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The Modified Computation Method (MCM) for Determination Water Resistivity (R_w) Using Spontaneous Potential (SP) Log

Alfageh, Z. A.

University of Benghazi, Faculty of Engineering, Department of Petroleum Engineering

E-mail zaid.alfageh@uob.edu.ly

Abstract:

The formation water resistivity (R_w) is the most important rock fluid properties for saturation (water and/or hydrocarbon) and salinity of NaCl estimation, Petrophysical analysis and Formation evaluation in the Petroleum field.*Resistivity is the one of the most difficult formation parameters to measure accurately, because of the complex changes that occur during and after drilling a well and that may still be occurring during logging. Formation water resistivity represents the resistivity value of the connate water (R_w) in a formation of interest. Connate water or interstitial water is the water uncontaminated by drilling mud that saturates the porous formation rock. It is resistivity can be determined by Spontaneous Potential (SP) Log, as one of many other methods. This paper presents a comparative of the Modified Computation Method (MCM) and charts means of water resistivity determination by the SP Log.*

Keywords **—Resistivity (R_w),Formation evaluation,** ***Drilling, Connate water, Modified Computation Method (MCM).***

I. INTRODUCTION

Petroleum reservoirs are composed of sediments were deposited in Marine, deltaic and other aquatic environments. These sedimentary beds were originally saturated by salt water, which part of it was displaced in the process of diagenesis and oil accumulations, the other remains suspending the hydrocarbons because of their density contrast. That water known as "Connate" or "interstitial" water because it was born with and is stored in the interstices of the sediments [1]**.**

Connate water or interstitial water is the water, uncontaminated by drilling mud that saturates the porous formation rocks [1]. Sedimentary formations are capable of transmitting an electric current only by means of the interstitial and adsorbed water they contain. They would be nonconductive if they were entirely dry. The interstitial or connate watercontaining dissolved salts constitutes an electrolyte capable of conducting current [2].

The resistivity of the reservoir rocks is a function of salinity of formation water, effective porosity, temperature, and quantity of hydrocarbons trapped in the pore space. Relationships among these quantities indicate that the resistivity decreaseswith increasing porosity and a rock contains oil and/or gas will have a higher resistivity than the same rock completely saturated with formation water. At a given salinity, the higher the temperature the lower the resistivity [1].

One of the most important parameters needed to calculate hydrocarbon in place from wire line logs is the resistivity of connate water (R_w) in a formation of interest. The resistivity of this formation water is an important interpretation parameter since it is required for the calculation of the saturation (water and/or hydrocarbon) from the basic resistivity logs.

IIWater Resistivity (R_w) from SP Log.

Since the SP log can be used to distinguish lithology such as shaly from sandy formation. So a good value of formation water resistivity R_w in many cases can easily be determined by the SP Log in clean sand (non-shale) formations. The chemical activities (aw and amf) of the formation water is related to the static SP (SSP) value in a clean formation through the formula:

$$SSP = K\log \ (aw/amf) \qquad (1)$$

Where:

K = constant and varies in direct proportion with temperature especially in NaCl solutions.

$$K = (61 + 0.133BHT);\ ^{o}F (2)$$

BHT = Bottom Hole Temperature.
aw = Chemical activity of water.
amf = Chemical activities of mud filtrate.

For pure NaCl solutions that are not too concentrated, resistivities are inversely proportional to activities.

Therefore,

$$SSP = -K\log \ (R_{mfe}/ R_{we}) \qquad (3)$$

Where:

R_{mfe} = equivalent mud filtrate resistivity.

R_{we} = equivalent water resistivity

After we have been able to relate these resistivities to the SP value for a particular zone (zone of interested), we can determining R_w by computation and by using the charts.

A The Modified Computation Method(MCM)

Identify a zone on the log that is clean, wet and permeable. Pick the maximum value of SP in that zone.

1- Calculate formation temperature T_f at the depth of SP.

$$T_f = (BHT - AMST)\ (F_d/TD) + AMST \ (4)$$

Where;

AMST = Annual Mean Surface Temperature.
F_d = Formation Depth.
TD = Total Depth.
T_f = Formation Temperature.

2- Convert Rmf from surface T to formationtemperature

$$R_{mf} = R_{mfsurf}\ (T_{surf}+6.77) / T_f + 6.77 (5)$$

Where:

$R_{mf} = R_{mf}$ @ formation temperature.
$R_{mfsurf} = R_{mf}$ @ measured temperature.
T_{surf} = Measured temperature of R_{mf}.

3- Find the equivalent formation water resistivity $R_{we}$from the SP, K and $\mathbf{R_{mf}}$.

$$R_{we} = R_{mf} \times 10^{\left(\frac{SP}{K}\right)} \quad (6)$$

Where:

R_{we} = equivalent R_w

4- Convert $R_{we}$to R_w @ formation temperature.

$$R_w=R_{we} + 0.131 \times 10^{A} /11.7 \times R_{we} + 10^{B} \ (7)$$

Where:

$$A = \left(\frac{1}{\log\left(\frac{BHT}{19.9}\right)}\right) - 2$$

$$B = \left(\frac{0.0126}{\log\left(\frac{BHT}{50.3}\right)}\right)$$

B Chart Method

1- To determine T_f for the zone of interest, enter TD (ft or m) and BHT degree (ºF or ºC) on the Estimation formation temperature chart (Figure 1), using the gradient line as indicated, than enter F_d (ft or m) , and read T_f (ºF or ºC).

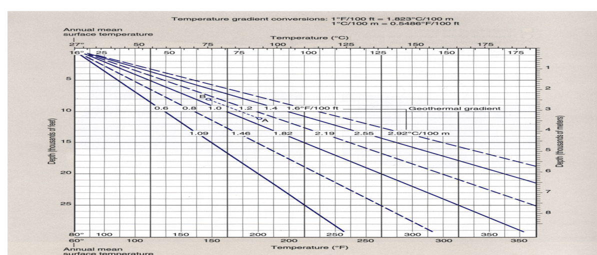

Figure 1 – Estimation formation temperature chart. Schlumberger Chart [3].

2- Convert R_{mf} to R_{mfeq} at T_f using the following Chart (figure 2).

(The mud filtrate resistivity reported on the log heading or calculated at formation temperature is its actual resistivity not its equivalent resistivity) [4].

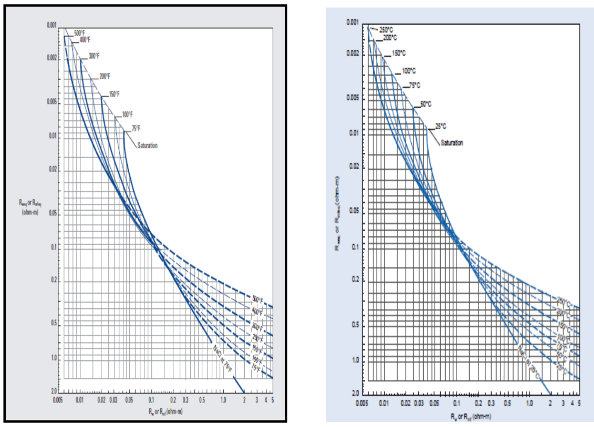

Figure 2 –R_w or R_{mf} vs R_{weq}or (ºF left chart & ºC Right chart), Schlumberger Charts [3].

Procedure:

A- The solid lines are used for predominantly NaCl waters. The dashed lines are approximations for "average" fresh formation waters (for which the effects of salts other than NaCl become significant).

B- The horizntal right line, represent R_{mf} values and the verticle bottom line represent R_{mfeq} values.

C- The horizntal left line, represent R_w values and the verticle top line represent R_{weq} values

3) By using the following chart (Figure 3) find the value R_{weq}.

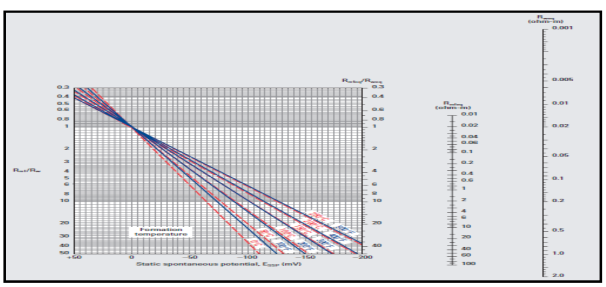

Figure 3 –R_{weq} Determination from E_{SSP} Schlumberger Chart [3]

Procedure:

- Enter the chart with E_{ssp} in millivoltes on x-axis and move upward to intersect the appropiate temperature line. From the intersecation point move horizontally to intersect the right y-axis for R_{mfeq} / R_{weq} From this point, draw a straight line through the equivalent mud filtrate resistivity (R_{mfeq}) point on the R_{mfeq} nomograph to intersect the value of R_{weq} on the far-right nomograph

4) Convert R_{weq} to R_w at formation temperture by using the chart in Figure 2.

5) Finally check against the Modified Computation Method (MCM) and other

III Conclusions

- The SSP value can be obtained from the SPLog only if the bed is thick, clean, porous, permeable, the formation is saline and the drilling mud is not too reactive. If not so, the SP deflection must be corrected to SSP value for; bed thickness, hole diameter, invasion and resistivity contrast [5, 6].

- R_w obtained from the Modified Computation Method (MCM), is quite simillar to that vlue obtained from the Chart Method.

- R_w derived from SP Log will probably be too low in the case of; very low permeability formation, depleted presuure formation, or the use of heavy drilling mud, so other sources of water resistivity data should be explored [7]

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- R_w is one of the most important interpretation parameters in well log analysis, since theknowledge of R_w opens the lock to calculate the water saturation (S_w) from the equation:

$$S_w^n = \frac{FR_w}{R_t}$$

When water saturation (S_w) is known, then hydrocarbon (S_h) in place is derivable by:

$$(S_h) = 1 - S_w.$$

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Nomenclature

AMST	Annual Mean Surface Temperature
ºC	Celsius
F	Formation Factor
ºF	Fahrenheit
F_d	Formation depth
K	SP Constant proportional to temperature
MCM	Modified Computation Method
n	Saturation exponent
R	Resistivity
R_m	Mud Resistivity
R_{mf}	Mud Filtrate Resistivity
R_{mf}	R_{mf} at formation temp.
R_{mfe}	Equivalent Mud Filtrate Resistivity
R_{mfsurf}	R_{mf} at measured temperature
R_w	Water Resistivity
R_{we}	Equivalent Water Resistivity
R_t	True Resistivity
S_h	Hydrocarbons Saturation
S_w	Water Saturation
SP	Spontaneous Potential
SSP	Static Spontaneous Potential
TD	Total Depth
T_f	Formation Temperature
Vs	versuse
Ø	Porosity
Ω-m	ohm meter
%	percentage
@	at

