Effect of Partially Hydrolyzed Polyacrylamide (PHPA) Mud Contamination on Rock Wettability

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ABSTRACT

Wettability is a key parameter that affects the petrophysical properties of reservoir rocks. Mud filtrate during drilling pay zone causes a significant change in rock wettability that will affect the oil production and enhanced oil recovery methods (EOR). This change depends on the mud filtrate and the oil rock systems studied. The objective of this paper is to investigate the influence of PHPA mud filtrate on the reservoir rocks wettability. PHPA mud composition recommended for drilling horizontal wells had been used in this study. The reservoir rocks used were Saudi water-wet sandstone and limestone. The contact angel was used to measure the rock wettability. Also, the effect of temperature on wettability alteration had been studied.

The results show that the rock samples used are originally water-wet. The PHPA mud contamination increased the Saudi reservoir rock wettability to strongly water-wet. The contact angle decreased due to PHPA mud contamination. The temperature increase reduced the contact angle and this reduction was higher in limestone rock than sandstone rock. Both reservoir rock changed from water-wet to strongly water-wet.

1. INTRODUCTION

Wettability is the tendency of one fluid to spread on or adhere to a solid in the presence of other immiscible fluids. It is the major factor controlling the distribution of fluids in the reservoir [1].

PHPA mud is nowadays recommended to drill oil and gas wells because of environmental regulations and shale stability. The most important factors for productivity ratio as well as waterflood evaluation are the determination of formation wettability and water saturation. An induced wettability change can alter the productivity of the producing well and hardly affect the enhanced recovery methods (EOR) [2 – 4].

In the previous works performed [5, 6], the effect of water-based drilling muds and oil-base muds on reservoir rock wettability was investigated. The results showed that water-based drilling muds tend to make the system water-wet in all cases studied. The contact angle tend to increase with increasing the concentration of sodium hydroxide (NaOH) and potassium hydroxide (KOH) in the mud. In contrast, oil base mud changed the system from water-wet to strongly oil-west, either sandstone or limestone. This reverse effect of oil base mud filtrate is attributed to the existence of oil wetting surfactant and emulsifiers in the filtrate. The contact angle change was higher in limestone than in sandstone system. These results are also confirmed later on by Sanner et al. [7]. They also reported that the change in reservoir rock wettability changed the effective permeability of the wetting fluid as well as its irreducible saturation.

Concerning the effect of temperature on the reservoir rock wettability, Wang et al. [8] tested the effect of temperature on pure quartz and calcite samples. They reported that the effect of temperature is changeable and depends on the rock and fluid compositions.

Because of the industry recommendations to use PHPA mud as an environmentally accepted mud [9, 10], this paper discusses the effect of the PHPA mud contamination and the reservoir temperature on the wettability of one sandstone and one limestone Saudi reservoir rock samples.

2. EXPERIMENTAL WORK

Samples 2.5" (3.81 cm) in diameter and 1.0" (2.54 cm) long with a very smoothed surface were used to measure the contact angle. The cores were obtained from wells drilled in Aramco production area in the Eastern part of Saudi Arabia. The composition of sandstone and limestone cores are shown in Figures 1 and 2. The sandstone cores consist essentially of quartz (70 %). The clay content in the cores is in the range from 10 to 15 %. The associated non-clay minerals are mainly feldspar and pyrite. The limestone cores consist of calcite and gibsite (70 %). This sample also has a clay content of about 20 %. The limestone sample also contain non-clay minerals which are mainly feldspar pyrite talc and iron oxides.

After the samples were cleaned after Cuiec [11], they had been dried under controlled humidity. The samples then saturated with 3.5 % NaCI brine water and the contact angle was measured. The same samples were contaminated with PHPA mud by displacing brine water with mud. The composition of the used PHPA mud was chosen from recommended manuals of specialized service companies [12, 13], Table 1. The wettability measurements were made using the contact angle method [1], where the contact angle between crude oil and an aqueous solution is measured. The aqueous solution sued was brine water 3.5 % NaCI concentration. The oil droplet was put in contact with downward surface of the core sample and then immersed in the aqueous solution. The oil droplet was photographed at different time intervals on a period of 24 hours to investigate the change of the contact angle with time. The measurements were carried out at temperatures of 25, 40, 50 and 60 °C. The measured contact angle in the aqueous phase was determined by making a tangent to both sides of oil droplet to decrease the absolute error. The error in this case was within ±1°.

3. RESULTS AND DISCUSSION

The results in Table 2 show that the PHPA mud has an intermediate plastic viscosity and normal yield and gel strength. The API filtration rate is really high which means that it will invade in the reservoir rock.

Concerning the contact angle measurements, the contaminated samples were stored for five days as a minimum time for mud to contact reservoir rock during drilling or completion. The results are shown in Figures 3 and 4. The contact angle was measured first for non-contaminated

Table 1 **Composition of PHPA mud**

Material	Amount mixed
Water	1 000.0 cc
PHPA	3.0 gm
Tackle	0.4 gm
Bentonite	15.0 gm
Caustic Soda	2.0 gm

Tackle – trade name of a thinner.

Table 2 **Properties of PHPA mud**

Property	Measured Value
Density, ppg.	8.7
Plastic viscosity, cp.	26.50
Apparent viscosity, cp.	19.50
Yield value, lb/100 ft^2	10.50
Gel strength, lb/100 ft^2	6.00
pH value	7.8
Filtration, cc/30 min.	140.0

Gel strength measured after 10 minutes.

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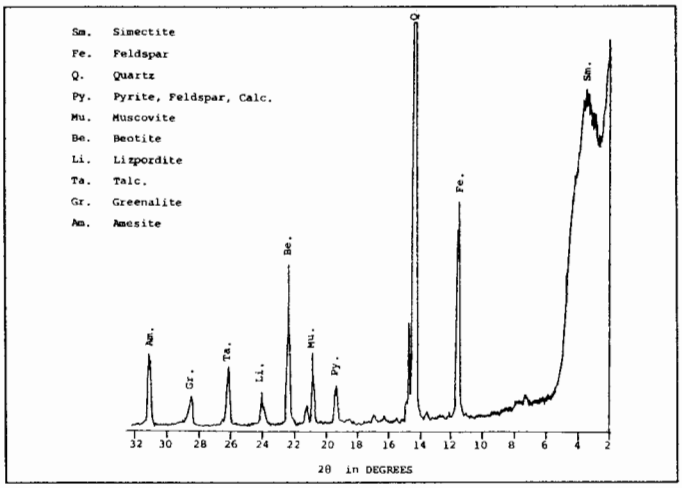

Fig. 1 X-ray diffraction characteristics for sandstone sample

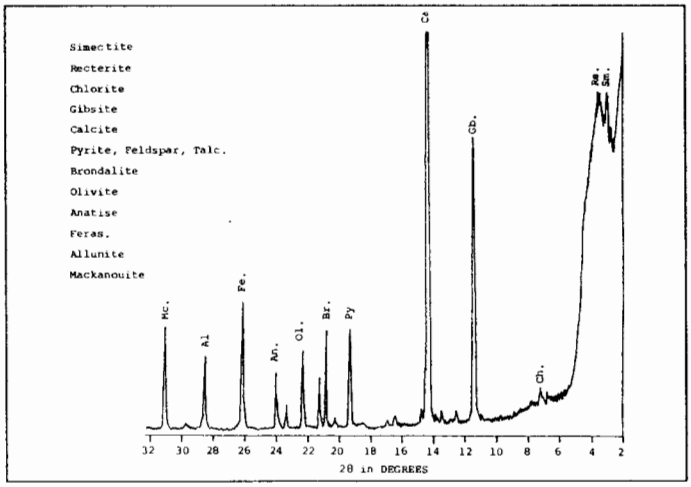

Fig. 2 X-ray diffraction characteristics for limestone samples

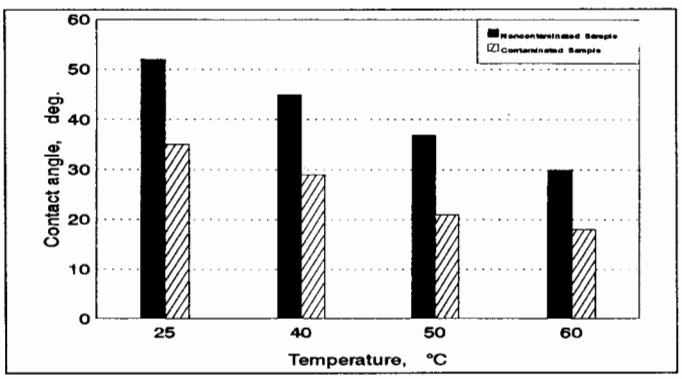

Fig. 3 Effect of PHPA mud contamination on contact angle for sandstone rock at different temperatures

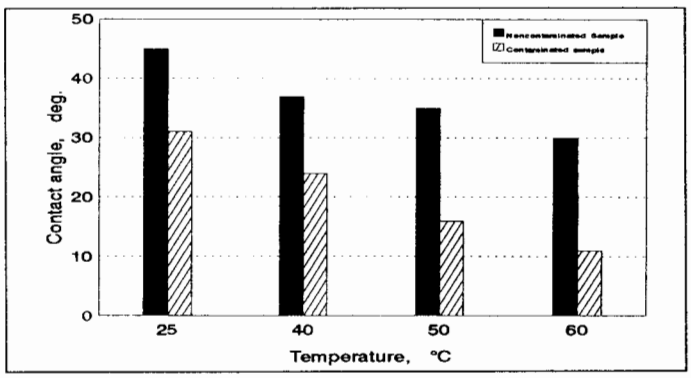

Fig. 4 Effect of PHPA mud contamination on contact angle for limestone rock at different temperatures.

samples and next for the same samples contaminated with PHPA mud filtrate.

Figure 3 shows that the sandstone samples saturated with brine water attained an average contact angle of 52°. This angle lies in the range of water-wet reservoir [1]. Contaminating the samples with PHPA mud decreased the contact angle to about 34° at room temperature which means that the wettability to water is increased [1]. This means that the PHPA mud contamination increases the reservoir rock wettability towards water. This could be attributed to the PHPA polymer adsorption on the grains. This adsorption increases the affinity of the grains to water and increases the hydrophilic properties of the rock.

Figure 3 also shows the effect of temperature increase on the contact angle for both non-contaminated and contaminated sandstone samples. It shows that increasing the temperature reduces the contact angle between oil and rock sample. This means that temperature increase the sandstone rock sample wettability towards water, i. e. the sample becomes more water-wet.

Figure 4 gives the results of the contact angle measurements for limestone samples at the same conditions that of the sandstone ones. The contact angle in this case is lower than in the case of sandstone samples at all conditions. This can be investigated by a composition of the limestone samples and its relationship with the mud composition which yields strongly water-wet samples. Also, the temperature increase changes the limestone rock samples to strongly water-wet.

4. CONCLUSION

Based on the results obtained in this study, the PHPA mud recommended for environmentally clean drilling yields moderate rheological properties and high filtration rate. The Saudi reservoir rock samples used are originally water-wet. Contaminating these samples with PHPA mud filtrate increases their wettability to strongly water-wet. Also, this increase is stressed by increasing the reservoir temperature. This change is lightly higher in limestone rocks than that in sandstone rocks.

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The cover photo shows the running of a 4 1/2" string in MW Cr 13 grade in a deep horizontal well.

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Contents