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Improved Recovery by Optimizing Water Flooding - An Experimental Approach

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SUMMARY

Since the inception of water flooding it has been used to improve recovery from oil reservoirs mainly light and medium oil and has very high success rate than other methods due to high recovery factor and low costs associated with it. Clay minerals are present as rock matrix in sandstone reservoir and adversely affect during water flooding as they swell and decrease the porosity and block the pore throat thus resulting in reduced production. An experimental study was done to determine formation damage due to clay swelling, and to identify a cost effective clay stabilizer to be used in the injection water. The study included performing core flood experiments using sandstone reservoir cores, analysing the effects of stabilizer type and concentration on permeability of core in detail and selecting critical salt concentration, below which there is loss of permeability occurs. Based on the data obtained, analysis of change in porosity and permeability was done. With the help of data obtained, clay swelling effect has been seen while flooding with distilled water; it reduces by the use of clay stabilizer. At the same time use of brine in place of distilled water increases recovery efficiency of water flooding, thus improving recovery.

Introduction

Since the inception of water flooding it has been used to improve recovery from oil reservoirs mainly light and medium oil and has very high success rate than other methods due to high recovery factor and low costs associated with it. Water flooding is applied on a large scale for rapidly ramping up the oil production but success of this technique greatly depends on the type of the reservoir rock and its composition. Adverse effect of water on clay minerals decreases the efficiency of water flooding and thus recovery.

Sandstone reservoirs consist of three major parts, the framework, pore space and the rock fragments. The rock fragments consist of different types of authigenic and detrital clays such as kaolinite, smectite, chlorite and illite. These clays adversely effect during water flooding as they swell and decrease the porosity and block the pore throat thus resulting in decreased relative permeability eventually causing reduced production. Another potentially significantly damaging mechanism of permeability impairment in unconsolidated sandstone reservoirs containing oil is that of clay deflocculation.

In many cases, producing heavy oil formations are inadvertently damaged by the use of low salinity or fresh water simply because preliminary petrographic analysis indicates an absence of classical fresh water swelling clays such as smectite. A variety of other particulates, including kaolinite clay, can be susceptible to deflocculation induced damage and this can have significant results with respect to impaired productivity.

Method/Theory

An experimental study was done to determine formation damage due to clay swelling, and to identify a cost effective clay stabilizer to be used in injection water. The study included performing core flood experiments using sandstone reservoir cores, analysing the effects of stabilizer type and concentration on permeability of core in detail and selecting critical salt concentration, below which there is loss of permeability occurs.

First of all, effect of water with varying concentrations of different clay stabilizers (e.g. KCl, Cs-X, Cs-A, Cs-B, Cs-C, Cs-D) on clay minerals, were analysed. On the basis of the results, best clay stabilizer and its concentration for each clay mineral were selected. Then, by XRD analysis, collected core samples were characterized on the basis of type and concentration of clay minerals present in it.

After that all the cores were flooded with the following fluids:

1. Distilled water
2. Distilled water with appropriate clay stabilizer
3. Varying salinity brine with clay stabilizer

The recovery was minimum when core sample was flooded with distilled water and it increased by 7-10 percent when core was flooded with distilled water having appropriate type and amount of clay stabilizer. We recorded a further 5-10 percent increase in the recovery while flooding brine with clay stabilizer. After flooding all the core samples, analysis of change in porosity and permeability was done. With the help of data obtained, clay swelling effect has been seen while flooding with distilled water; it was reduced by the use of clay stabilizer. At the same time use of brine in place of distilled water increases recovery efficiency of water flooding, thus improving recovery.

Figure 1 (a) Swelling behaviour of Kaolinite with different concentration of KCl (Increasing from Right to Left). (b) Swelling behaviour of Bentonite with different concentration of KCl (Increasing from Left to right).

Conclusions

1. Clay swelling is the main cause of reduced efficiency of water flooding while flooding with distilled water as it reduce the porosity and plugs the pore throat.
2. Efficiency of clay stabilizer was observed to be a function of type and concentration of clay stabilizer.
3. Clay Swelling effect was reduced to a minimum by using clay stabilizer.
4. Low salinity water when used with appropriate clay stabilizer increases the efficiency of the technique and also causes the least reservoir damage. Thus, is the best way to optimize water flooding

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