Research Article

Petrophysical Characteristics of Arenito Namorado - Campos Basin: The Use of Laboratory Data

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Citation: Costa LP, Bueno GS, da Silva JW (2018) Petrophysical Characteristics of Arenito Namorado - Campos Basin: The Use of Laboratory Data. Arch Pet Environ Biotechnol: APEB-142. DOI: 10.29011/ 2574-7614.100042

Abstract

In reservoir characterization, due to information-acquisition's high costs, frequently only indirect measurements of the subsurface properties such as seismic reflection data is available. In this work it is showed how data acquisition from practical analyses can help to understand the reservoir behavior. We used data disposed online by Petrobras S.A., from 3-NA-01-RJS, 3-NA-02-RJS and 3-NA-04-RJS wells, sampled in 1982. Therefore, it was showed that the compressibility is the most unpredictable of the Petrophysical properties, and must be taken serious when understanding uncertainties involved in reservoir modeling, which is an essential tool to support decisions in the petroleum industry. Porosity and permeability can be positive related, and they have not shown good correlations to compressibility or deep.

Introduction

The oil field of Namorado was discovered in 1975, being one of the greatest exploratory plays of the Campos Basin. This is located in the central-north region of the basin, approximately 80 km from the Rio de Janeiro coast (Figure 1) [1,2]. Namorado oil field is called by the ANP as "School Field" for having a high knowledge degree of its geology and petro physics. Its oil reservoir, characterized by excellent porosity and permeability, corresponds to the beginning of coastal explorations in the country [3].

Figure 1: Satellite image with location of Campos Basin / Namorado Oil Field.

The main reservoir of this oil field, Namorado Sandstone, is composed of turbidity arcosean sandstones, correlated to the Outeiro Formation of the Macaé Group, within the time interval of the Upper / Cenomanian Albian in the Campos Basin. It is considered that the sandstone was formed during the marine transgressive mega sequence [4,5].

Due to its high economic value and long exploration time many Petrophysical analysis were carried out, since properties such as porosity, permeability and compressibility are essential in the characterization of the reservoir and, consequently, these data are needed to a better estimation of the actual production of oil and gas.

Among these properties, the porosity is related to the ability of a rock to store fluids and it is defined as the relationship between the volume of cavities and the total volume of the rock [6]. In this study we focus on the sandstone porosity, which may be due to the remaining empty space after the initial porosity was reduced by the cementation, known as intergranular. Normal porosity values for sandstones are between 10 to 20%, however their actual porosity may be much higher due to fractures [7,8].

The permeability is considered to be the ability of the porous media to conduct fluids. For the purpose of the study, it was considered only one fluid saturating the rock - absolute permeability. According to Winter et al. (2007) [9] the average permeability of the Namorado sandstone is of 400 mD, being able to reach values of 1 D.

Compressibility is defined as the property that a rock has to reduce its volume when subjected to a certain compression (pressure). The relation between this fractional variation of the pore volume and the pressure variation is called the "effective compressibility of formation", and it can play an important role during a certain stage in the productive life of an oil reservoir [10,11].

Several efforts are being put in place on researches about the interactions between rock and fluids and also on the physical laws that describe the fluid behavior in porous media, in order to optimize the production of hydrocarbons in an economic and effective way [12]. This work has as main goal to use the mentioned definitions for a better interpretation of the Petrophysical characteristics of the Namorado oil field, through testimony analysis.

Methodology

For the interpretation of the results that will be show, data collected and arranged online by Petrobras were used. The well analyzed were 3-NA-01-RJS, 3-NA-02-RJS and 3-NA-04-RJS, sampled in 1982. As reported by Petrobras, ten cleaned and dried on-inch in diameter plug-sized samples ranging in depth from 30005.20 meters to 3092.29 meters, were submitted to analyze. The samples were dried in a vacuum oven at the temperature of 180° C and permeabilities to air and Boyle's law porosities were determined using helium as the gaseous medium. The samples were then mounted in heat shrinkable tubing.

The core plugs were then evacuated and saturated with a standard brine containing 30,000 ppm sodium chloride. External and internal pressures were equivalent to the maximum effective overburden pressure. A known specific volume of brine was withdrawn from the sample and the internal pressure had stabilized at less than 500 psi. The pore volume-pressure data gathered were used to calculate the compressibilities reported.

It should be notes that the compressibility values of samples from well 3-NA-2-RJS are considerably higher than the values exhibited by samples from the other 2 wells. In addition, the values for half the samples indicate matrix failures from the beginning stages of testing; and the other half exhibit apparent failures at pressures exceeding 4000, 5000 and 8000 psi.

Results and Discussion

The results presented in (Table 1) show the properties results such as porosity, permeability and compressibility as we increase the depth. Due to laboratory problems during compressibility measurement of the sample NA-02 4V, its value was removed in the calculation of the means obtained in this work.

Well	Sample	Deep (m)	Pressure (psi)	φ (%)	K ar (mD)	Compressibility (10^{-6} psi)
NA-01	1V	3005.20	6010.40	31.20	253	3.2104
NA-01	2H	3011.80	6023.60	31.40	257	3.9189
NA-01	3H	3014.00	6028.00	28.30	147	2.0420
NA-01	3V	3014.00	6028.00	31.90	226	2.7140
NA-02	4V	3041.48	6082.96	34.50	880	29.1583
NA-02	5H	3047.90	6095.80	31.30	272	5.7766
NA-02	6V	3048.68	6097.36	32.10	185	3.4292

NA-04	7H	3087.80	6175.60	35.80	631	4.0824
NA-04	8H	3092.29	6184.58	30.00	289	0.9815
NA-04	8V	3092.29	6184.58	29.60	205	4.9554

Table 1: Petrophysical description of the samples studied - Namorado Field.

The porosity values ranged from 28.30% to 35.80%, with an average of 31.29%. The permeability ranged from 147 mD to 631 mD, with a mean of 273.89 mD. It is also noted that the highest values of permeability and porosity are found in the same sample, 7H, and that the well NA-04 and NA-02 behaved in a similar manner, presenting the best (highest) values in these properties. Well NA-01 showed below-average permeability values, even when porosity increased. Nevertheless, a correlation coefficient (r^2) of 0.7093 was calculated, thus confirming the directly proportional relationship between the two properties (Figure 2). The mean permeability values are below those cited in the literature, which is 400 mD [9]. However, the average porosity is higher than expected for this sandstone, 26% [13,14], and for this type of rock, which is 10 to 20% [7,15].

Figure 2: Porosity versus permeability for the samples presented, Namorado Oil Field.

The estimated compressibility is, in averaged, 3.46×10^{-6} psi, and can reach up to 5.77×10^{-6} psi. No direct or inverse relationship was found between the compressibility and the two other properties discussed. Some variation in H- horizontal - and V- vertical - compressibility can be notice in sample 8, and in this case, compressibility can be inverse related to permeability. However, in sample 3H and 3V the opposite happened and the higher compressibility tends to help increasing permeability.

These results showed how anisotropic a reservoir can be, and changings in its properties are dependent on the axis took in consideration. Also, it is important to notice the increase in compressibility may be good or bad for the reservoir. Compressibility must be taken serious as the oil field exploration starts and during its life time. The depletion of oil reservoirs causes significant effects on its surroundings [16], and compressibility can the used to monitor the well integrity under the geomechanical perspective.

Conclusion

As it was expected, it is possible to find good correlation between porosity and permeability, but the uncertain rests in the compressibility. The problem of obtaining a high quality average to be used remains a challenge. Core analysis is fraught with sources of errors that can also alter the rock properties. Core analysis provides the only direct and quantitative measurement of "intact" oil and gas reservoir properties mostly because unrepresentative

test samples or test conditions. Even though, this study can be used as a way to elicited the issues concerning laboratory quantification of well properties and their relations.

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