Water saturation on Albian Carbonates reservoirs - ancient Brazilian oil fields

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Abstract

One of the objectives for petroleum exploration is to perform a good quantification of the *oil in place* for prospects; normally, the process to calculate this hydrocarbon volume is based on the quantification of petrophysics parameters, among others the reservoir water saturation (Sw) represents the main factor to determine hydrocarbon saturation (Sh). On this hand, the classical petrophysics analysis, on any hydrocarbon reservoir, includes the use of two main constants: cementation (m) and tortuosity (a), both of them obtained from plug measures. In the case of most of the ancients oil fields in Albian carbonates in Brazil, the petrophysics from plug data is not available on the full water saturated reservoir, because of this, our propose is to apply CAPE (Core Archie Parameter Estimation) to determine these main factors (a and m) using wire logs, the methodology even allowed determination of water resistivity formation (Rw) on the main reservoir.

The importance to calculate water saturation using the right parameters is that the m factor will add a large error on the final hydrocarbon volume estimated on the reservoir. For this research the Rw was obtained in a reservoir level full saturated by water using Archie (1941) equations, and two log-log graphics were built to obtain the “m” and “a” factors.

As result, it was determine a water formation resistivity in 8 Kppm of NaCl for the main oil producer level (Quissamã Formation), m = 1.6 and a= 0.87. Finally, it is possible to conclude that the value of “m” is higher affected by the pore configuration and its size; and, the “a” value appears to be a logical answer for carbonates reservoir with high porosity, because it is the answer of the electrical current traveling through the interconnected pore system embedded by fluid, this answer is like to siliciclastic environment.

Introduction

The reservoir hydrocarbon saturation (So) represents one of the main values for petrophysical evaluation, and it is the most important value for petroleum economic evaluation because it represents the volume of hydrocarbon in place. The process to calculate the So is very well know when the reservoir rock is a siliciclastic, but in the case of carbonates reservoirs the process is quite different.

There are at least two factors that justify the application of the Core Archie Parameter Estimation (CAPE), the first one is relate to the absence for research of core in the full water saturated Brazilian Albian reservoirs and the second is that the water resistivity (Rw) on the main reservoir was not measured for this kind of target. As consequence an approximation or estimation done from wire-logs will help geocientists to better estimate the volume of hydrocarbon in place contained on Albian Brazilian Reservoirs (carbonates).

In order to calculate the water saturation normally core analyses are developed to determine reservoirs factors like cementation (m) /tortuosity (a) factors and water resistivity (Rw).

Hovewer, there are a lot of ancient oil fields that don´t contain petrophysical cores studies, and it database is formed by basic well logs as well as Gamma Ray, Density, Neutron and Resistivity, and the data related to laboratory-core analysis is not available for researches out of operator companies.

This work is based on the analysis of some carbonates Albian reservoirs on Campos Basin in Brazil. The research is justified because the oil fields data related to the petrophysical factor defined by Archie (1941) to evaluate clean reservoirs (without clay) are absent for Albian reservoirs, and the use of default values like m=2 and a=1 will cause a large error on the fluid saturation volume.

The Albian carbonates reservoirs on Brazilian offshore basins represent a good opportunity for oil re-exploration; on this hand, these values are fundamental to evaluate the economical potential of a specific petroleum prospect, and it represents values that let us a better understanding about the geophysical expression of fluid saturation on carbonates reservoirs .

The technique, that is proposed here, has been applied along carbonates oil fields around the world and the result is particular for each carbonate bank evolution. Nowadays, researchers are working on a unique answer but it is still early to apply a particular result for different carbonates fields. The name of the technique is CAPE (Core Archie Parameter Estimation) and it is based on the back calculation on waters zones for Archie equation.

On well cores were proved that the measured values for the cementation exponent (m) are very variable in complex lithologies, and it is considered this variation very large for carbonates reservoirs. In the case of the tortuosity factor, the value of "a" depends on the connectivity of the pores.

Objective

The main objective is to calculate the values of the cementation factor (m), tortuosity factor (a) and the water reservoir resistivity values (Rw) on Albian Carbonates rocks from ancient oil fields of Campos Basin in Brazil.

These values will less the saturation uncertainty related to carbonates reservoirs along Albian hydrocarbon opportunities.

Database:

It was evaluated 35 wells that contain logs of resistivity (ILD), porosity (Neutron), and density (RHOB) among others. These wells are from two ancient oil fields and statistically represent the Albian carbonate reservoir. distribution

Method

First of all, stratigraphic reservoirs levels for Albian Quisamã Formation were well correlated along the oil fields as show on the figure 1.

The main reservoir level full water saturated, present in most of wells is selected, as the Archie principle the formation factor (F) is the same at the same reservoir, independently of the fluid content inside them, in this way, the F factor was calculated.

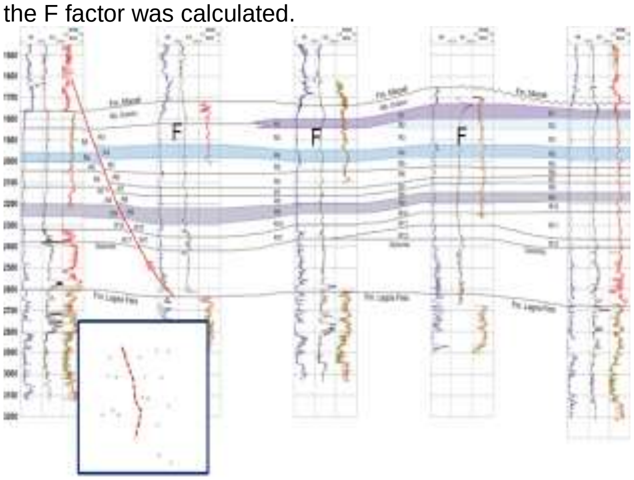

Figure 1.- Well correlation on Quisamã Formation (Albian reservoir for Campos Basin)

The formation factor (F) is defined as:

$$F = Rt/Rw = Rt/Ro \quad (1)$$

Where:
Rt: is the reservoir total resistivity.
Ro: is the resistivity on the zone full water
Rw: is the water reservoir resistivity

On the other hand, F was defined as

$$\ldots\ldots\ F = a/\text{ø}^{m} \quad (2)$$

Where:
a: tortuosity factor
ø: reservoir porosity
m: cementation factor

and the equation of water saturation (Sw) is defined as:

$$Sw^{n} = (a/F^{m}) * (Rw/Rt) \quad (3)$$

For each reservoir and using all the wells, Rt and Ro were calculated based on the mode of its own values on the frequency histogram as show on the figure 2.

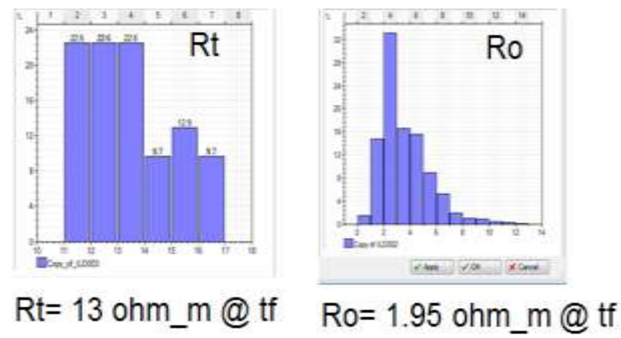

Figure 2.- Frequency histogram showing the mode value for the main reservoir in order to calculate the F factor, for the selected level F= 6.66

The other value to be calculated before the calculus of m and a factors is the Rw, if we consider F on the full water saturated level, it is defined as Rt/Rw. Rt was obtained as the mode value from the resistivity log (ILD) (Figure 3), as result of the mathematical operation Rw is 0.43 ohm_m @136 °F. The calculated reservoir temperature is 136 °F and it considers a local thermic gradient from the well temperature measured on the sea bottom and over the total well´s depth.

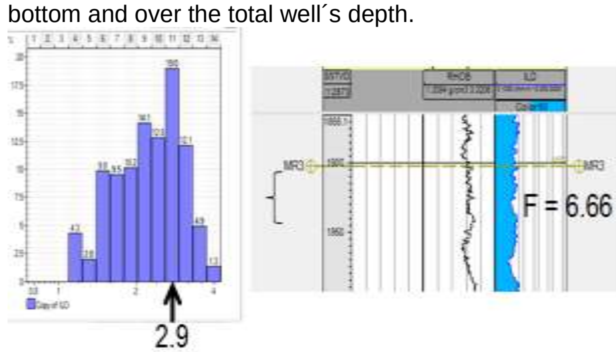

Figure 3.- Frequency histogram showing the mode value for the Rt on the full water saturated, as result Rw = 0.43 ohm_m @136 °F.

In order to get the main parameters m and a, two log-log graphics where build, the first one the log (F) vs log (ø) let the m calculation and it is representing by the line equation :

$$\log (F) = \log (a) - m\log (\phi) \quad (4)$$

On the figure 4 the value on the x axis when the porosity is 1 represents the m value.

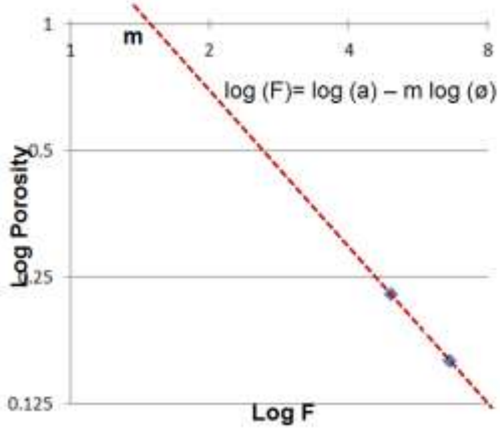

Figure 4.- Log porosity Vs log (F) graphic, an example to find m value using well logs.

The m value represents the dip of the saturation line on the picket plot, it is built by the plot on logarithmic scale of the porosity vs resistivity, and in this case, the line equation (5) of the relationship is:

$$\log (Rt) = aRw - 1.6 \log (\phi) \quad (5)$$

On the graphic of the figure 5, it is show the way to reproduce the saturation line dip, and the curve with 100% of water saturation is put on the region full saturated by water.

The point where the 100% line saturation cuts the axis log (porosity) with value 1, the value of a*Rw is found, Rw was previously calculated, in consequence the a value is know now.

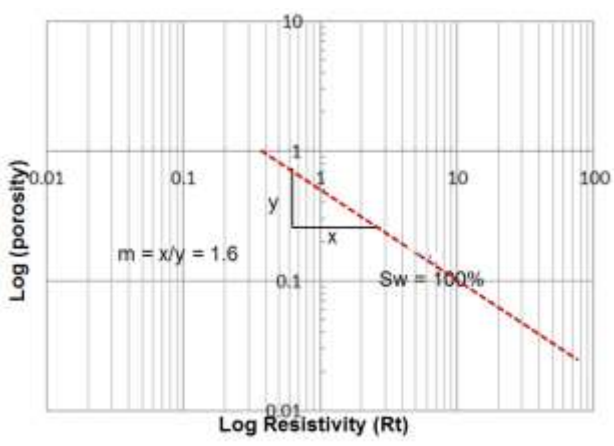

Figure 5.- Picket plot representing log porosity Vs log (Rt) graphic, an example to find a*Rw value using well logs.

Results

F factor was calculated in 6.66, F is a non-dimensional parameter, and Rw for the main reservoir level is considered as 0.43 ohm_m @136 °F that is equivalent to 8 Kppm of NaCl.

When the graphic of log (porosity) Vs Log (F) was interpreted the "m" value was determine as 1.6 (Figure 6). On the another graphic "picket plot" (Figure 7) the value of a multiplied by Rw is 0.4 (Figure 7)

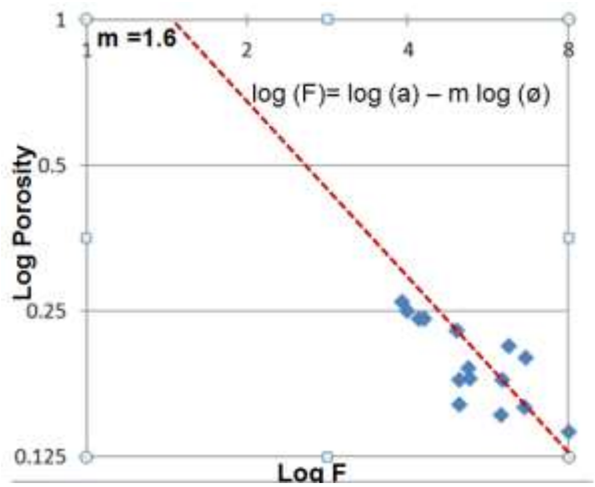

Figure 6.- Log porosity Vs log (F) graphic, observe the m value (1.6) on the x axis.

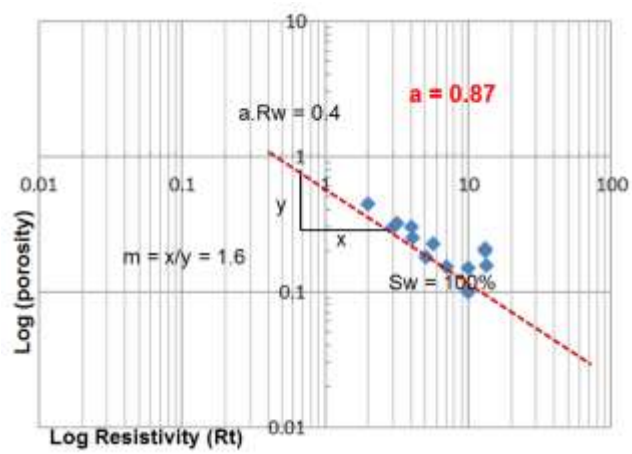

Figure 7.- Picket plot, when the curve of water saturation is 100% a*Rw= 0.4

As result with the value of Rw for the same reservoir along the Albian carbonates reservoir of Campos Basin, the calculated a factor or tortuosity factor is about 0.87.

Conclusions

As result, it was determine a water formation resistivity in 8K ppm of NaCl for the main carbonate oil producer level on Campos Basin. The values of the cementation and tortuosity factors are m = 1.6 and a= 0.87, and when compared with the default factors for carbonates reservoirs m=2 and a=1 it is concluded that the default values are valid for low porosity carbonates.

In this way, as summary of the work the value of m is higher affected by the pore configuration and size, and the a coefficient appears to be a logical answer for carbonates reservoir with high porosity, because it is the answer of the electrical current traveling through the interconnected pore system embedded by fluid.

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Palavras-chave: parâmetro de corte, resistividade, porosidade, volume de argila, saturação de água.
Key-words: cut-off parameter, resistivity, porosity, shale volume, water saturation.