Seismic Characterization of Macaé Group in Bonito Field Campos Basin – RJ

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ABSTRACT

A real vision of mature hydrocarbons oil fields will be useful on the comparison and re-evaluation of geophysical and geological data. The definition of the geological characteristics from seismic data represents an important step on the developing of oil exploration research, considering the worldwide exploration evolution. In this context, this paper provide a Seismic Attribute Evaluation along Bonito Oil Field-RJ, through the use of conventional workflow for hydrocarbons exploration: well data analysis and correlation to support on the geological features and seismic interpretation, enabling the application of Seismic Attributes above the interval of interest, Quissãma Formation, in this case, it was search for anomalies on Seismic Attributes related to rock physical properties (Porosity, Resistivity).

As result, the RMS Amplitude and Average Energy Attributes had a best response among other applied attributes, showing the geometrical distribution of anomalies related to the principal reservoir.

INTRODUCTION

Nowadays, it is difficult to recognize the effective reservoir distribution on carbonates rocks; in this sense, a research oriented to seismic characterization of the main reservoir properties will be important to better understand the geometrical distribution of the reservoir facies related to oil production.

The seismic characterization, developed here, is based on seismic and rock attributes interpretation with the aim of link geophysical with geological facies in Bonito oil field.

The Bonito oil field is located on the Southern of Campos Basin; it is one of the producer fields in the oil trend of Campos Basin (Figure 1). Along the mentioned trend, the Badejo, Pampo, Linguado, Enchova, Bicudo and Bonito oil fields are recognized; the first four mentioned are productors from Lagoa Feia Group (Early Barremian to Late Aptian ages), the reservoir is formed by carbonates interbedded with shale, siltite and sandstone (Figure 2). The principal oil reservoir was defined as a high-energy bivalve grainstones (Coqueiros Formation). (Guardado L. R,Spadini A. R, Brandao J. S. L, Mello M. R,2000). Bicudo, Linguado and Bonito oil fields are produtors at Macaé Group, this stratigraphyc level respresents an Albian marine megassequence, composed by shallow water carbonates mudstones and malrs.The Macaé Group was divided into two levels (Baumgarten, 1986): “Lower Macaé”(Quissãma Formation),reservoir level, defined by calcarenite and calcisilte distributed in diferents facies, the principal reservoir is composed by packstones oolitic facies; and, the ‘’Upper Macaé’’(Outeiro Formation) composed by calcilutite and mars and represents the seal of the petroleum system recognized as Lagoa Feia – Macaé (!).

The oil production of Bonito field comes from calcarenites of the “Lower Macaé” Quissamã Fm. and sandstones of Carapebus Formation (Campos Group). In this context, the objective of this research is to develop a seismic attribute evaluation of the Macaé Group providing the understanding of the structural and stratigraphic controls of the reservoir facies distribution. This paper establishes the relationship between the physical properties of the rocks and the seismic response on carbonate layers.

This research has a relevant importance since the current exploratory context focus on carbonates rocks, and the lack of work aiming the geophysical characterization of carbonates.

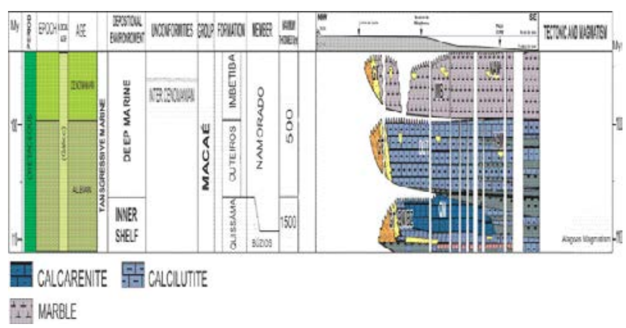

Figure 1.Strathigraphy chart of Macaé Group (Modified from winter, 2004)

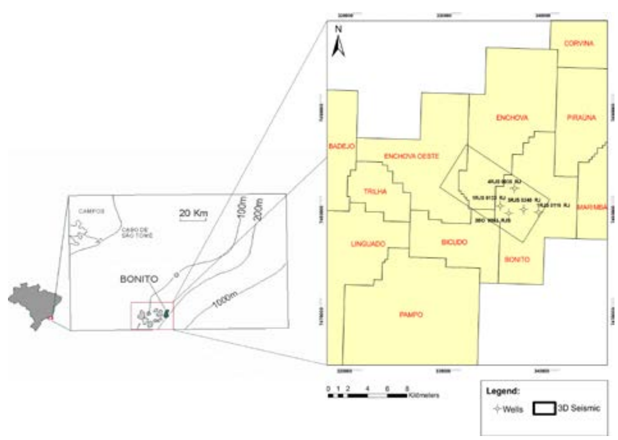

Figure 2- Location map with seismic data and wells.

METHOD

Data Base:
This paper was based on a 3D seismic cube of 50Km^2 and 5 Wells with the four basic logs (GR- Gamma Ray, ILD- Resistivity, DT - Sonic and RHOB porosity). The Data was provided by BDEP (Production Exploration Database), division of ANP (National Agency of Petroleum).

The methodology is summarized on the next workflow:

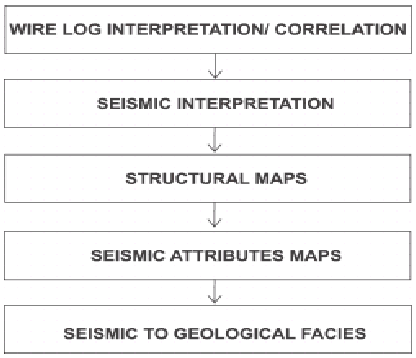

Figure 3- Methodology Workflow

Log Interpretation and well correlation: this phase is based on a lithological and stratigraphy interpretation using wire logs as: Gamma Ray, Resistivity, Sonic Profile, and Density logs in order to define the main stratigraphic tops that configure the reservoir (Macaé Fm., Outeiro Fm., Quissãma Fm, and Lagoa Feia Group), It is important to mentioned that the top of the Macae Group is marked by a boot shape on the Resistivity log.

The main reservoir is defined as the interval between Top Quissãma and base of the R2 stratigraphic level. Three more stratigraphic levels were also interpreted (Outeiros. Fm, R1, R3) and correlated between the 5 wells available for the study, as show in the figure 4.

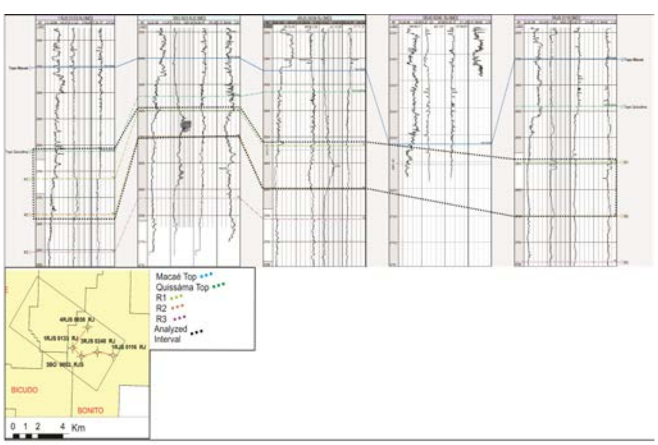

Figure 4- Well correlation for the main stratigraphic levels identified on Macaé Fm.

Seismic Interpretation:

The Outeiro Top corresponding to Top Macaé, below them the Quissãma Top and R2 reservoir levels were interpreted on the seismic volume; the well information was calibrated on time domain through the pseudo check shot and the synthetic seismogram, after this phase the main reflectors were picking.

Seismic Calibration: this step was based on a pseudo-check shot table resulting in the graph of the figure 5, obtained from the sonic log. For the stratigraphic levels without sonic record, it was applied the replacement velocity of 2300 m/s. The pseudo check shot table gives the deep and the corresponding two way time (TWT), enabling to position the stratigraphic layers (depth) on the seismic profile (TWT).

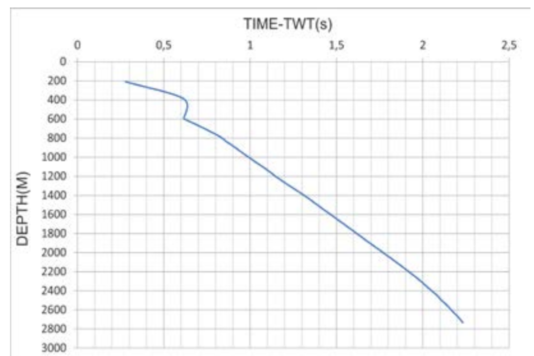

Figure 5 Time/ Depth graphic, from pseudo checkshot table.

Seismic Interpretation: The sea bottom reflector was interpreted to control the water layer geometry. In this sense, the Oligocene horizon was interpreted because it gives an idea about the geometry between the Neogene and Mesozoic reflectors. The Macaé Fm. and Lagoa Feia Group configuring the pale-geometry of the carbonates sequences observed along Bonito field (Figure 6). Finally the top of Macaé Group (Outeiro Formation) was interpreted based on wire log calibration as well as the main reservoir top (Quissamã Fm.).

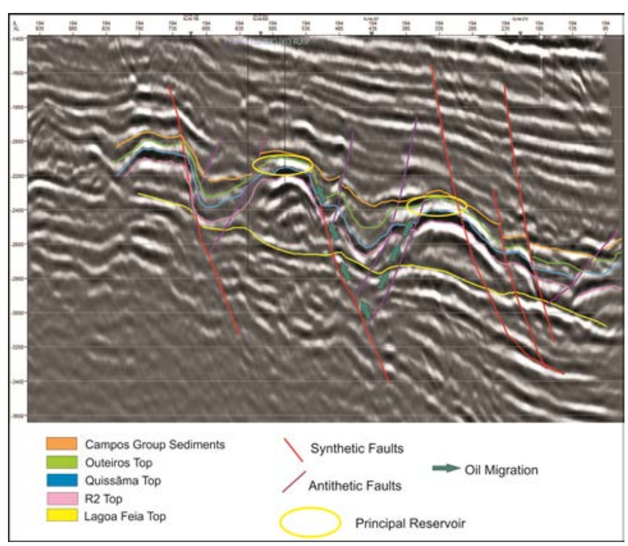

Figure 6 - Interpreted Seismic Session with a schematic model of oil migration.

Contour Structural Maps: when the seismic interpretation was completed the contour structural maps for each stratigraphic level were generated.

The interpolation applied method was Ordinary Kriging, this method is based on the variance of the data with the distance. In another words, the value at an unknown point should be the average of the known neighbor's values, weighted by the neighbors distance to the unknown point. The weight of the ''neighbors values'' is calculated from a linear system that considers the model variogram (function which describes de relation between the values and the distance of points). The model variogram was obtained using the Gaussian model. Once the model variogram is constructed, it is used to compute the weights used in kriging.

Seismic Attributes Maps:

The seismic waveform changes as it encounters geologic interfaces, these changes are function of subsurface rock properties, in conclusion, the understanding the geologic modified waveforms provide qualitative inferences about the variability of geological/reservoir zones. The seismic attributes constitutes a way to analyze the variation of waveform, it is based on algorithms applied to wave complex trace derived from original seismic signal.

On this work were applied some attributes the majority showed a good contrast as summarized on table above:

Seismic Attribute	No Contrast	Low Contrast	High Contrast
Rms Amplitude			X
Average energy			X
Average magnitude			X
Average Negative Amplitude			X
Geometric mean	X		
Harmonic Mean			X
Interval average - arithmetic			X
Average peak value		X	
Minimum Amplitude		X	X
Median		X	

The qualitative selected seismic attributes for the main reservoir were correlated with rock attributes (petrophysical properties) and crossplots were performed (porosity vs attribute, resistivity vs attribute, among others).

RESULTS

As observed on the figure 7, Bonito oil field is formed by two apparent structural highs, maybe configured by a mix system of structural and stratigraphic traps, demined by the paleo-geometry of the carbonate bank. The analysis of time structural map (contour) shows three arched structures delimited mostly by normal faults. The structural highs probably control the hydrocarbons occurrences according the integrate analysis of well logs.

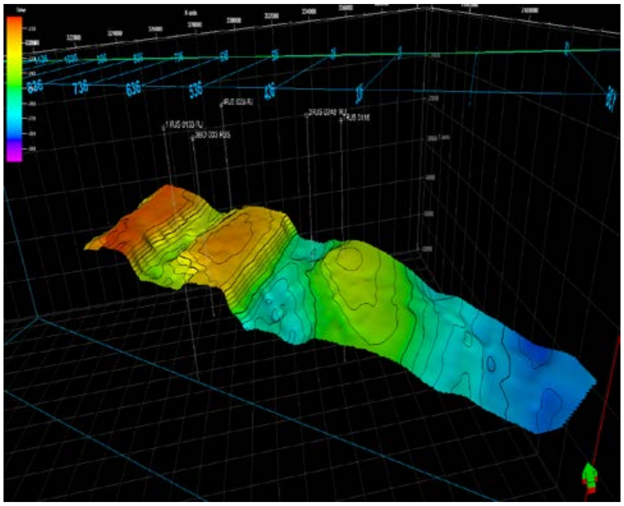

Figure 7- Contour Structural map in time of Quissamã Fm. Top.

The attributes maps show clearly the main and the secondary reservoir on Bonito oil field. On this paper three of them are showing the same anomalies zone as observed on the figures 8 (RMS amplitude), 9 (Sum of negative amplitude), 10 (Average Energy).

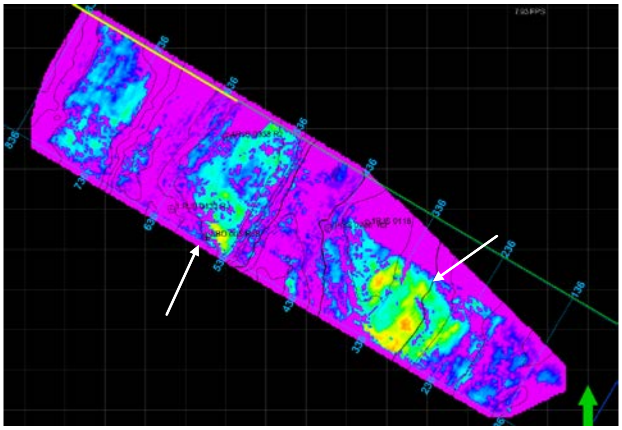

Figure 8 – RMS Amplitude Map of the interval between Quissãma Top and R2 Top.

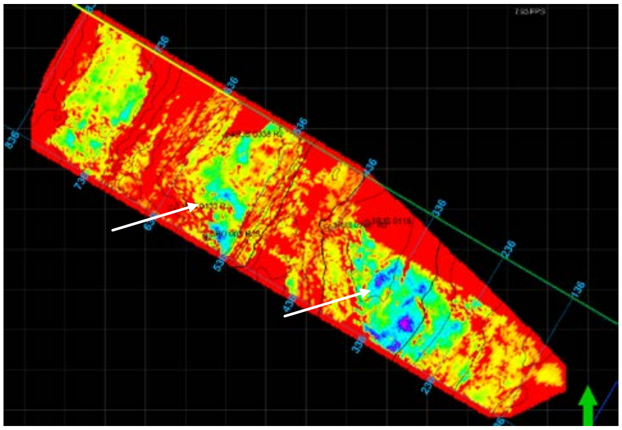

Figure 9 Sum of Negative Amplitudes Map of the interval between Quissãma Top and R2 Top.

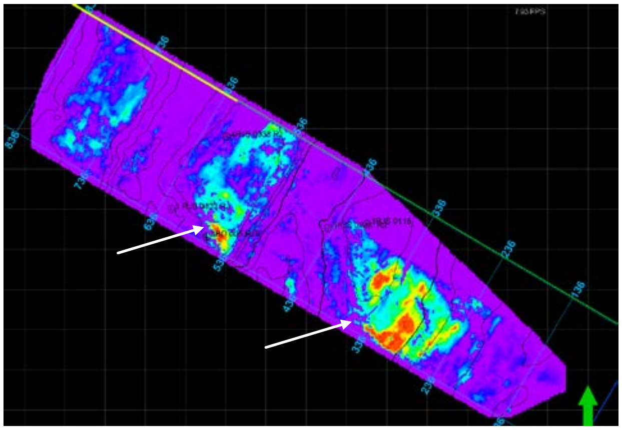

Figure 10– Average Energy Map of the interval between Quissãma Top and R2 Top.

The rock meaning of this attributes were obtained from cross-plot from the amplitude vs rock attributes get from well information.

Before show the process from seismic to geological facies, a brief explanation about each selected attribute is given follow.

The RMS *Amplitude* is mathematically represented by the square root of the sum of square amplitudes, divided by the total number of live samples from the selected interval (Schlumberger, 2007, (1)):

$RMS = \sqrt{(\sum amp^2)/k}$ (1)

k= number of live samples

The Average Energy and Sum of negatives Amplitudes Attributes deserves more attention on carbonates explorations since the high contrast observed on figures 9 and 10. Average Energy response is the amplitude of reflection strength at the point which the energy envelope is a maximum value. One value is obtained for each energy lobe is returned a as a constant for the entire time width of energy lobe, it's mathematically represented by:

$(\sum amp^2)/k$ (2)

Both of the mentioned attributes, identify isolated amplitude response from background features, mainly lateral variations.

Seismic to Geological Facies: for the establishment of the relation between rock properties and the seismic attributes cross plots were generated. The Cross Plots describe a specialized chart that compares multiple measurements made at a single time or location along two or more axes. In this work, cross plots were generated to the interval between Quissãma Top and R2 Top.

The Cross Plot Porosity versus Rms Amplitude (Figure 11) identified a negative moderate correlation between the quality of the reservoir and the attribute. In other words, the RMS amplitude is inversely proportional to Porosity expecting negative anomalies to Rms representing reservoir facies, mainly calcarenites and secondary calcisiltite.

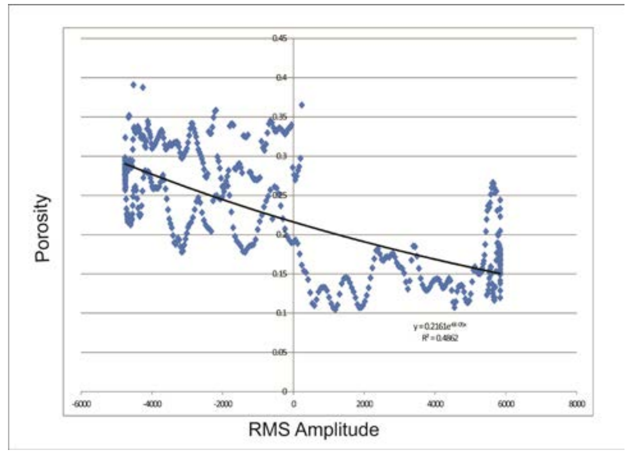

Figure 11– Average Energy Map of the interval between Quissãma Top and R2 Top.

The Cross Plot Resistivity versus Rms figure also identified a moderate negative correlation, as the expecting, since the positive relation between the hydrocarbons content and high values of resistivity and the low values of amplitude to hydrocarbons reservoir.

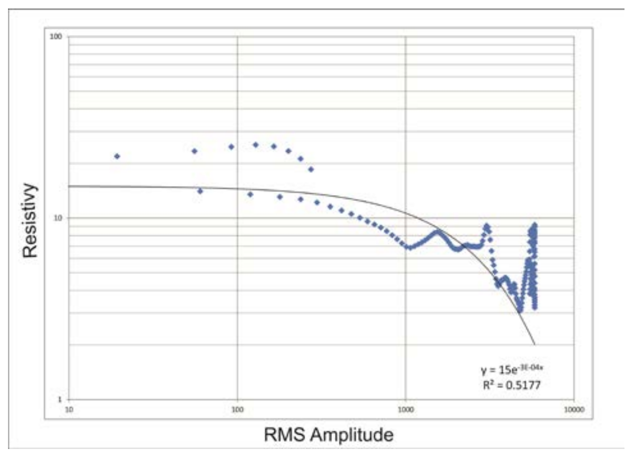

Figure 12- Resistivity / RMS amplitude cross plot, ...

CONCLUSIONS

The integrate analysis of well data, seismic interpretation and seismic attributes show that the principal reservoir of Bonito Field, Quissamã Top – R2 Top is controlled by the structural highs with high influence of the carbonate bank geometry.

The seismic attributes are showing a mix answer between reservoir quality and fluid content, highly influenced by the velocity of the carbonate, once the relationship of these properties are not linear.

References

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