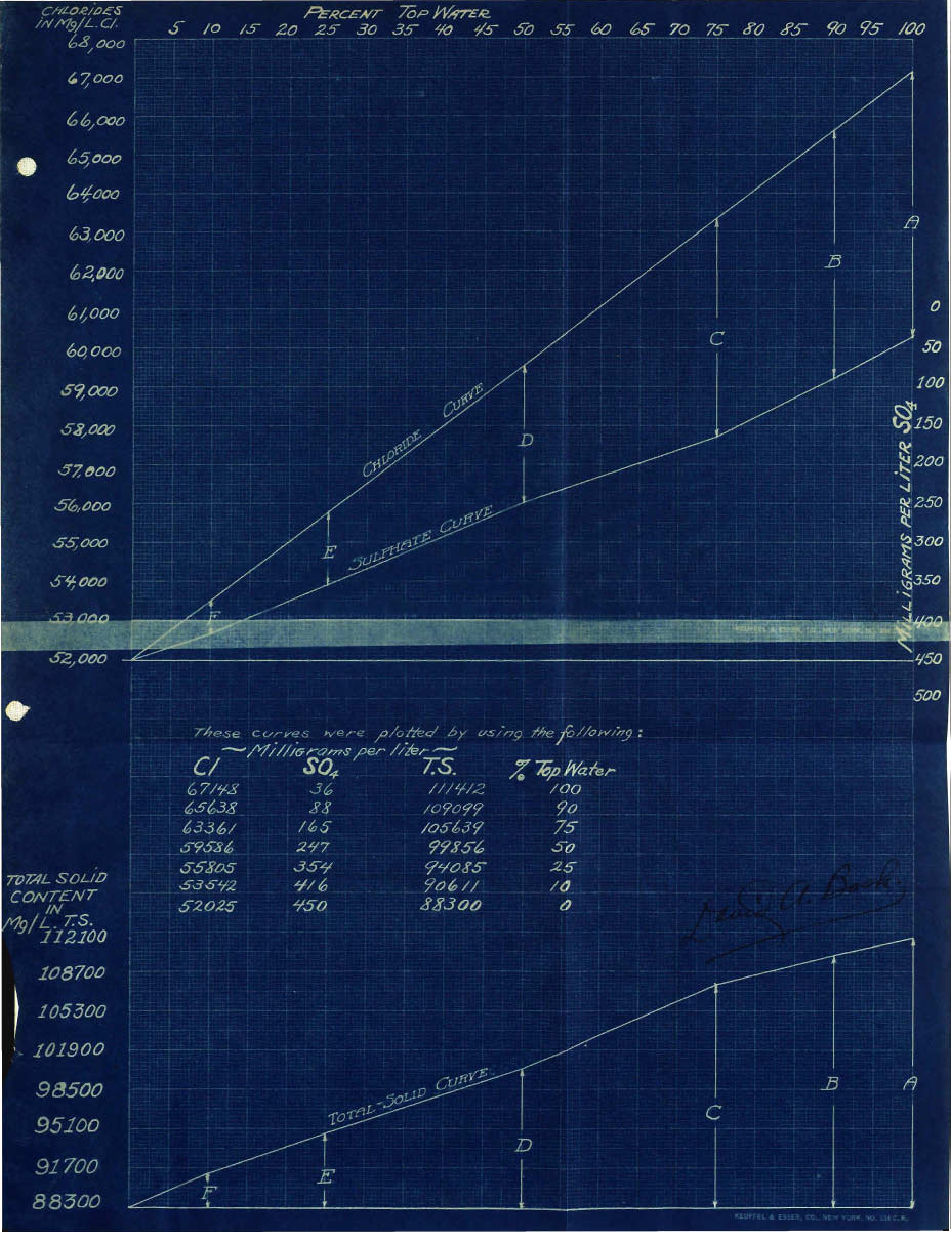

These curves were plotted by using the following:

~Milligrams per liter~

Cl	SO_4	T.S.	% Top Water
67148	36	111412	100
65638	88	109099	90
63361	165	105639	75
59586	247	99856	50
55805	354	94085	25
53542	416	90611	10
52025	450	88300	0

A. Bock