A Preliminar Petrophysical Evaluation of Coquinas on Morro do Chaves Formation (Alagoas, Brazil)

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This paper was prepared for presentation during the 14th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, August 3-6, 2015.

Abstract

Knowledge of petrophysical parameters of rocks is extremely important to evaluate the results of exploratory processes of hydrocarbonates. Historically, the study of siliciclastic rocks has always been the main focus of analysis, however, with the current exploratory possibilities from carbonate systems (here concerned the pre-salt), the study of petrophysical behavior of calcareous rocks started to have more focus.In this work will be carried out some considerations on the analysis of coquinas and its petrophysical behavior, specially the effects of the “n” exponent in the evaluation of Rt considering several levels of saturation, Sw. The main finding of this work is that small variations of Sw (in this case 0.01%) on rocks with 99% saturation resulted in an increase of almost one in the value of "n" for each 0.0005 Sw variation. Thus, if always used the value of n=2 for the determination of other Archie parameters outside of the system of 100% saturation, the data obtained may have a greater divergence of the actual value.

Introduction

According to Lima (2014), in geophysics applied to oil exploration, the interpretation of well data relies on the knowledge of the physical properties of the rocks involved, properties derived from the characteristics of its mineralogical components, internal microstructures and its geological evolution.

Within the group of geological materials that have characteristics of interest of the oil industry the carbonate rocks highlight, as they represent approximately 50% of reserves and 60% of world production of hydrocarbons (CÂMARA, 2013).

The study of lacustrine carbonate rocks, in national terms, has always been neglected, since the main Brazilian reserves were in reservoirs of turbiditic origin, which have several studies since the 70’s. However, with the recent discoveries of potential reservoirs in lacustrine carbonate rocks in the pre-salt, these has been the focus of further research and investment.

The Sergipe-Alagoas Basin, specifically in the Morro do Chaves Formation, presents large strata of coquinas that geologically resemble to pre-salt strata producers.

Thus, the study of samples from outcrop of this formation allows a better petrophysical characterization of this extremely complex system and little studied.

Method

For this work, five plugs were used (obtained from outcrop of Morro do Chaves Formation (Figure 1), which is located in the eastern portion of Mina de São Sebastião - City of São Miguel dos Campos -AL, having approximately 60 meters thick and coquinas domain. The plugs were removed with vertical guidance in a range of one meter distance and named 4.1A (top) to 4.5A (base). Other plugs were removed from this outcrop and are being used in other projects research.

Although the sampling interval can be considered small due to their nature, the plugs have distinct characteristics, which is expected in carbonate rocks, it can be exemplified through permeability values obtained (Table 1):

Table 1: Permeability (K) in mD

Plugs	4.1A	4.2A	4.3A	4.4A	4.5A
K	82,935	21,766	625,859	399,417	36,654

Figure 1 - Outcrop of Morro do Chaves in the eastern portion of Mina de São Sebastião. Extracted from CÂMARA (2013).

The process of cleaning and acquisition of basic petrophysical data was performed through scientific cooperation agreement between the LAGEP and the Brazilian Research and Geoengineering Center (BRGC) / Schlumberger®, following these steps: cleaning, drying and saturation by applying isostatic pressure of

2,000PSI, with a concentration of 50,000 ppm NaCl brine. Density of the brine = 1.0427 g/cc to 21.5°C.

The following measures were taken: porosity and permeability (Helium gas), electrical resistivity and NMR (not yet used in this phase of the research).

Resistivity measurements provided, for each sample, the following parameters:

• Resistivity of the sample (Rt);

• Resistivity "water formation" (in this case, the brine - Rw);
Whereas the porosity obtained by NMR and the obtained above data, it is possible to calculate the Formation Factor (FF) for each sample using the equation:

$$FF = \frac{Rt}{Rw}$$

The Formation Factor can be also written as:

$$FF = \frac{a}{\phi^m}$$

where "a" and "m" (cementation coefficient) are petrophysical constants of extreme importance for the calculation of water saturation.

Associating the FF values and porosity for each sample it is possible to chart$log_{10}\phi vs log_{10}FF$, and through linear fit of a line obtain the function:

$$\log_{10} FF = \log_{10} a - m.\log_{10} \phi$$

Thereby allowingtoobtain the value of "a" and the individual value of "m" for each sample:

$$m_i = \frac{(\log_{10} a - \log_{10} FF_i)}{\log_{10} \phi_i}$$

Where the parameter "a" is obtained by rising 10 the value of the intercept point on the adjust line in the log10 (FF) axis.

With these calculated values is possible to solve the equation of Archie (Nery, 2012) for each sample:

$$S_w^n = \frac{aR_w}{\phi^m R_t}$$

Traditionally, for carbonates, the value n=2 is used as an exponent for the water saturation (Sw).

Results

Through the resistivity measurements and gas porosity were obtained the following data (Table 2).

Table 2: Porosity and Resistivity data

Plugs/ Sample	Phi(%)	Rt (ohm-m)	Rw (ohm-m)	FF
4.1A	13,6	6,750	0,1708	39,520
4.2A	14,1	6,190	0,1708	36,240
4.3A	15,7	4,830	0,1708	28,300
4.4A	18,1	4,910	0,1708	28,770
4.5A	11,8	9,620	0,1708	56,320

Graphically (Figure2):

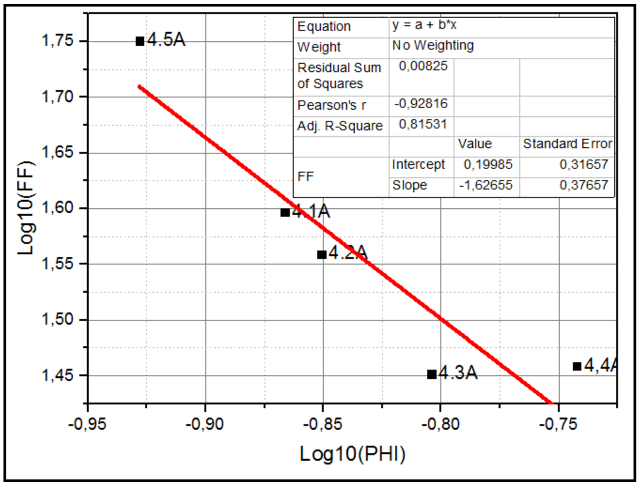

Figure2–Chart of Porosity vs Formation Factor, with linear fit.

Note that the sample 4.4A differs in behavior from the other, thus, it will be disregarded for achievement of the adjustment. As all samples are of the same lithology, the value of "a" obtained is used for this. The new setting, disregarding the 4.4A is:

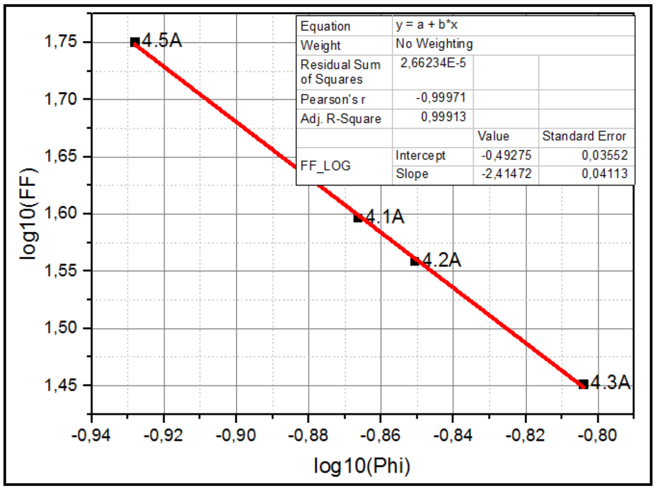

Figure 3 – Chart of Porosity vs Formation Factor, with linear fitdisregarding the 4.4A sample.

With this adjustment it is obtained for the "a" parameter value of 0.320. Calculating m for each sample (Table 3):

Table3: Values for "m"

	4.1A	4.2A	4.3A	4.4A	4.5A
m	2,4085	2,4086	2,4149	2,6255	2,4142

Solving the Archie equation with the parameters obtained it is possible to obtain water saturation for each sample considering n=2 (Table 4):

Table 4: Values for WaterSaturation with n=2

	4.1A	4.2A	4.3A	4.4A	4.5A
Sw	99,449	99,442	99,484	99,485	99,440

Table 4 shows that for all samples saturation is close to 100%. The resistivities values were experimentally obtained, one can determine what the effect of varying the parameter “n” to “m, a, Sw, Rt and Rw” fixed, and checking whether the value traditionally used for n=2 for carbonate rocks will be valid for the coquinas concerned. To which was calculated the value of "n" for each sample, for a variation of the saturation Sw going from 99.3% to 99.5% thus covering the whole range Sw previously obtained (Figure 5).

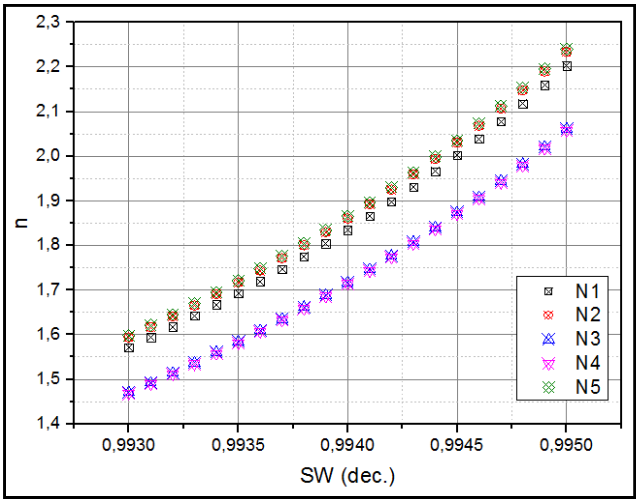

Figure5–Chart of “n”for small variations of Sw in decimal values.

The result shown in figure 5 is important since it shows that for very small variations in saturation, the resistivity value remains constant for a range of different values of the parameter "n". The saturation values were varied in a range of only 0.01%, which resulted in range "n" ranging from 1.4 to 2.3. This result indicates that further investigation for this parameter must be made, since for lower saturations Rt variation can occur, which lead to erroneous information on water saturation in the formation. Below is an analysis to 4.1A plug (Figure 6):

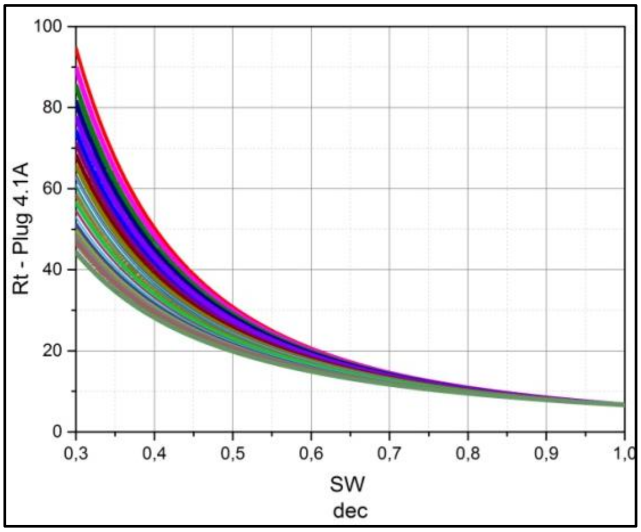

Figure 6: Possible Rt values for each "n" calculated according to the water saturation of the plug 4.1A.

It is possible to observe in the above example that as the value of n used to lower saturations, the resistivity will have a large variation, resulting in erroneous predictions for Sw and consequently to So.

Conclusions

The main finding of this work is that small variations of Sw (in this case 0.01%) on rocks with 99% saturation resulted in an increase of almost one in the value of "n"for each 0.0005 Sw variation. Thus, if always used the value of n=2 for the determination of other Archie parameters outside of the system of 100% saturation, the data obtained may have a greater divergence of the actual value.

An example of this occurs in cases where it is not possible to maintain the sample over long periods of saturation or in cases of well logging acquisitions, where it is not possible to ensure that the system is with high water saturation.

As known, the "n" is a rock parameter which is independent of saturation, however, in experimental processes where it is considered that the sample was completely saturated, which may not match reality if the system has structures such as micro pores. Thus, analysis of the saturation and of porosity distribution in the sample can be performed by other analytic techniques such as NMR, and microtomography (these data will still be obtained) in order to better evaluate the characteristics of the sample and consequently obtain "n" and other parameters more accurately.

Acknowledgments

We would like to thank: to the PRH-18 ANP by doctoral fellowship; to Prof. Leonardo Borghi and to Prof. Patrick Corbett, for providing the plugs to LAGEP/UFRJ for this research; to BG Group for the financial support for the acquisition of plugs; to the BRGC/Schlumberger by petrophysical measurements; to CIMPOR Cimentos do BrasilLtda (CCB) for providing access to the outcrop; and, to the members of the LAGEP and LAGESED team that aid at various stages in this work.

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