# Seismic Attribute Analysis in carbonate reservoir physical properties distribution: Neobarremian-Eoaptian coquina reservoir case

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## Abstract

The seismic attribute analysis could be a reliable tool for identify physical properties distribution on coquina carbonate reservoirs. The use of seismic information correlated with the data from well logs make possible a reservoir characterization based only on geophysical methods and it's may help to decrease the geological uncertainty in field development. The Neobarremian-Eoaptian coquina reservoir from the Southwest of Campos Basin represents, again, the currently carbonate reservoir challenge due to the new Campos and Santos basin hydrocarbon pre-salt discoveries. The seismic attribute analysis when applied on coquina carbonate reservoir shows correlations between rock property and seismic attribute ranging from $R^2 \geq 0.7$ to $R^2 \geq 0.92$ using attributes of Amplitude, Relative AI and Sweetness. This analysis showed to be a good option when applied for seismic attribute characterization in reservoir physical properties distribution.

## Introduction

The geological complexity of hydrocarbon fields at the rift section of Campos and Santos basins mainly in carbonate reservoirs has been attracted the attention of specialists and directed the studies efforts for this type of reservoir. The understanding of the distribution of reservoir´s main physical properties and the geometric behavior of its permo-porous system represents a challenge in reservoir analysis, even in an analogue form.

The reservoir characterization is the process where you can map the principal reservoir physical properties as thickness, pore fluid, porosity, permeability and water saturation. This can have been done using well logs, but after past few years, it has become possible integrate seismic attribute and make some maps with available well control. The main advantage of use seismic attributes and well logs, instead of just wells alone, is that the seismic can be used to interpolate and extrapolate the information between the wells.

Vincentelli et al. (2014) applied the seismic attribute analysis in Albian carbonate reservois in brazilian basins and obtained good reservoir visualization without any previous seismic interpretation using the sweetness attribute. The analysis show that is possible to define carbonate reservoir with less geological uncertainty using the seismic characterization based on the density changes in comparison with the surrounding layers.

This analysis use only geophysical methods such as seismic attribute and its correlation with petrophysical data. The attribute maps were generating from three seismic volumes (Amplitude, Relative Acoustic Impedance and Sweetness) and extracted from a horizon that correspond to a main reservoir level.

The case area is located 80 km from Rio de Janeiro coast, in a bathymetric depth of 110m in the Southwest of the Campos Basin (Figure 1). The geological context of this area shows carbonate reservoirs formed by coquinas of Upper Barremian - Lower Aptian ages, belonging to the Coqueiros Formation of the Lagoa Feia Group, which represented major discoveries of hydrocarbon-producing fields in the 1970s (Baumgartem, 1988).

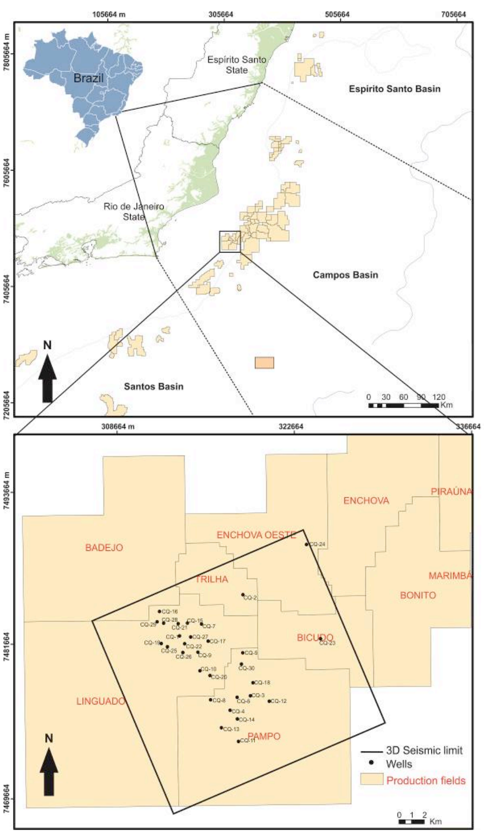


**Figure 1.** Location map of case area.

The principal goal here is to define the distribution of physical properties associated with some carbonate reservoirs, formed by coquinas deposits (rudstones and grainstones of bivalve molluscs) applying seismic attribute analysis with a correlation between these maps and basic petrophysical data.

## Dataset and Method

The dataset corresponds to a 3D seismic amplitude volume, with about 500 km$^2$ of area, and 30 wells. The methods applied were executed as illustrated by the following steps in the workflow on Figure 2.

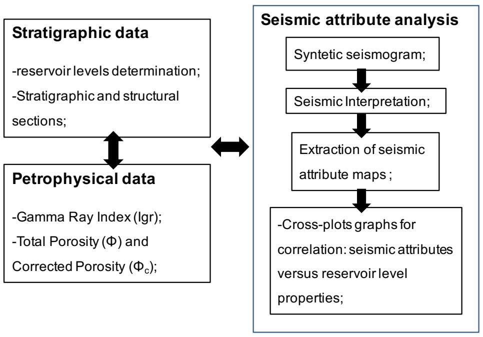


**Figure 2.** Analysis workflow

The analysis starts with the previous integration between stratigraphic and petrophysical data for a reservoir characterization based only in well logs. The main reservoir level studied here belongs to Rosa (2016) previous well log interpretation and it's occur near of the base of Lower Coquina strata (Figure 3).

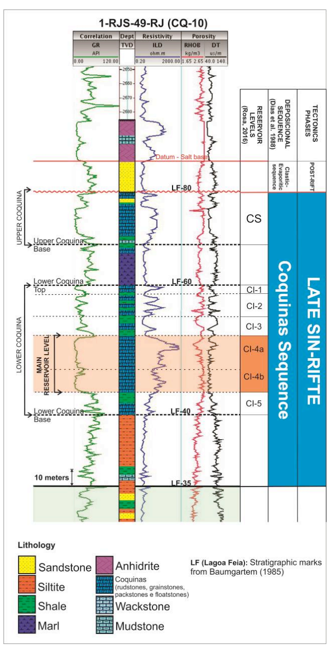


**Figure 3.** Typical profile for Lagoa Feia Group with the depositional sequences. The top of the Coquinas Sequence is marked by the regional Pre-Neo-Alagoas unconformity (LF-80). Datum: LF-85 (base of evaporite section). (Source: adapted from Rosa, 2016)

The seismic attribute analysis use the information obtained with the stratigraphic analysis, such as the top and bottom of the main sequences interpreted on well scale, and transferred to time domain and plotted on the 3D seismic data based on time to depth relationship (synthetic seismograms) (Figure 4).

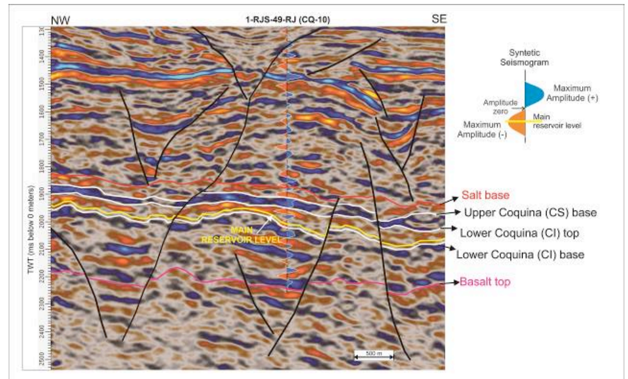


**Figure 4.** Seismic section NW-SE with the well 1-RJS-49-RJ (CQ-10) showing the synthetic seismogram and horizons.

The seismic interpretation and subsequent interpolation allows obtaining a horizon that comprises the seismic information and the structural framework for the reservoir level analyzed. The relative acoustic impedance and sweetness attributes were calculating from the amplitude cube. The seismic attribute maps were extracted from the seismic cube of amplitude, relative acoustic impedance and sweetness.

A previous qualitative analysis was performed with the seismic attribute maps to select those who presented a good anomalies contrast. The chosen attributes maps were correlated to the petrophysical properties of corrected porosity (Φc) (total porosity corrected from Gamma Ray Index (Igr)), Water Saturation (Sw) and reservoir`s thickness. This analysis allows a quantitative correlation that could help determine which physical properties are represented by the seismic information.

## Results

The main reservoir has the physical properties of corrected porosity (Φc) ($R^2$ > 0,9), calculated from well log, with a good correlation with the Mean Amplitude map (Figure 5). The correlation shows that the porosity values increase as the mean amplitude values become more negative (Figure 6.).

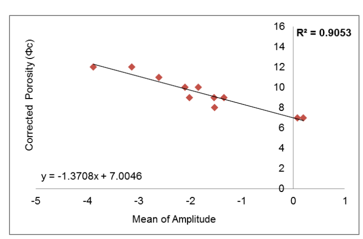


**Figure 5.** Cross-plot graph showing the correlation between corrected porosity (Φc) and Mean Amplitude map.

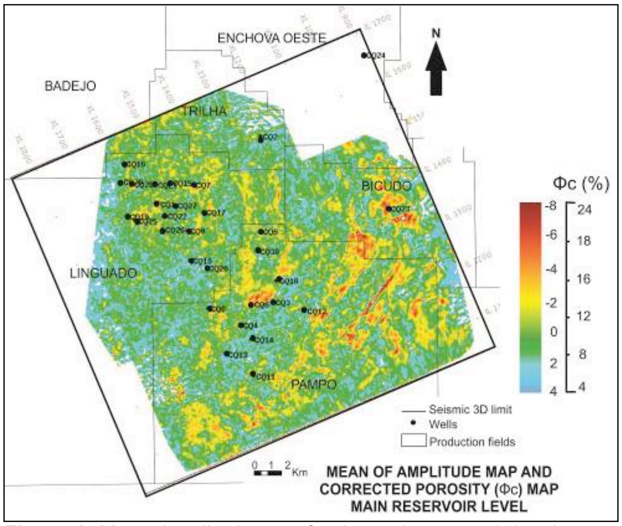


**Figure 6.** Mean Amplitude map for the main reservoir level.

The Mean Amplitude map shows some similarities with the base structural map and isopach map (Figure 7) for the main reservoir level. The higher negative values of mean amplitude seem to follow the fault structures with NE-SW direction and the higher thicknesses. The amplitude attribute helps to identify that there is a high influence of the tectonic structure in the distribution of the physical properties as porosity in this reservoir level.

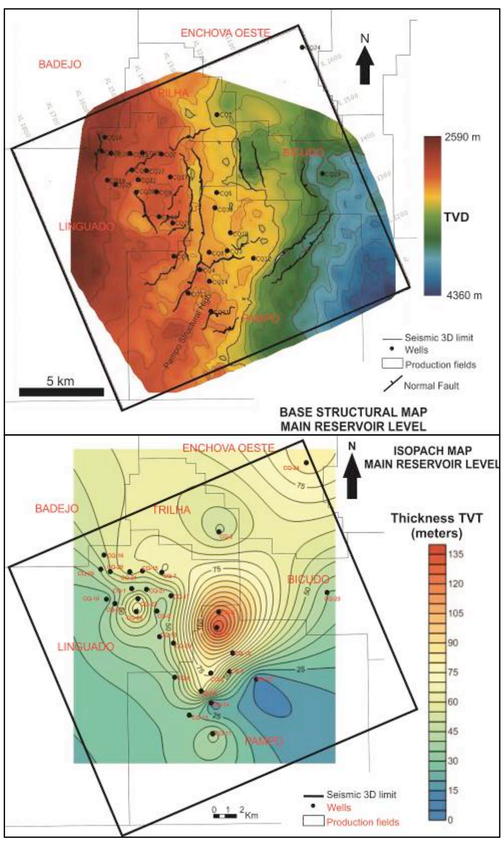


**Figure 7.** Structural base map and isopach map for the main reservoir level.

The physical property of corrected porosity also shows a good correlation with the Instantaneous Relative Acoustic Impedance (AI) ($R^2$ > 0,79) (Figure 8). It means that the porosity values increase as the values of Instantaneous Relative AI becomes more negative.

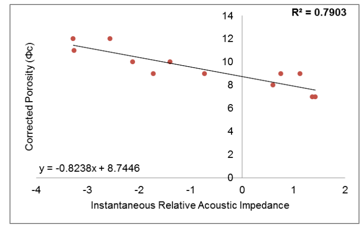


**Figura 8.** Cross-plot graph showing the correlation between corrected porosity (Φc) and Mean Amplitude map.

The Instantaneous Relative AI map (Figure 9) as well as the Mean Amplitude map can be used to interpret the physical property distribution. According to the Relative AI the higher porosities values are located on Northwest, central and Southeast following a NE-SW trend structure.

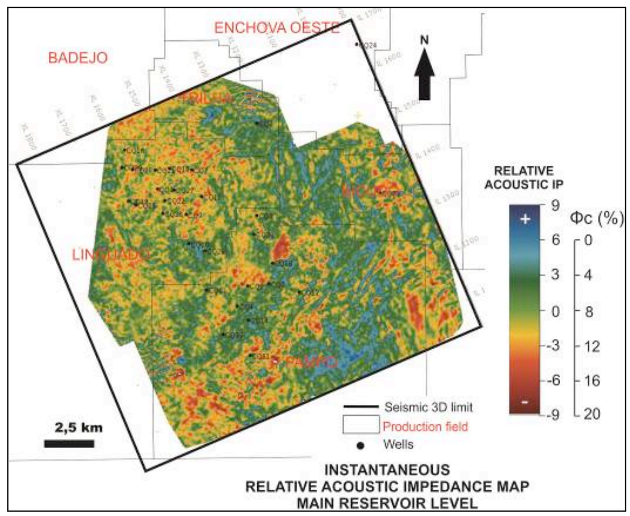


**Figure 9.** Instantaneous Relative AI map for the main reservoir level.

The seismic attribute map of RMS sweetness shows a good correlation with the petrophysical properties of corrected porosity (Φc) ($R^2$ > 0,71), water saturation (Sw) ($R^2$ > 0,82) and reservoir thickness ($R^2$ >0,73). (Figura 10).

This sweetness attribute seems to be the best one to visualize the whole reservoir physical properties distribution. The cross-plot graphs show that the porosities values increase, the water saturation decrease and the reservoir thickness also decrease when the RMS sweetness value becomes higher. The RMS sweetness map (Figure 11) has a better define boundary with the estimate limit for major porosities occurrence.

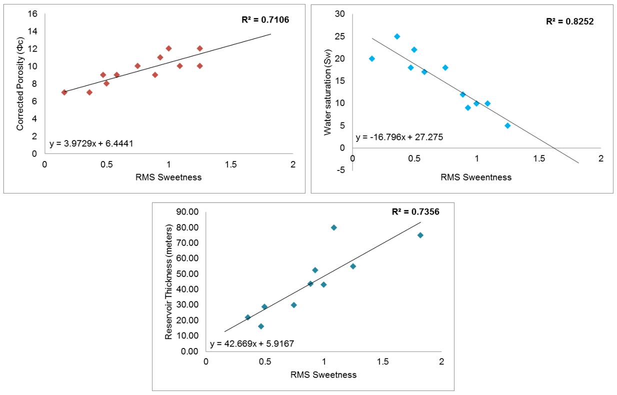


**Figure 10.** Cross-plot graphs showing the correlation between corrected porosity (Φc), Water Saturation (Sw) and Reservoir thickness, and RMS Sweetness map.

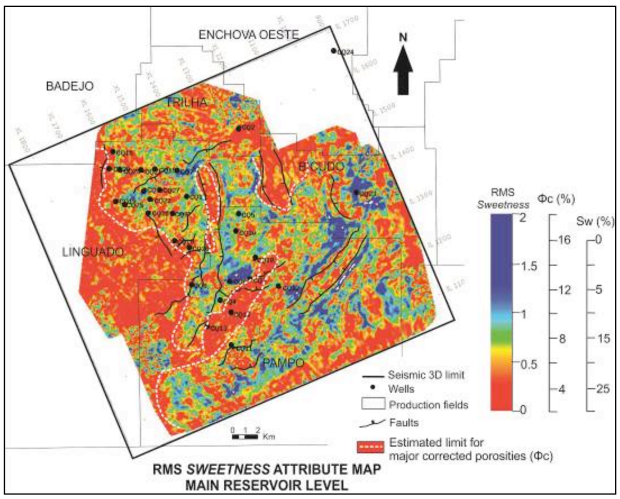


**Figure 11.** RMS Sweetness map for the main reservoir level.

## Conclusions

The seismic attribute analysis when applied on coquina carbonate reservoir shows correlations ranging from $R^2 \geq 0.7$ to $R^2 \geq 0.92$ with the seismic attributes of Amplitude, Relative AI and Sweetness. The cross-plots graph analysis confirms the correlation between the physical properties that reflects the coquina carbonate reservoir and the seismic information, thus allowing a reservoir level analysis based on this property.

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