SOURCE AND OCCURRENCE OF BRINES FOR WATERFLOODING IN ILLINOIS

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INTRODUCTION

Since 1943, Illinois oil-field operators have increased the demand for water for secondary recovery of oil through waterflooding. A recent inventory of Illinois waterflood operators shows that during 1956 nearly 30 million barrels of oil were recovered by injecting 289 million barrels of fresh and saline water into oil-producing formations (Pryor, *et al.*, 1957). Produced water (Fig. 1) is that water which is produced with and separated from oil. All water other than produced water is called make-up or supply water. It may be either fresh or brine. An attempt has been made (Fig. 2) to distinguish between produced and make-up brine. It is often difficult to do this because some operators consider all water that is not being produced in a particular flood project as make-up water, although some of it was produced in another project.

This paper describes, within the limitations of available information, the source and occurrence of brines in Illinois, problems involved in their development, and their potential as a source of water for waterflooding. Water used for pressure maintenance projects, dump floods, and brine disposal projects is not considered.

STRATIGRAPHY AND WATER-YIELDING CHARACTERISTICS

In the Illinois basin many sandstones and limestones ranging in age from Cambrian to Pennsylvanian contain brines (Fig. 2). The distribution, thickness, composition, and permeability of these brine aquifers vary considerably throughout the area. In general, all these formations will yield fresh water at or near their outcrops along the margins of the basin, but within the basin they contain saline waters that become more mineralized with depth.

It is difficult to predict the water-yielding potential of the aquifers in the basin because their hydrologic characteristics are not well known. Waterflood operators are becoming increasingly aware of the need for these basic hydrologic data as they demand new and larger supplies of water. Without such data, our knowledge as to their potential is based on the assumption that if water is obtained from a formation, similar amounts can be obtained from it in other areas where similar conditions prevail. The "drying up" of brine-supply wells in some places demonstrates the lack of consideration of the geologic and hydrologic factors as they may affect the waterflood program. Such short-sighted-

[180]

FRESH WATER INJECTED 104 MILLION BBLS.
BRINE WATER INJECTED 184 MILLION BBLS.
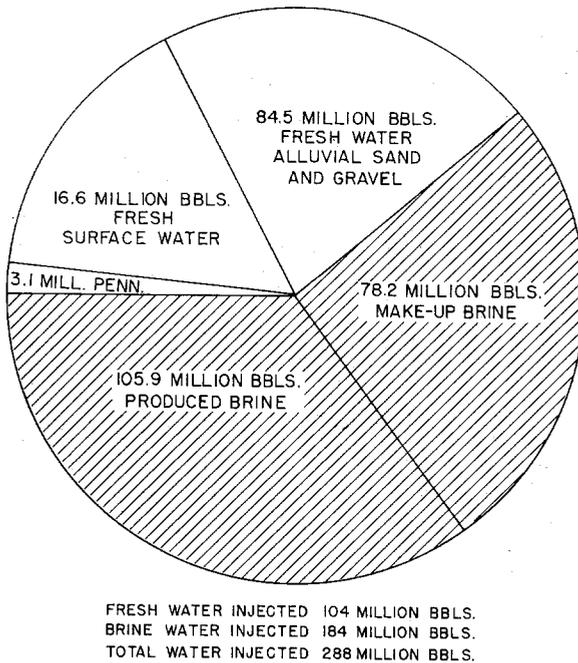TOTAL WATER INJECTED 288 MILLION BBLS.

FIG. 1.—Chart showing distribution among sources of water used for waterflooding in Illinois during 1956.

ness and unnecessary expense can be avoided by conducting pumping tests on these formations to determine their specific capacity, storage coefficients, transmissibility, and other important hydrologic characteristics (Pryor, *et al.*, 1957:51-55).

The water-yielding potential of formations shown on Figure 2 may be roughly evaluated on the basis of present use. However, large quantities of produced water are being disposed of in brine-disposal projects. If this considerable but unknown amount of water were used for waterflooding, the data on produced water (Fig. 2) would be increased considerably in some instances.

Lower Paleozoic formations.—The Cambrian rocks are not shown in the column because their thickness and lithology are little known in the central part of the basin. In northern Illinois, Cambrian sandstones are important fresh-water aquifers. If Cambrian sandstones occur in the basin, and if brines are available from them, economic limitations of depth will determine their use.

At present only small amounts of fresh water are obtained from the St. Peter sandstone in its outcrop area along the western margins of the basin. None of this water is being used for waterflooding.

The Trenton limestone and dolomite, the Silurian limestone and dolomite, and the Devonian limestone all yield varying amounts of fresh water where they crop out along the western and southern margin of the basin. Water is obtained
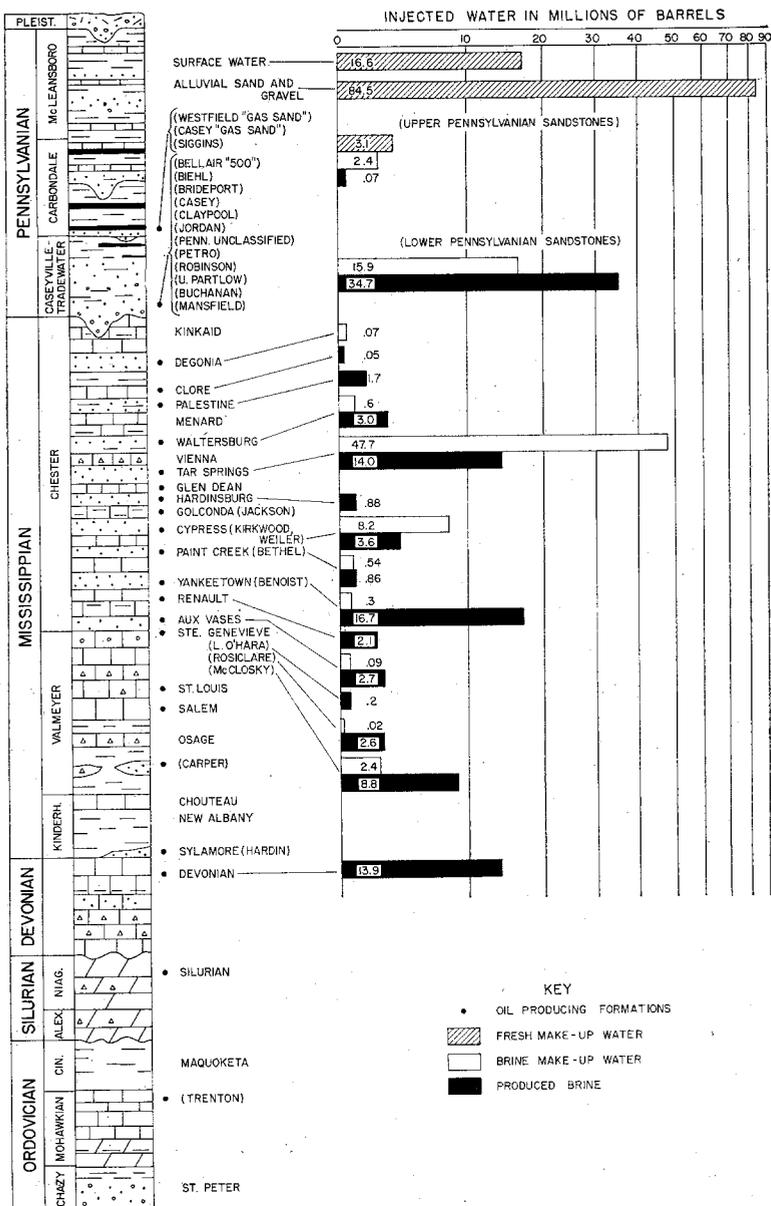
Fig. 2.—Generalized geologic column for the Illinois basin and chart showing oil-producing formations and the amount, type, and source of water used for waterflooding in 1956.
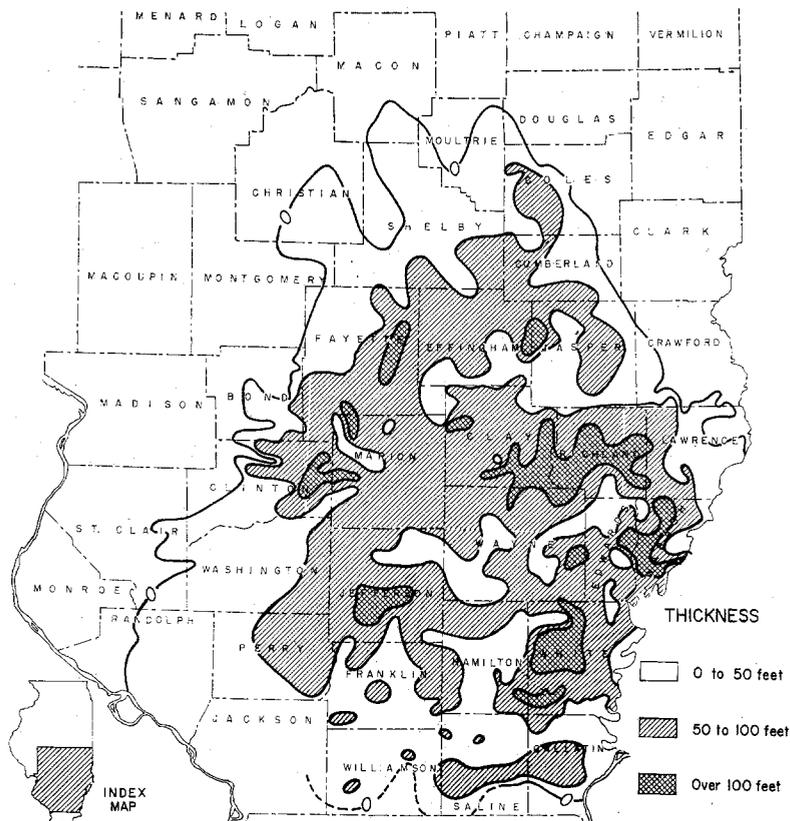
FIG. 3.—Approximate cumulative thickness of sandstone in the Tar Springs formation (from Pryor, *et al.*, 1957).

from joints, fractures, and solution channels. If these features are present in the deeper portions of the basin, then brines may be obtained from them, at least locally. Water is not being obtained from these deep aquifers because: 1) Sufficient quantities of water are economically withdrawn from shallower aquifers or surface reservoirs; 2) Waterflood projects have not been initiated in areas where these formations might be economically used; and 3) Oil drilling does not extend to these formations in deeper portions of the basin.

At present, Devonian strata are the only Paleozoic formations below the Mississippian rocks that yield large amounts of water for waterflooding. This is produced water, but it is likely that make-up brines could also be obtained from Devonian rocks in some fields.

Mississippian formations.—Widespread occurrence of shales excludes the lower Mississippian rock as sources of water. The permeable, oolitic Ste. Genevieve limestone is the lowest important Mississippian formation from which brine water is obtained. The "Rosiclare" and "Mc-

Closky'' aquifers are important sources of water for waterflooding in some localities. Large amounts of produced water are also obtained from them.

Permeable Chester sandstones are the most used brine aquifers in Illinois. They also yield the most oil. The most important Chester aquifers are shown in Figure 2. The Aux Vases, Renault, Benoist, Cypress, Tar Springs, and Waltersburg sandstones are all notable sources of produced brine, and the Tar Springs and Cypress sandstones are particularly important sources for make-up water.

Figure 3 shows cumulative thickness of sandstone in the Tar Springs formations. During 1956, flood projects of the Louden field withdrew about 43 million barrels of brine from the Tar Springs sandstone where it is 100 feet or more thick. This is the greater part of total Tar Springs brine used in all pools in the basin. The widespread occurrence elsewhere of thick Tar Spring sandstone suggests the great potential of this formation in other areas. The same conclusion can be drawn for certain other sandstones in the Chester group.

Pennsylvanian formations.—The Pennsylvanian rocks are characterized by alternating beds of shale, siltstone, limestone, coal, and sandstone. The lenticular sandstone formations of the lower part of the Pennsylvanian System are characterized by clean, coarse-grained quartzose sandstones, whereas the upper Pennsylvanian rocks generally contain finer grained sandstones with considerable amounts of clay, silt, and mica. Therefore, the lower Pennsylvanian formations are generally more permeable than the upper Pennsylvanian formations, although both are highly variable in permeability. Locally, well defined pre-Pennsylvanian drainage channels are superimposed on the underlying Mississippian surface. In these channels thick, permeable, basal Pennsylvanian sandstones were deposited (Siever, 1951).

PROBLEMS CONCERNING THE USE OF BRINES FOR WATERFLOODING

Two types of problems associated with the use of brines for waterflooding are common to both brine and fresh-water supplies.

1. Several related geologic and hydrologic problems are: location of aquifers that yield sufficient quantities of water; construction of efficient water wells into these aquifers; and placement of wells to prevent well interference. Information concerning these factors can be obtained by basic geologic studies, by evaluation of driller's logs, electric logs, and sample studies, and by interpretation of pumping-test data.

2. Formational clogging may occur as a result of reactions between clay particles on sand-grain surface and injected water which can cause clay particles to separate from sand grains (Witherspoon, 1952). Brines are not always compatible with these clays and may cause clogging if certain components in the brines are adsorbed by the clay material (Grim, 1947).

Injection of saline water rather than fresh water is often advantageous when expandable type clays are present. Saline water generally has

less effect on the clay-mineral particles, whereas fresh water may cause expansion and dispersion of clay material (A. W. White, pers. comm.). Before initiating a waterflood, it is advisable to establish the character of the clays present in the oil formations and to evalute the possible effects injected waters may have upon these clays.

Other problems are for the most part unique with respect to brine supplies. These include:

1. Mixing of incompatible water. Only locally have brine supplies been avoided in Illinois because of their restrictive chemical nature. Recently developed water-treatment practices (Watkins, 1957) have allowed the use of all brines with the exception of those containing barium and, in part, high concentrations of iron. In these two instances, precipitates of iron sulfide (FeS) and insoluble barium sulfate ($BaSO_4$) have been produced. According to Squires (1951) acid treatments have restored intake rates by removing some of the iron precipitate. Calgon and calcium hypochlorite have also been added by operators to prevent iron precipitation. Recent investigations by the Pure Oil Company (Bernard, 1957) indicated that the mechanics of water displacement prevent the mixing of injected water to any great extent with water in the oil reservoir during a water drive. In the zone where incompatible waters do mix, only negligible reductions in pore space will result.

In Bernard's opinion, this accounts in part for the success some operators are having at present with incompatible waters. However, if incompatible waters are mixed at the well head or within the injection well, precipitates should be anticipated. These precipitates will be filtered out at the sand face of the injection well and will reduce injection rates.

With further study it may prove feasible to use those brines which were previously considered unsuitable for waterflooding.

2. Corrosion of oil-field equipment by chemically active constituents in brines. This is of great economic importance to oil field operators. Measures being taken to minimize the corrosion problems include: a) Use of corrosion inhibitors in brine. Their use in other areas was discussed by Breston (1949), Heck *et al.* (1949) and Robinson (1956); b) Use of aeration equipment and baffled brine-setting pits to remove chemically active gases (CO_2, H_2S). According to Watkins (1957), a new method of removing hydrogen sulfide and oxygen from water employed elsewhere is by countercurrent scrubbing in a packed tower using synthetic or natural combustion-exhaust gases. Applications and principles have been discussed by Doscher and Tuttle (1954) and Crawford (1955). A similar submerged-burner method was discussed by W. J. Hart and R. T. Wingate (unpubl., 1955); c) Use of non-corrodible equipment, such as wooden brine-treatment tanks, plastic pipes, non-corrodible liners made of plastic or cement-asbestos, and certain equipment made from corrosion-resistant alloys; and d) Cathodic protection.

Conclusion

Several factors allow brines to compete economically with fresh-

water supplies in Illinois despite more elaborate water-treatment requirements.

1. Competition for brines is limited to waterflood operators as compared to competition among a host of fresh-water users.

2. Brines are readily available from numerous formations throughout the Illinois basin. These formations are widespread geographically and contain adequate supplies of water for waterflooding.

3. Produced brines in increasing quantities should be anticipated during the advanced life of most Illinois oil-pools. Since this water has to be disposed of without contaminating potable water, it may be advantageous to invest in water-treating facilities capable of treating these brines and using them for waterflooding, thus alleviating make-up water demands.

4. Brines are often chemically more acceptable than fresh water.

5. Some dry holes and abandoned oil wells may be converted to brine-supply wells, thus reducing development costs.

6. Excess quantities of brines are often in demand for use by neighboring operators.

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