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AFFECT OF SATURATION EXPONENT AND CEMENTATION FACTOR ON WATER SATURATION IN CARBONATE RESERVOIR "CASE STUDY"

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Abstract

Assessment of rock and fluid properties such as porosity, shale content, and water saturation are very essential for exploration and development of hydrocarbon reservoirs. Archie's parameters (cementation factor "m", tortuosity factor "a" and saturation exponent "n") calculated from a graphical solution, which they are either use the wire line (Porosity "Ø" and deep electrical resistivity "Rd") or core data measurements (formation factor "F or FF" and resistivity index "RI"). However, these sensitive reservoir parameters (m and n) have an affect on saturation percentage, where an increase of m and n values reveal to water saturation content increase. In addition using core measurement instead of Pickett technique to evaluate carbonate reservoir water saturation will illustrate accurateness's of close results to reality.

Keywords: Porosity; Deep electrical formation resistivity; Formation Factor; Resistivity Index.

GENERAL OVERVIEW

Determination of cementation factor (m) and saturation exponent (n) are necessary and used in the Archie's equation, which is changed for the same reservoir type, to compute water saturation content of shale free reservoir. These parameters called Archie's parameters or coefficients. Cementation exponent is highly dependent on the degree and type of cementation in the pore system. Although a value of 2.0 is commonly used, for poorly cemented rocks maybe less than 2.0 and in highly cemented or oolicastic rocks "m" values as high as 3.0 have been observed. While, Saturation exponent value is a function of pore system geometry and formation wettability, commonly used value equal to 2.0. This parameter varies considerably from reservoir to another and may result in over or under estimation of water saturation in many situations. Researchers have shown that the values of the m and n exponents are largely affected by reservoir pressure and temperature conditions, mineralogy, pore throat size distribution, pore geometry, and the wettability condition of the reservoir rock, among other relevant factors [2].

The studied carbonate reservoir rock is oil produced and a complete package wire line and special core analysis were available over 321ˈft feet thickness. Conventional petrophysical analysis presents an average of porosity 20.95 % and 19.39 % for well 1 and 2 as respectively. Two wells (1 and 2) have been chosen to illustrate the comparative and influence of the Archie's parameters on the water saturation (Sw) by using the petrophysical graphical procedure. However, determination techniques of Archie's parameters are relatively well known and validated for sandstone reservoirs. But in case of carbonate rocks, there are considerable variations in texture and pore type, so, Archie's parameters become more sensitive to pores pattern distribution and lithofacies properties (Hamada et al., 2010) [3]. The main objective of this study is to determine Archie's parameters in order to get the very close accurate estimation of water saturation using the above technique.

GRAPHICAL SOLUTION PROCEDURE:

Water saturation of the shalness reservoir rocks is mainly estimated by Archie's Equation (1), which is depend on physical rock properties even measured by wireline or core samples. It is an empirical relationship between rock resistivity (R) and its porosity (Ø). Texture of carbonate rock is different from clastic, which is effect on the behavior of pore geometry (tortuosity) and fluid flow.

$$Sw^n = \frac{axRw}{(\emptyset^m)xRt} \tag{1}$$

Taking logarithms of both side of the Equation (1) and rearranging it gives the following; log Rd = -m log (Ø) + log (a Rw) – n log (Sw).

According to last equation, the Pickett cross-plot was constructed by plotting porosity (Ø) versus deep resistivity (Rd) on log-log paper to estimate the m and n. A line of wet resistivity at 100 % water saturation has fit the plot values have low resistivity. Then slope of this line; represent the (m) value. Figures 1.a and 1.b present these cross – plot of well 1 and 2 respectively. The n values estimated by the same steps except it determine at lower percentage of water saturation (Table 1).

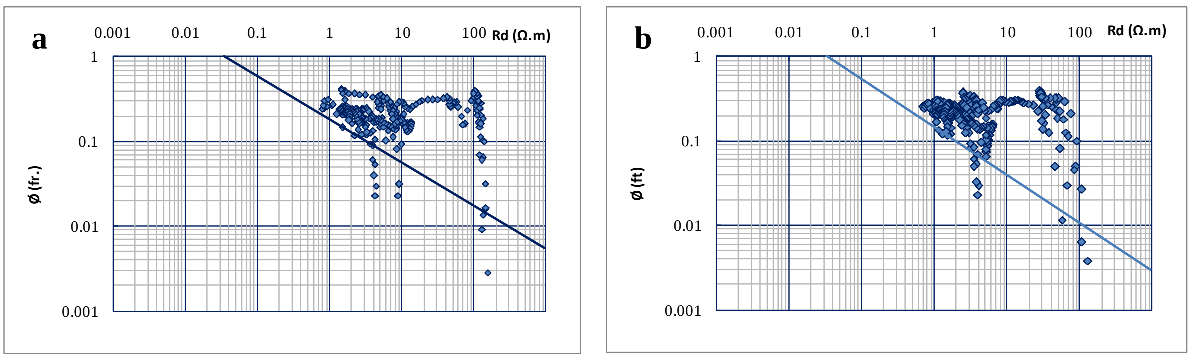

Figure (1.a & 1.b) Pickett cross – plot for wells 1 and 2.

The Archie equation is made up of two equations (2 and 3); the "Resistivity Index" (RI) and the "Formation Resistivity Factor" (F). The RI and F, which can be impacted by many parameters, are defined as:

$$\boldsymbol{RI} = \frac{R_d}{R_o} = \frac{1}{S_w^n} \text{ or log RI = -n log Sw} \tag{2}$$

$$\boldsymbol{F} = \frac{R_o}{R_w} = \frac{a}{\phi^m} \text{ or log F = log a - m log Ø} \tag{3}$$

The plot of log F versus log Ø is used to determine the coefficients "a" and "m" for the core samples (Fig. 2.a and 2.b for well 1 and 2 respectively). The m is determine from the slope of the least square fit straight line of the plotted points, while the a factor is given from the intercept of the line where Ø = 1. The same technique treats the determination of n by plotting log Sw and log RI, and the "n" value is derived as a slope. The values of each coefficient "m, a and n" varies from well to well, for the same studied reservoir rock. Table 1 includes results of the different data (wire line logs or core analysis sample) application. Differences in the pore structure can be one of the factors responsible for the variation observed in these values.

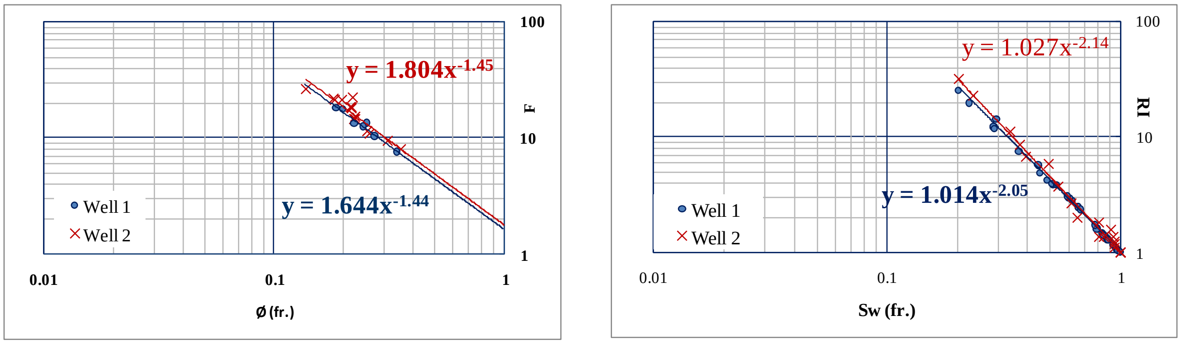

Figure 2.a & 2.b. Ø -F and Sw – RI cross – plot for wells 1 and 2.

Table 1. Graphical solution results by wire line logs and Core sample data.

Well No	Saturation Exponential (n)		Cementation Factor (m)		Tortuosity Factor(a)	
	Pickett Cross-plot	Core measured	Pickett Cross-plot	Core measured	Pickett Cross-plot	Core measured
1	2.69	2.05	1.85	1.44	1.17	1.644
2	2.47	2.14	2	1.45	1.05	1.804

Water saturation estimation

Reserve estimation in early reservoir exploration or recovery stages is depend on stoarge coefficient, which related to saturation percentage evaluated by petrophysic analysis in pay zones of any reservoir. Consequently, the pore space distribution manner is expressed in Archie equation through cementation factor (m) and saturation exponent (n) parameters. The carbonate studied reservoir has various types of vuggy and inter -granular porosities exist. This variety causes the pore spaces distribution and consequently water saturation calculation parameters varied in the reservoir. Therefore, the equation (1) is used to estimation of reservoir water saturation (Sw) and compares performance of the Archie's parameters, with is computed by each different above techniques.

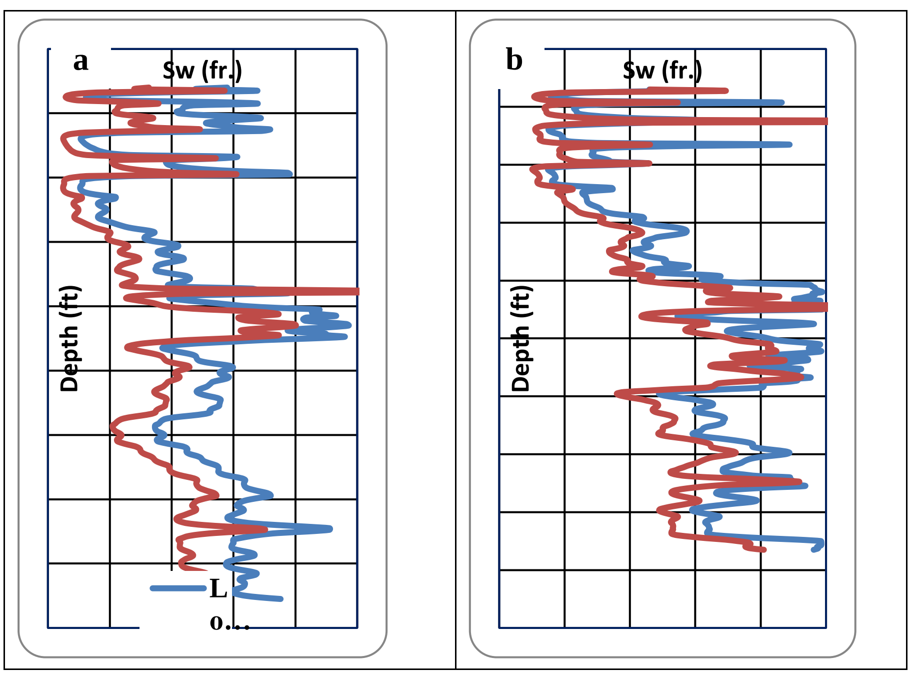

Figure (3.a & 3.b) Comparative of Sw estimation for wells 1 and 2.

Conclusion

Water saturation profiles were generated using the different Archie parameters determined by the two techniques and different data. Clearly, Pickett cross plot gives high values of m and n values rather than core measured values. Although, tortuosity values are reveal different state. Wireline data is influence by well bore environment. Therefore, lower water saturation evaluation of studied reservoir rock in both different wells is notified, which is illustrated influence of Archie's parameters from core analysis on water saturation estimation. In other words, a sensitivity analysis was performed in order to investigate the influence of cementation factor and saturation exponent varied values on water saturation calculation. The values of m and n exponents measured by core data resulted in a maximum reduction of 15% of water saturation values, in comparison with the values considered from graphical Pickett technique.

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