Technical Note 84——

THE INTERPRETATION OF CHEMICAL WATER ANALYSIS BY MEANS OF PATTERNS

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ABSTRACT

The classification and correlation of water analysis data presents many problems which can be solved by graphic methods. The pattern system, a new type of graphic procedure described in this communication, is believed to have several advantages over older methods. Examples of the application of the pattern system to the solution of problems encountered in petroleum production are given.

INTRODUCTION

Several graphic methods for presenting analytical water data have been developed and are now in use.[1,2,3,4] It is believed, however, that a recently developed type of graph called the "pattern" offers several advantages over other methods. This system presents a better picture of the total salt concentration than is usual in such graphs. The effect of dilution or concentration has been reduced to a minimum, and at the same time distinction between various types of water has been improved. The system is extremely versatile, yet so simple it can be plotted on ordinary graph paper and adapted to almost any type of filing system.

DISCUSSION

The essential feature of the pattern system is the graph shown in Fig. 1. Horizontal lines extending right and left from a vertical line at zero form the graph. Positive ions are plotted to the left while negative ions are plotted to the right. The figure immediately beneath each ion gives the scale. Most oil field waters can be plotted on a scale where 100 milliequivalents of sodium and chloride and 10 milliequivalents of each of the other ions are represented by one scale unit. For highly concentrated brines, 1,000 milliequivalents of sodium and chloride and 100 milliequivalents of each of the other ions are represented by one unit. For convenience sodium, potassium, lithium, etc., ordinarily determined as the difference between the positive and negative ions, are referred to as sodium.

It will be noted that the chemical unit of "milliequivalents per liter" is employed. If the results of the analysis are in parts per million, they can be readily converted by dividing by the equivalent weight in milligrams or multiplying by its reciprocal. Appropriate conversion factors can be found in standard chemical handbooks.[5]

When the points have been properly placed on the graph, they are connected by lines as shown in Fig. 2, thus forming a closed "pattern." These patterns present a variety of shapes

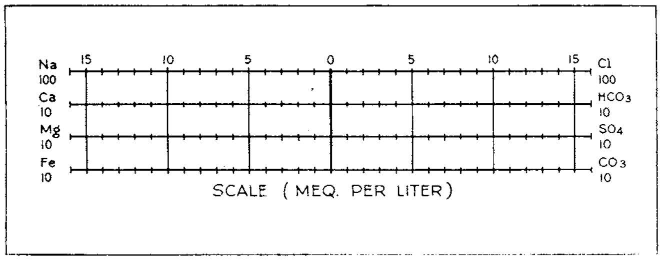

FIG. 1 — ESSENTIAL FEATURE OF THE PATTERN ANALYSIS SYSTEM.

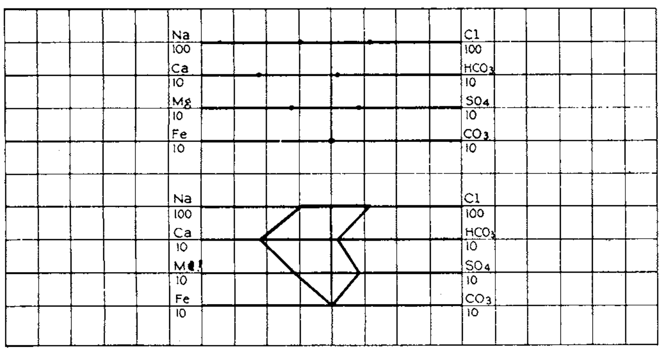

FIG. 2 — METHOD OF CONSTRUCTING A PATTERN.

and sizes, each easily recognized and remembered and each characteristic of a certain water.

Fig. 3 shows some common water patterns, including those of fresh water, sea water, chemical solutions and oil field brines. The straight line pattern of fresh water shown in the first diagram results from the use of a scale ordinarily employed for oil field brines. Any system of scales thought suitable to a particular operation may be used. Single scales, in which all ions are represented by an equal number of units, are used in plotting fresh waters, while multiple scales, in which all ions are not represented by the same number of units, find application in work with oil field waters. Various types of multiple scales can be used to advantage in water treatment work, corrosion control, and injection water studies.

One of the distinctive features of the system is the tendency of the pattern to maintain its characteristic shape as the sample becomes dilute. In this way the total salt concentration as well as the chemical composition of the water is shown by the pattern.

The availability of various scales makes it possible to select one which emphasizes the differences and similarities of the waters being studied, thereby making direct comparison and correlation between these waters possible.

Another very valuable feature of this system is its extreme simplicity. The pattern can be constructed by anyone on

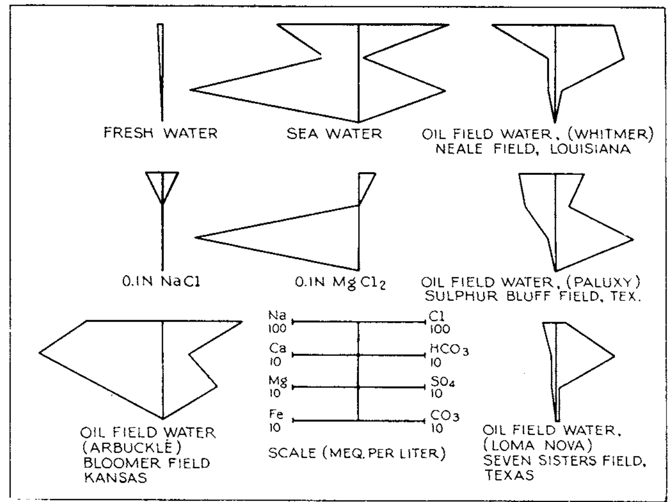

FIG. 3 — COMMON WATER PATTERNS.

ordinary graph paper. The use of a printed card containing a graph similar to that shown in Fig. 1, and in addition blank spaces for pertinent well data, is very convenient for this work. By this means a large and very useful library of patterns can be built up in a small space.

APPLICATION

The applications of the pattern system are many and varied. It is believed that this system will facilitate the solution of almost any problem in which water analysis is a factor. The following examples illustrate its application to various problems encountered in petroleum production.

Correlation of Producing Formations

Since the pattern tends to maintain its shape upon concentration or dilution, a formation may be expected to yield water of a characteristic pattern. A study of the water patterns can, in many cases, be utilized to identify different producing strata and correlate them in a given locality. In Kansas, for example, the Arbuckle group of the Ordovician period can be traced from Ellsworth County down through Barton County and into Stafford County by means of water patterns. Fig. 4 shows patterns from Stoltenberg Field (Ellsworth County), Bloomer Field (Barton County), and Drach and St. John's Fields (Stafford County). The characteristic pattern of the Arbuckle formation can be easily followed.

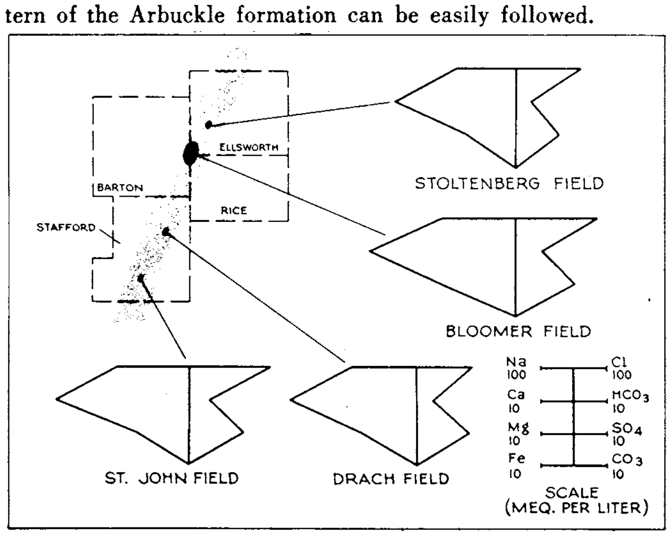

FIG. 4 — COURSE OF ARBUCKLE FORMATION THROUGH KANSAS SHOWN BY WATER PATTERNS.

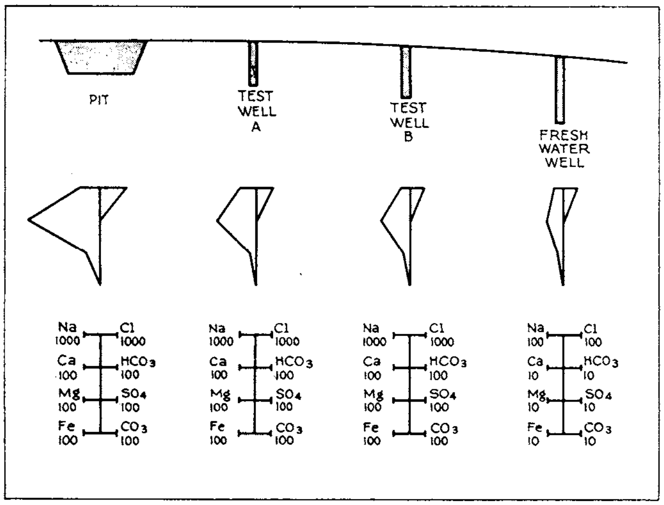

FIG. 5 — PATTERN ANALYSIS USED AS A TRACER.

Tracer Problems

It is often possible to trace the passage of water through a sand by a study of the patterns obtained from properly spaced test holes along its path. In the case presented in Fig. 5, seepage of salt water from a disposal pit into a fresh water well was suspected. Shallow test holes were drilled at *A* and *B* and allowed to fill by seepage. Samples were taken, the water analyzed, and the patterns plotted. The appearance of the disposal pit pattern, somewhat reduced in size, definitely established seepage in the direction of the well. When a sample from the fresh water well plotted on a magnified scale gave the same pattern as the pit, contamination became evident.

Drill Stem Testing

Because of the uncertainty regarding contamination of water samples by drilling mud encountered in drill stem testing; attempts to establish the formation from which such samples originate are often unsuccessful. In some cases, however, this information is extremely helpful. Because of the ease with which one pattern can be compared with another, the pattern system is especially useful for this purpose. Fig. 6 shows the results of a case where pattern analysis was successfully utilized to determine the formation from which a drill stem test sample originated.

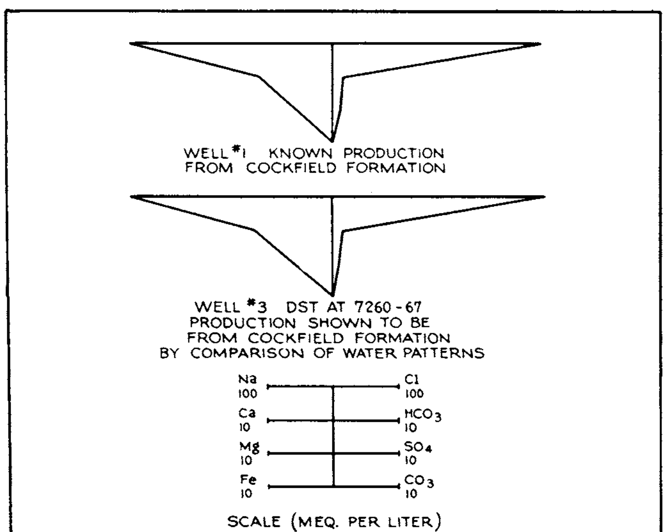

FIG. 6 — PATTERN ANALYSIS USED IN DRILL STEM TESTING.

Detection of a Foreign Water and the Determination of Its Source

Oil wells are completed so as to yield a minimum of water, but a break in the cement or a leak in the casing may allow extraneous water to enter. Water yielded by a well in the normal course of operation is usually bottom water, that is, water from the producing formation, while water entering through a leak or cement break may come from some other strata. If sufficient information is available on the composition of the waters in the area, the source of a foreign water may be discovered, and its exclusion brought about with a minimum of trouble and expense.

Fig. 7 presents a case in which water patterns were used to determine the source of water entering a well. Well No. 1 had been producing water of a consistent pattern from formation *A* since its completion, when suddenly the water pattern changed. Another well in the field was producing from formation *B* which was located about 150 ft above *A*. This formation had, of course, been cemented off during completion of Well No. 1. The patterns of various mixtures of *A* and *B* were calculated and plotted as shown. It then became evident that the new pattern resulted from a mixture of approximately 25 per cent water from formation *A* and 75 per cent water from formation *B*. It was therefore concluded that foreign water was entering from formation *B* either through a casing leak or through a break in the cement. Accordingly, the casing was pressure tested and since no leak was found, a cement job was undertaken. At the conclusion of this operation the well was again put on production and at the end of several months the pattern was again similar to that of formation *A*.

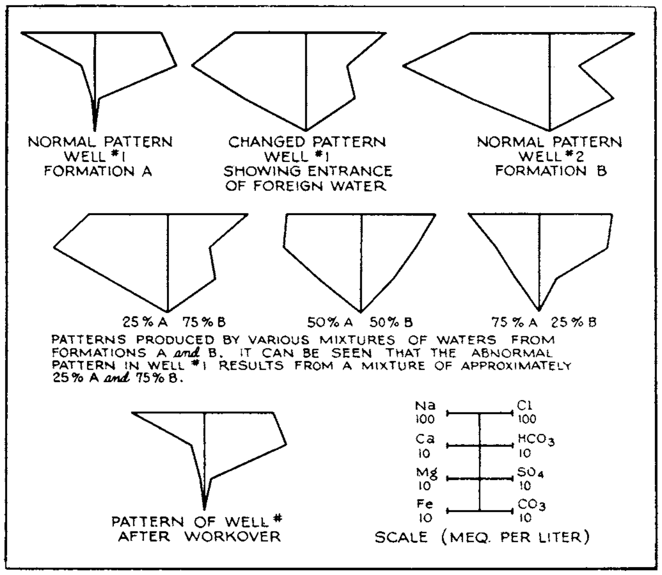

FIG. 7 — DETECTION OF FOREIGN WATER AND DETERMINATION OF ITS SOURCE.

CONCLUSIONS

The pattern analysis system presented in this paper offers a simple, practical means of characterizing, comparing, and correlating ground waters. It is particularly useful in facilitating the solution of many petroleum production problems, but can be used to advantage in the study of any question in which water analysis is a factor.

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