THE EFFECT OF KOH LIGNOSULFONATE DRILLING MUDS ON SPONTANEOUS POTENTIAL LOG INTERPRETATION

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Typical log analysis treats NaCl as the dominant salt in the formation, mud filtrate and drilling mud. However, the use of KOH-based muds changes these conventional relationships. This is indicated by some anomalies when normal methods of log analysis are used.

From laboratory experiments an original method for the interpretation of spontaneous potential logs has been derived. Field comparisons illustrate the large discrepancies in the determination of formation water resistivity that could otherwise arise. Further log anomalies from other tool responses also require attention.

THE USE OF KOH MUDS

Potassium hydroxide lignosulfonate drilling muds are being used to reduce problems caused by shales. The advantage of KOH mud systems is that treatment results in almost permanent clay stabilization [1,2].

Potassium hydroxide treatment causes clay stabilization in two stages. The potassium ions react quickly but temporarily to stabilize the clays. The hydroxide ions then slowly lock the potassium ion affect by forming a potassium zeolite reportedly resulting in the permanent and irreversible stabilization of the clays [1,2].

The result is the successful confinement of soft and hydratable clays. Consequently, smoother boreholes, improved well production and lower costs have been demonstrated.

TEMPERATURE - RESISTIVITY RELATIONSHIP OF KOH MUDS

For NaCl based muds, the correlation of temperature and mud filtrate resistivity is known as the Arps Formula:

$$R1 = R2 \frac{(T2 + 6.77)}{(T1 + 6.77)}$$

Laboratory experiments were conducted using KOH lignosulfonate mud filtrate solutions. These muds normally have a pH range of between 11.5 and 13.0 (200 - 5700 ppm). Resistivity - temperature analyses were conducted using different KOH concentrations representative of this range. The temperature range selected for the experiments was between 68 and 200 degrees F as this is representative of typical wellbore conditions. These experiments revealed the following relationship :

$$R1 = R2 \frac{(T2 + 4.6)}{(T1 + 4.6)}$$

Although the constant in the original Arps equation for NaCl has changed from 6.77 to 4.6 within the temperature range of 67 degrees and 190 degrees F, the constant does not appear to be influential (see Figure 1). This reinforces the conclusions of Cox and Raymer [3] by showing that Arps' formula can be used for KOH as well as NaCl and KCl solutions without much loss of accuracy.

ELECTROCHEMICAL EFFECTS OF POTASSIUM MUDS

There are three sources of the total electrochemical potential (Ec) that contribute to the total spontaneous potential.These are the membrane potential (Em), the liquid junction potential (Ej) and the bi-ionic potential (Eb). Thus,

$$Ec = Ej + Em + Eb$$

In order to use the above equation, a comparison of the electrical resistivity of KOH to its NaCl equivalent was determined.

Experiments showed that KOH solutions are more than twice as conductive as NaCl solutions at the same concentration in ppm (Figure 2). When solutions of KOH and NaCl of the same molal concentration, thus the same activity, were used, the resistivities of the KOH solutions were 47% that of the equivalent NaCl solutions.

A graphical conversion of Rmf to Rmfe (or Rw to Rwe) was thus derived (Figure 3).

STATIC SPONTANEOUS POTENTIAL

The static spontaneous potential, SSP, is the maximum SP that can be obtained with a shale and two waters of different salinity. It is essentially the SP that would be obtained if no current flowed. The SSP has is not influenced by boundary effects. It is a simple logarithmic function defined as:

$$SSP = -K \log \frac{Rmfe}{Rwe} \quad \text{in mV} \qquad [4,5]$$

Where, $K = (61 + 0.133\ Tf)$ for NaCl muds [4]

However, Cox and Raymer [3] showed that when potassium-based muds such as KCl and $KHCO_3$ are used, the bi-ionic potential (Eb) must be taken into account. This is because potassium and sodium ions have different electrochemical properties. Thus, the general SSP formula is modified as follows:

$$SSP = Eb - K \log \frac{Rmfe}{Rwe} \quad \text{in mV}$$

In NaCl-based muds Eb is zero. In a KCl system it has been demonstrated that Eb = 22 mV. Thus, the KCl system equation must incorporate Eb as a modified relationship for K. Hence,

$$SSP = 22 - (56 + 0.12\ Tf) \log \frac{Rmfe}{Rwe} \qquad [3]$$

Using similar techniques, our research with KOH-based mud systems has shown that Eb = 24 mV and the following relationship has validity:

$$SSP = 24 - (74.4 + 0.16\ Tf) \log \frac{Rmfe}{Rwe}$$

This is graphically presented in Figure 4.

The relationship has been verified by analysis of water produced from drill stem tests with comparison to the SP logs in different wells in Indonesia.

CASE STUDY

A section of a log from an example well drilled in a formation with fresh formation water is shown (Figure 5). A potassium lignosulfonate mud with a concentration of 7000 ppm was succesfully used to control the clays in the shale-sand sequences. A permeable sand exhibits negative SP development.

Calculation of the formation water resistivity (Rw) using the SP equation when modified for KOH muds is conducted as follows:

Formation temperature	= 206 degrees F
Rmf of the KOH mud	= 1.35 ohm.m at 77 degrees F
SSP	= -58 mV
Rmfe	= 2.79 ohm.m (from Figure 6)
Therefore, Rmfe	= 1.08 ohm.m at 206 degree F
$\frac{Rmfe}{Rwe}$	= 5.802 (from Figure 7)
Rwe	= $\frac{1.08}{5.802}$ = 0.186 at 206 degrees F
Rw	= 0.47 ohm.m at 77 degrees F
	= 12,200 ppm NaCl equivalent

Using SP relationships for the NaCl mud/water system the formation water resistivity would have been 0.292 ohm.m at 77 degrees F [5].

This is equivalent to 21,000 ppm NaCl - a difference of over 40% from the proposed KOH mud system relationship. This could have a significant effect upon the result of the well.

FURTHER WIRELINE TOOL RESPONSES TO KOH MUDS

Potassium hydroxide mud treatments have proved to be useful in stabilising clay swelling and migration in formations surrounding boreholes.

However, alkaline solutions such as KOH and NaOH, dissolve silica in the invaded zone[6] surrounding the borehole. This primarily affects sand reservoirs where silica can be dissolved from pure quartz. Logging tools could respond to this as an increase in porosity, i.e. one that is not representative of the reservoir.

In addition, the shallow-reading resistivity and Rxo tools show reduced resistivities. This is due to the higher conductivity of KOH solutions when compared to the more commonly used fresh water muds, such as are used in in many part of the world. This may result in faulty interpretation of true formation resistivity (Rt) and water saturations (Sw and Sxo).

A gas found in some reservoirs that can cause serious problems is carbon dioxide. During the drilling of a well with a KOH-based mud system this may not be detected. Although the wireline logs can show a noticeable gas effect.

This can be explained by the very high solubility of CO_2 in KOH solutions which are present in the drilling mud. Consequently, this absorption of CO_2, which is produced from the formation, can prevent detection at the surface.

POTENTIAL LOG INTERPRETATION PROBLEMS:

* Conventional SP interpretation methods can yield anomalously high Rw salinities when KOH muds are used.

* Increased conductivity of the invading KOH mud filtrate causes a reduction in Rxo measurements. Thus, movable oil calculations may be affected, if this is not taken into account.

* Invasion corrections and depth of invasion calculations should be used with caution if standard charts have been used.

* KOH can dissolve silica causing an apparent increase in porosity in the invaded zone of siliclastic reservoirs. This may not be representative of the reservoir as a whole[6].

* Petroleum acids in the reservoir crude have a great affinity to alkaline solution, i.e. KOH, bringing about an in situ reaction to produce surfactants. Wettability and residual oil saturation from core analysis will also be affected by the surfactants from the reaction.

Thus, the reliability of log analysis calculations are reduced by the influence of KOH solutions on Rw, Rt and porosity.

CONCLUSION

We have demonstrated a new relationship for the interpretation of spontaneous potential logs when potassium hydroxide drilling muds are used. We also confirmed the validity of the Arps Formula for resistivity versus temperature.

Further log responses when KOH lignosulfonate muds are used have also been noted. The influence of these on log interpretation methods is potentially significant.

References

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5. Schlumberger Log Interpretation Charts, Schlumberger Well Services, 1985.

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Nomenclature

Eb	bi-ionic potential, mV.
Ec	electrochemical potential, mV.
Ej	junction potential, mV.
Em	membrane potential, mV.
K	constant defined in SSP equation.
R1, R2	resistivity, Ohm.m.
Rmf	resistivity of mud filtrate, Ohm.m.
Rmfe	resistivity equivalent of mud filtrate, Ohm.m.
Rw	resistivity of formation water, Ohm.m.
Rwe	resistivity equivalent of formation water, Ohm.m.
SSP	static spontaneous potential, mV.

RESISTIVITY VS TEMPERATURE FOR KOH SOLUTION AT PH = 12.8

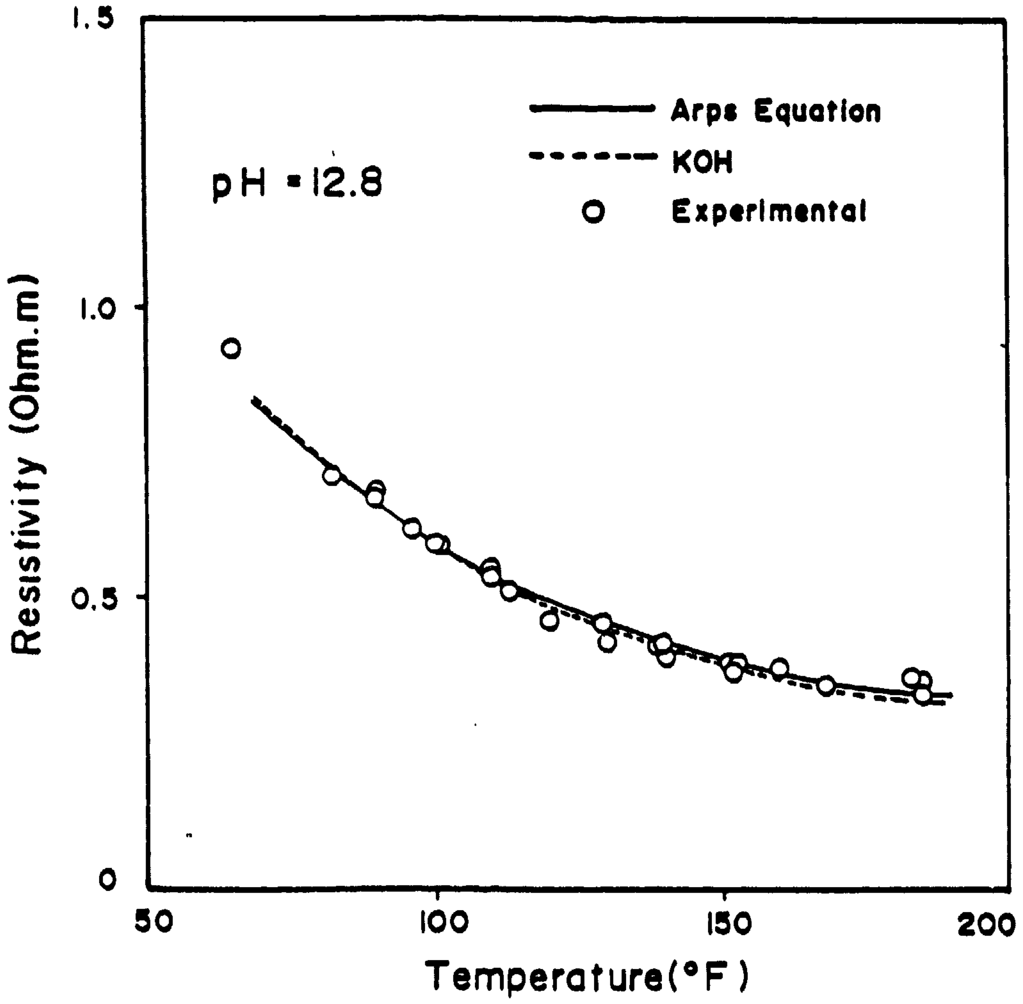


Figure 1

REISTIVITY VS CONCENTRATION AT 68°F
FOR KOH AND NaCl SOLUTIONS

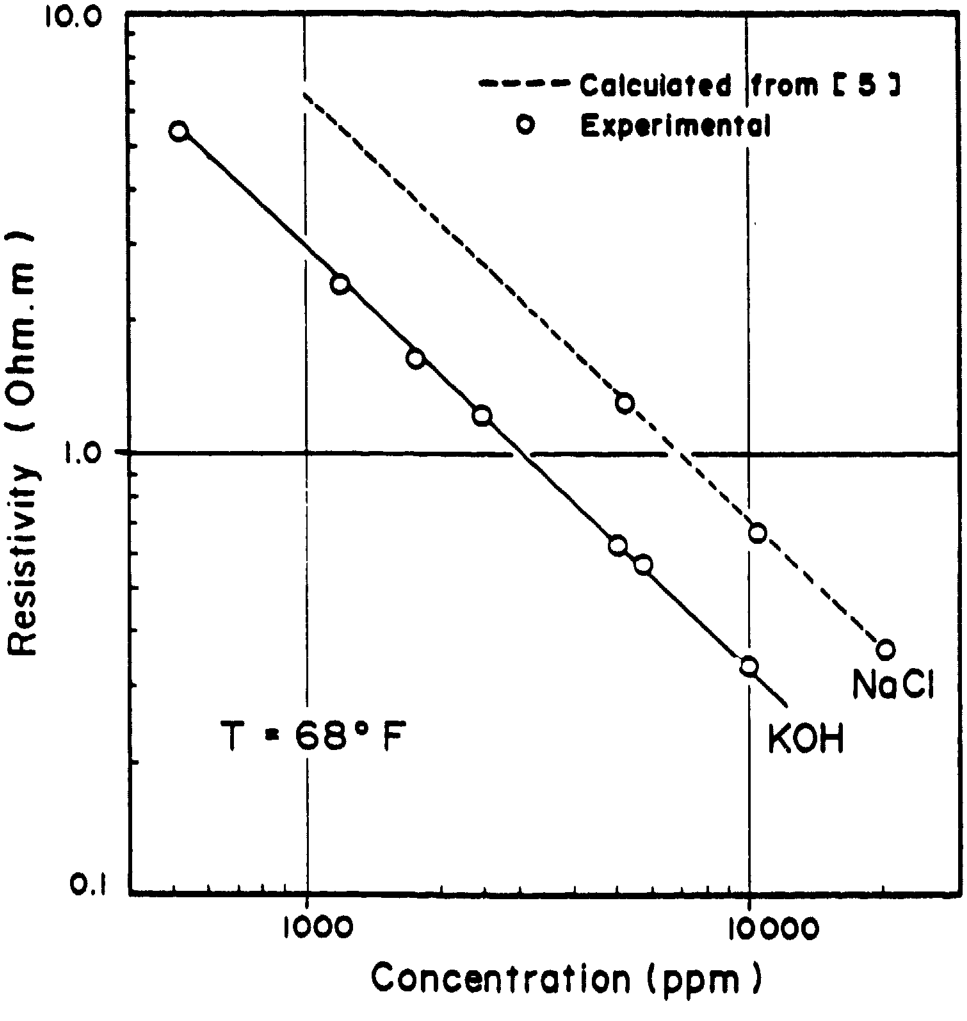
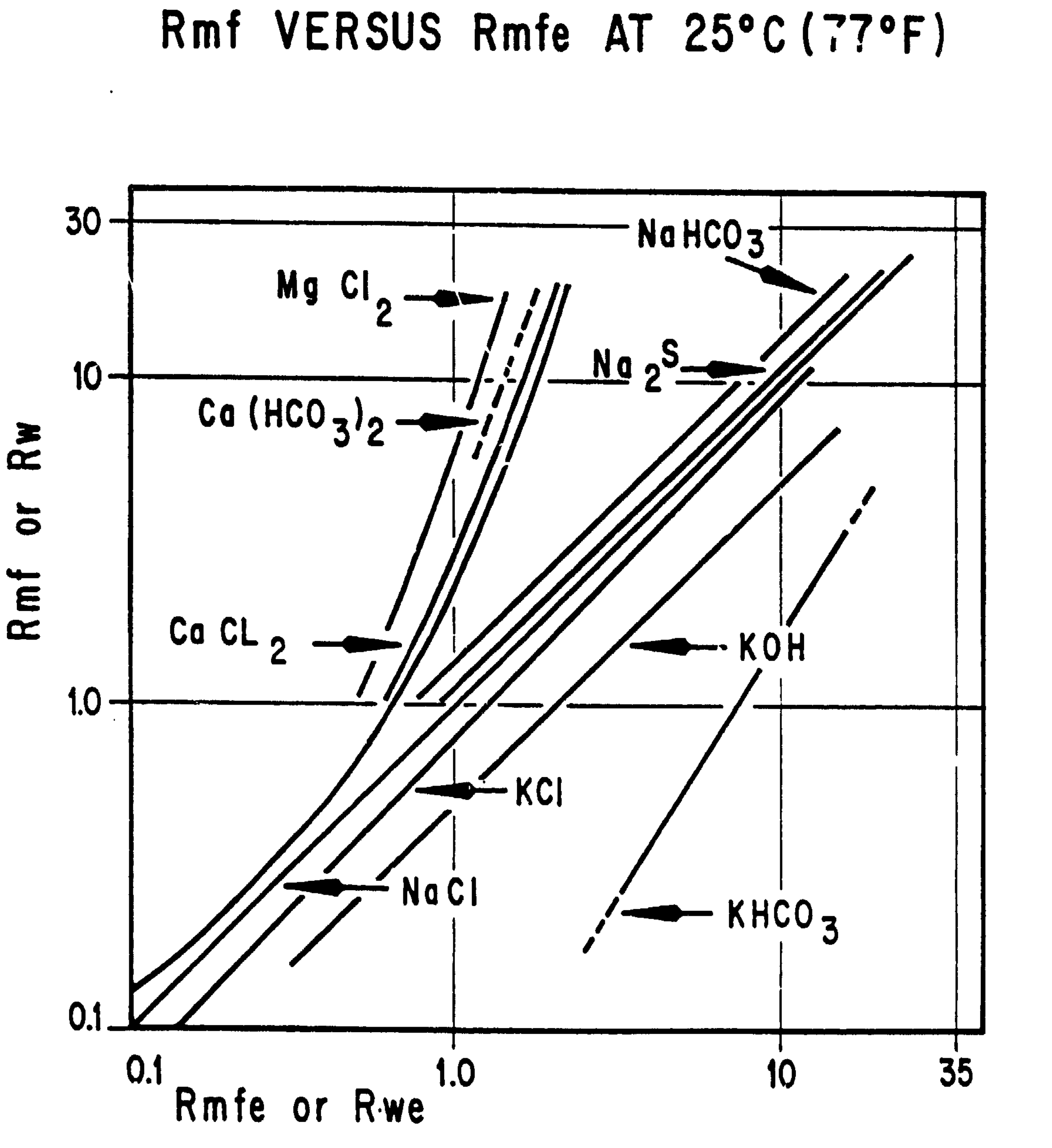


Figure 2



(after Cox and Raymer, 1976)

Figure 3

SP VERSUS Rmfe / Rwe FOR KOH MUDS, CLEAN FORMATIONS.

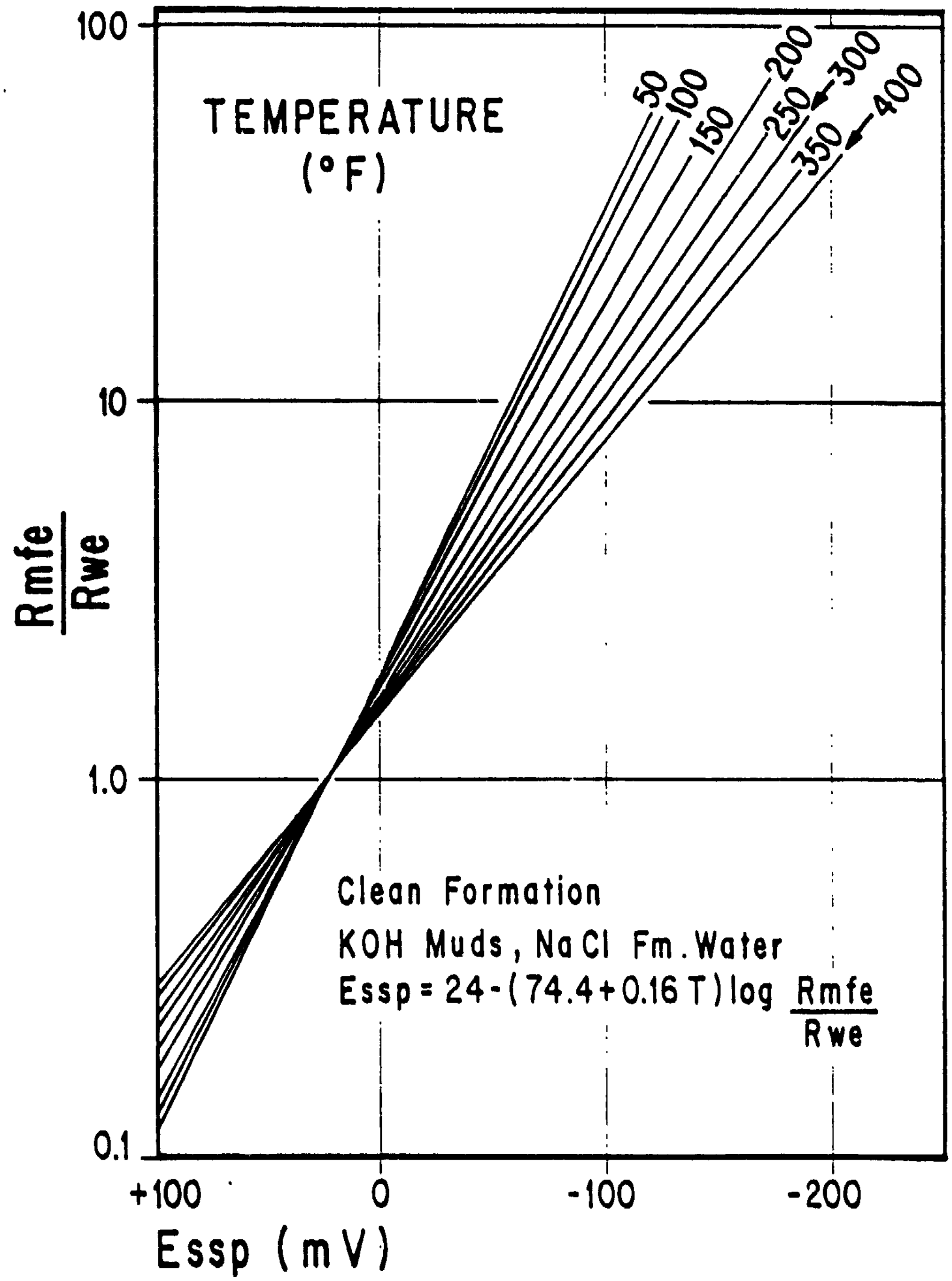


Figure 4

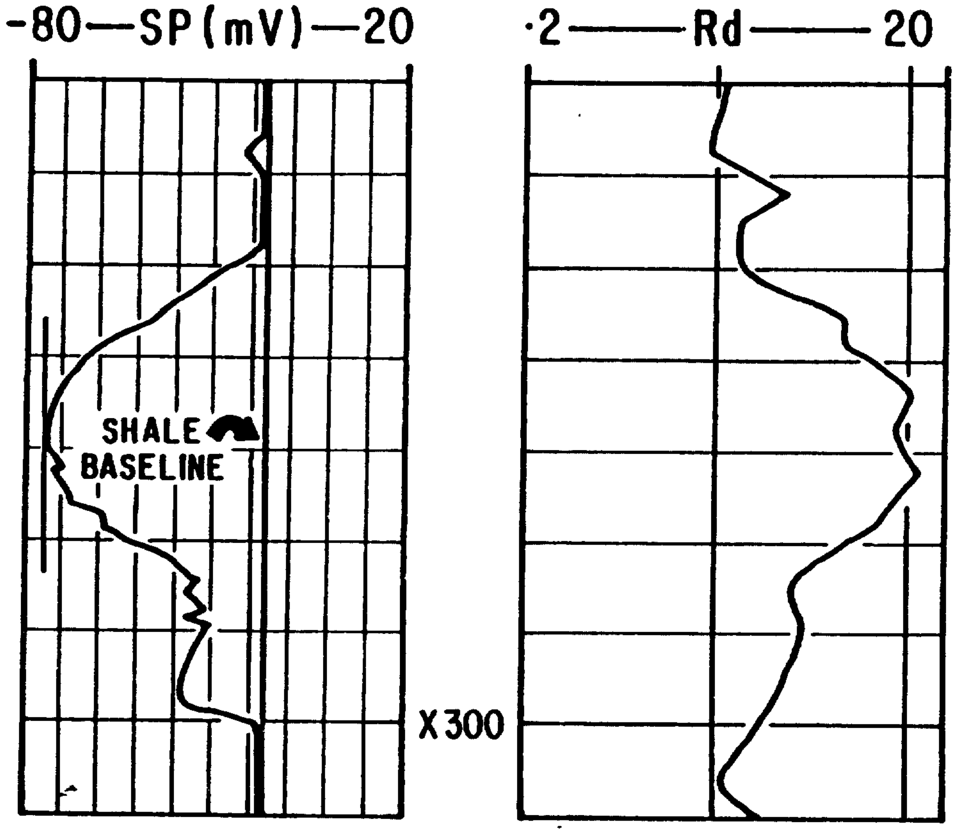
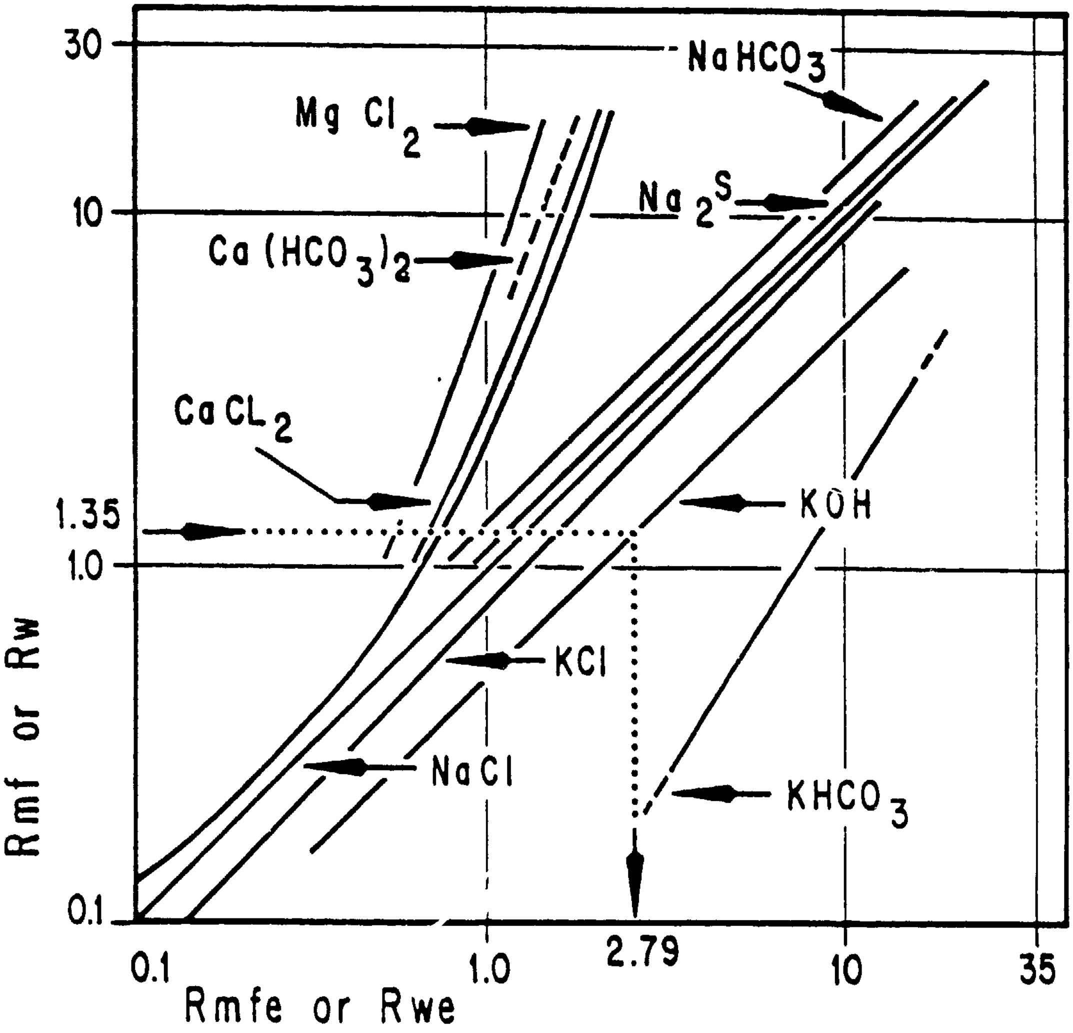


Figure 5

Rmf VERSUS Rmfe AT 25°C (77°F)



(after Cox and Raymer, 1976)

Figure 6

SPE 1614-69

SP VERSUS Rmfe / Rwe FOR KOH MUDS, CLEAN FORMATIONS.

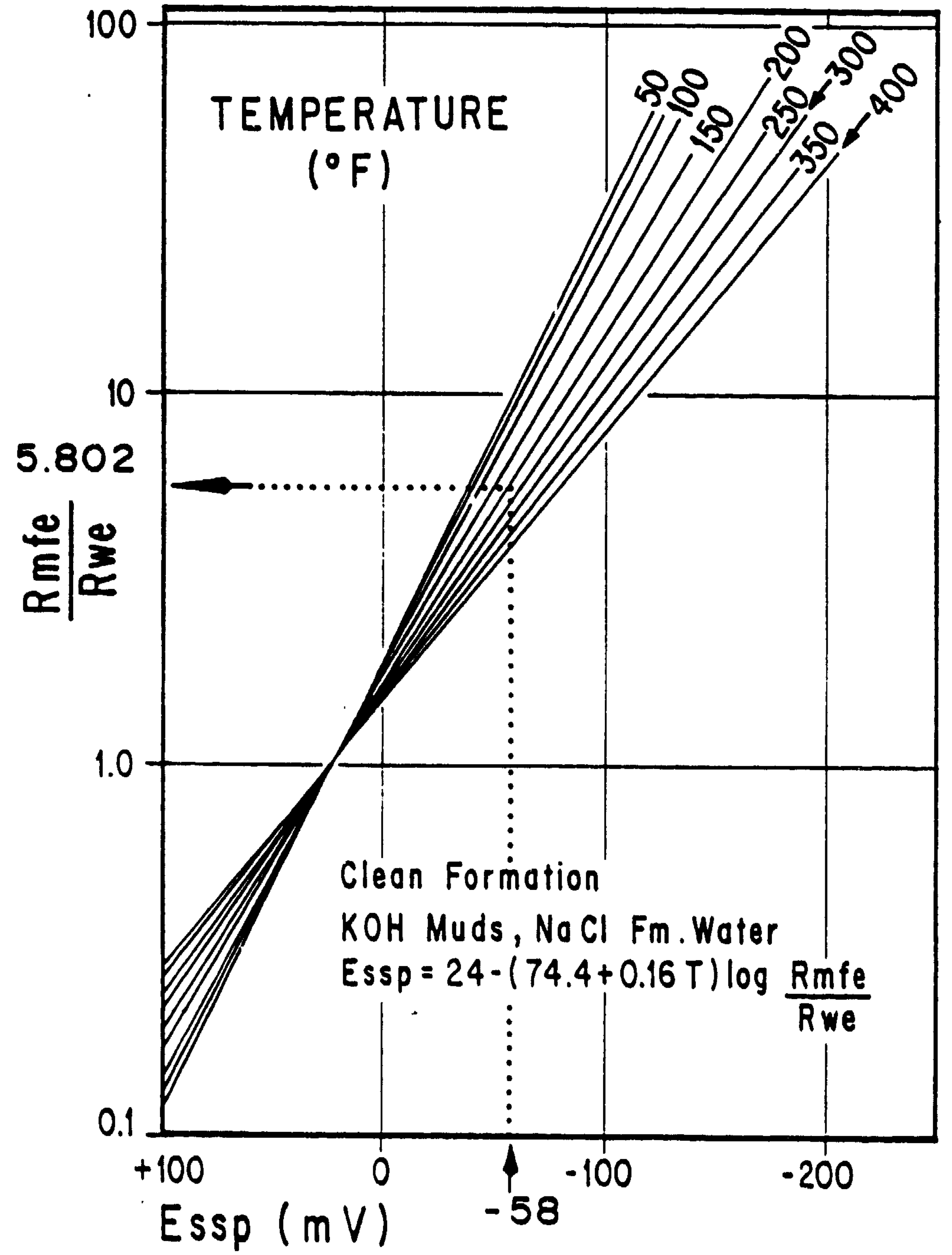


Figure 7