Facies Prediction in Unconventional Reservoir using Stratigraphic Inversion Post-Stack. Case Study in the Sergipe Basin.

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Abstract

Unconventional hydrocarbons resource requires integrating skills exploration for improved prediction and reservoir understanding. Methodology integrates 3D seismic inversion data, well logs information and geological knowledge applied to the Sergipe Basin to define shale facies that could act as an unconventional reservoir. The present work shows the model stratigraphic poststack seismic inversion to contribute reservoir characterization from facies distributions and shale probability volumes at the target, possible shale in Coqueiro Seco Formation.

Introduction

The unconventional play has become an important target in the petroleum industry as a viable resource. Therefore, efforts to the characterization of reservoir shale have gained significance. Exploratory success in unconventional reservoirs depends on the determination of properties of potential shale as to where to find sweet-spots, areas with the significant volume, maturity of total organic carbon (TOC) and network fractures.

Usually, reservoir properties associated with facies distribution. These expresses distinct rock types, deposition environment and tectonic setting of sedimentation. Such information contributes to prediction facies. In this study, performed post-stack seismic inversion for convert seismic data in quantitative physical rock property parameters which characterized reservoir (Pendrel, 2006).

The goal of applying seismic inversion was extracted acoustic impedance from seismic data to derive facies distribution at level shale Coqueiro Seco Formation.

For such purpose, followed a workflow of wavelet estimation, the build the low-frequency model based on the seismic interpretation and after that, the Model-based algorithm (Russel & Hampson, 1991) was applied to obtain the acoustic impedance volume.

Geologic Setting and Stratigraphic Framework

The Sergipe Basin located in the northeast of Brazilian continental margin (Figure 1), coast parallel to the NE-SW direction. The onshore portion extends 150 km, and 35 km wide, belonging to the respective state (Aquino & Lana 1990). It is bounded on the north by the Pernambuco-Paraiba Basin, to the south by the Jacuípe Basin and west by crystalline basement rocks of the Sergipano Belt (Feijó 1994).

The tectonic context of Sergipe Basin is defined by four stages of tectonics and distinct sedimentation: syneclise, pre-rift, rift, post-rift and drift the basin (Campos Neto et al., 2007).

The structural framework established in rift phase, control by an NE-SW trending fault system, separate by half-graben and host, synthetic and antithetic normal fault systems, controlled the subsidence and sedimentation within the basin, developing internal highs and lows distributed along a standard en-echelon pattern (Ojeda & Fugita, 1976).

Investigated target is source rock of the Coqueiro Seco Formation, deposited in the continental lacustrine environment in syn-rift phase (Barremian/Eoaptian), strongly controlled by tectonism.

Coqueiro Seco Facies is defined as intercalation of sands and shales (Schaller 1970). Shale presents TOC up to 5% and thermal maturity in the window of oil generation (ANP/UFRN/FUNPEC, 2008).

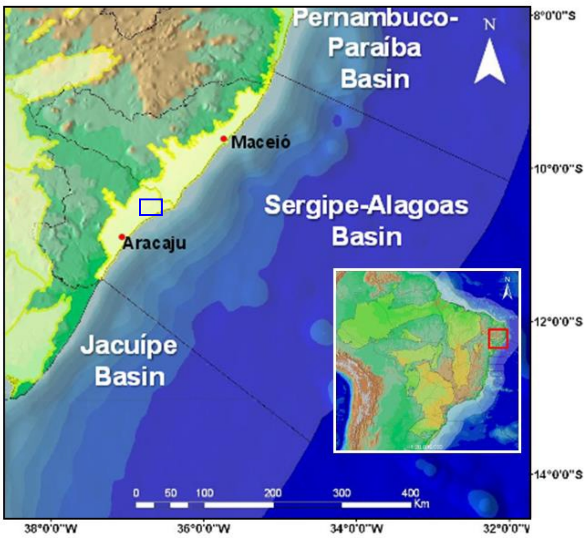

Figure 1. Location of Basin Sergipe and study area (blue rectangle).

Data and Method

The dataset available by Brazilian Petroleum Agency (ANP) includes the 3-D post-stack seismic volume Brejo Grande, located in the area of production fields into the petroleum system Barra de Itiúba-Coqueiro Seco Formation and well-logs profiles (gamma ray, sonic, density, and resistivity) in addition to check-shot surveys.

The seismic inversion consists in to obtain an acoustic model estimate of the quantitative physical rock property that allows determines from of differences in impedances. The change in the surface lithology is represented variation in acoustic impedance, a product of density and velocity.

The method used a Model-based is the deterministic convolution of the two-way time (TWT) reflectivity inversion. This approach involves integrating the seismic data and well logs to produce a band-limited inverted trace with the low frequency not present in the input seismic, limited about 10 to 60 HZ, as result output a volume of acoustic impedance (Russell and Hampson, 1991).

The stratigraphic inversion steps require an initial lowfrequency model, built from well data and seismic horizons through processed convolution between the original model and a wavelet.

Seismic Interpretation

The seismic data was filtered by Rocha (2016) to reduce incoherent high-frequency noise. The seismic horizons were mapped along this filtered volume and interpolated following routine the calibration well-seismic tie.

In figure 2, presents to mains horizons associated with the main stratigraphic framework (H1 to H9). The cross section between wells shows interpretation seismic stratigraphic (Figure 2) with depositional sequences of the basin.

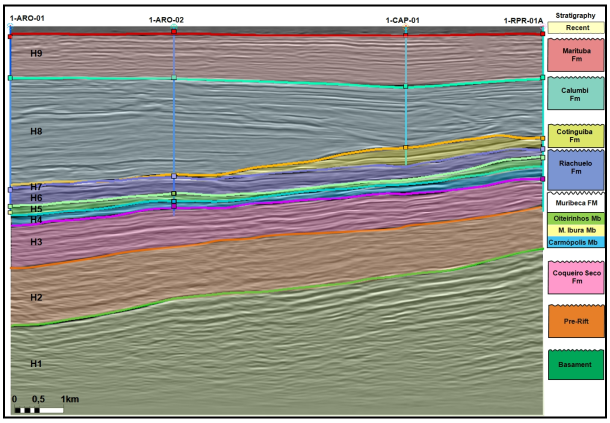

Figure 2. Main stratigraphic horizon along the arbitrary line shown in Fig. 3.

To better visualization and understanding were generated from the seismic horizons (H3) the 3D display in section (Figure 3) and Coqueiro Seco formation horizon map (Figure 4) in the target for unconventional, shale formation.

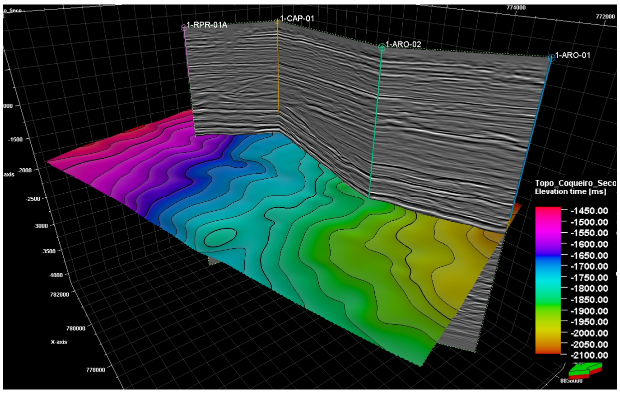

Figure 3. 3D view of the horizon Coqueiro Seco Formation.

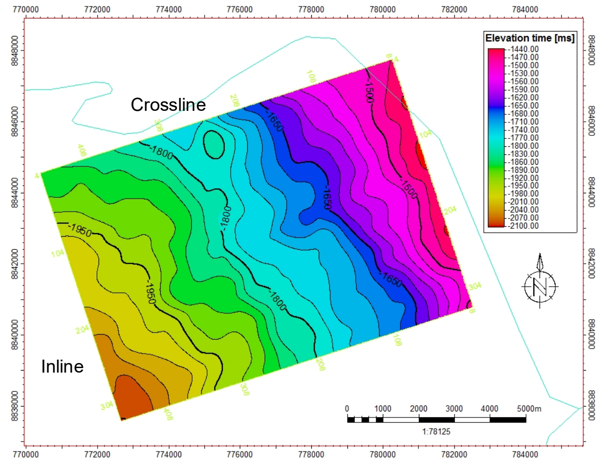

Figure 4. Coqueiro Seco Formation Horizon Map.

Seismic Inversion

Performed background impedance model building by blocking from the parameters of extracting from interpolates of the sonic and density well logs and the horizon interpreted built based on the seismic interpretation stratigraphic formation of the Sergipe Basin.

The inversion process shows of the inverted trace at well 1-ARO-0002 (Figure 5), overlain on the original impedance logs and synthetic traces results from the inverted data and compares them to the input seismic volume, allowing quality control and calibration carried out interactively.

Inversion analysis of the uncertainty shows excellent correlation, around 99%. The quality control of the process seen in Figure 5 presents the low residue between the synthetic and the seismic trace on both control windows and the good correlation between the well tie and the inversion. Note red line is indicating the inverted result and the blue line showing the original log.

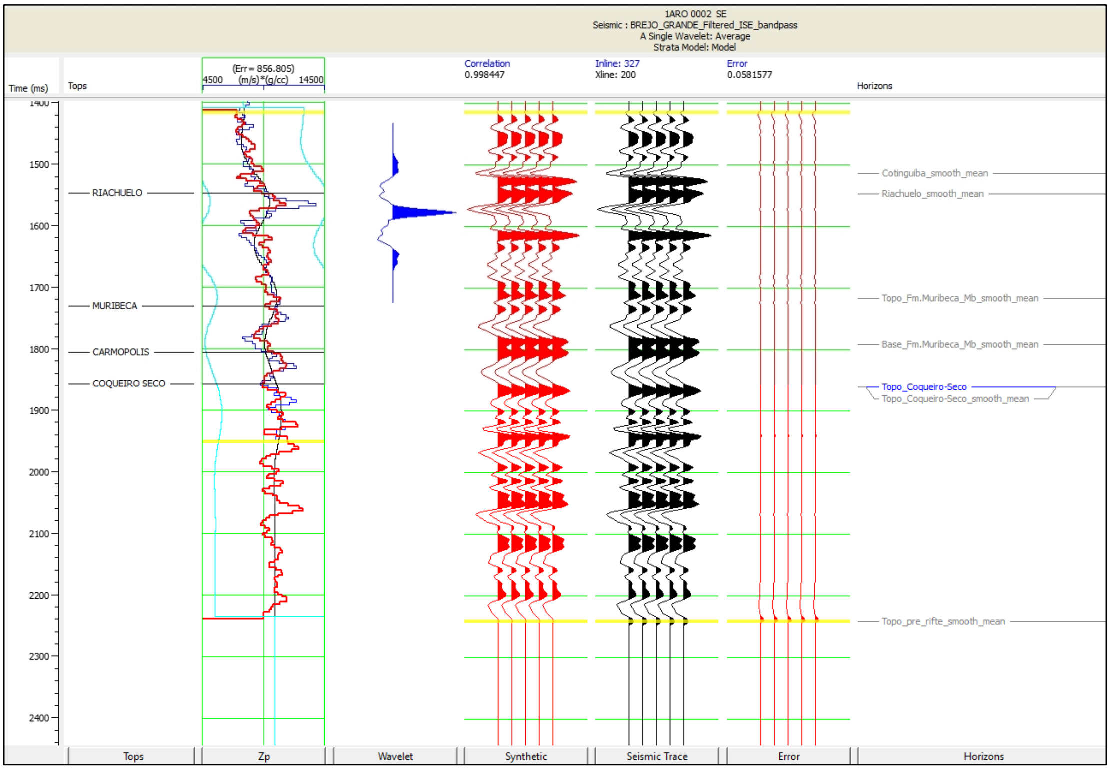

Figure 5. The inversion analysis window for well 1ARO-0002.

In Figure 6 shows arbitrary line through wells 1ARO-0001, 1ARO-0002 and 1RPR-0001 with model of low-frequency acoustic impedance (filtered 5Hz, 10Hz).

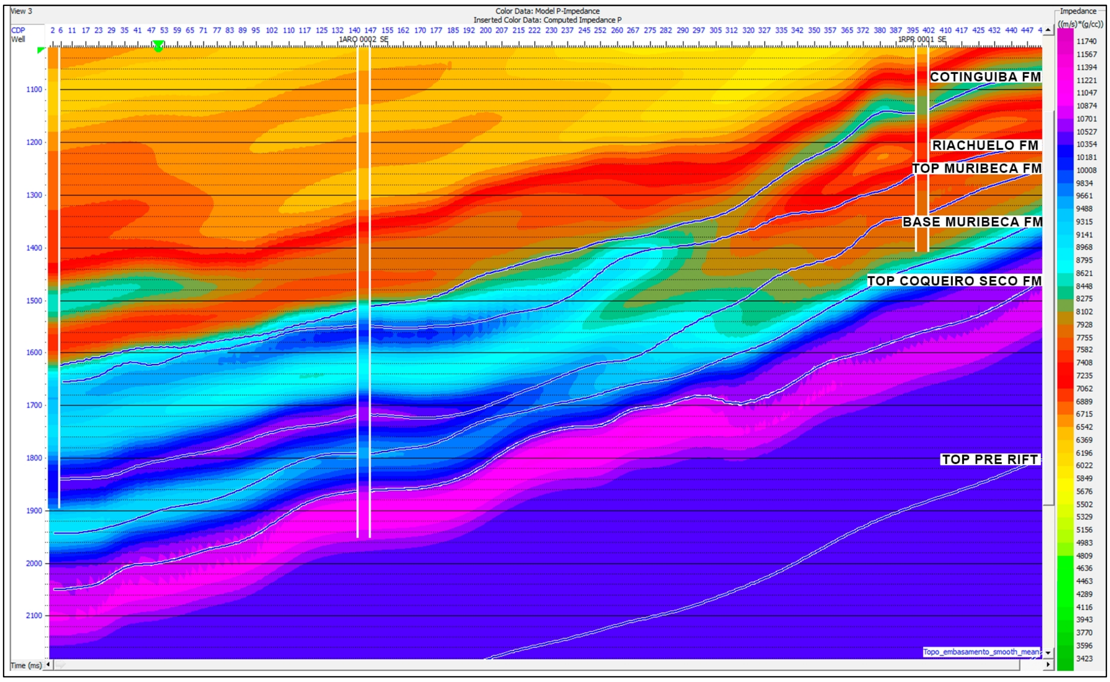

Figure 6. Initial low frequency P-impedance model and the horizons.

After that, have been generated 3D seismic volume acoustic impedance output in high resolution without a wavelet from input seismic data, increasing band frequencies.

Figure 7 shows the comparison between the acoustic impedance at 1ARO-0002 well and the recovered acoustic impedance (IA) along inline 327. Note a good correlation between the impedance of the well and the probability facies of shales and sands. In blue color (10151 to 11371 impedance values), represent a high probability of shale facies and between 11982 to 12146 IA possibility of sand.

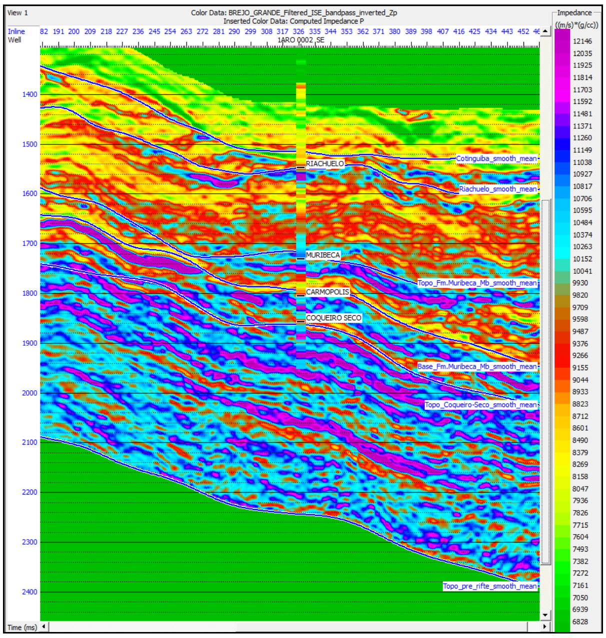

Figure 7. Volume acoustic impedance of Sergipe Basin.

In figure 8 shows a cross plot of impedance with sample gamma ray. High gamma ray (clay content) and values impedance lower are diagnostic of hydrocarbon, facies shale compared to values impedance high and low gamma ray typical of facies sand (clastic).

In Figure 9 presents cube volume inverted with gamma ray curve data and main horizon interpreted. The evaluation performed cube impedance with gamma ray data inverted allowed identified reservoir facies from shale and sand in Coqueiro Seco Formation (around 1750 ms). Observed the correlation between volume acoustic impedance presented in Figure 7 and interpreted facies distributions (Figura 9). The facies of the shale in the Coqueiro Seco lies within the 69-101 API color, associated with lower impedances values (10151 to 11371), which allows us to identify possible reservoir unconventional.

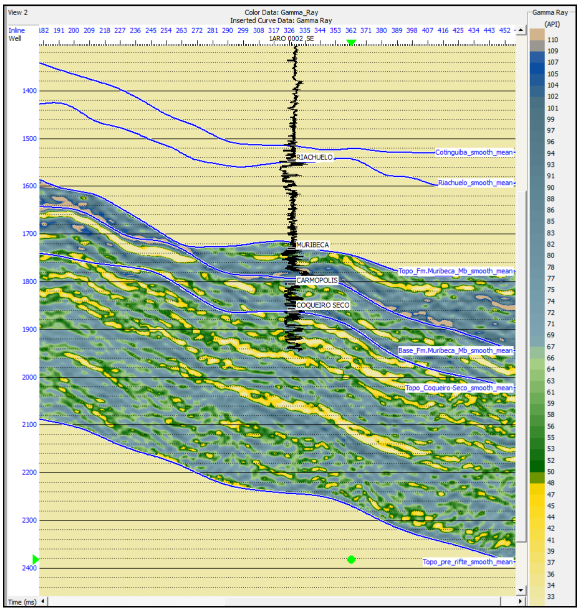

Figure 9. Interpreted facies distribution. Volume inverted with gamma ray curve data.

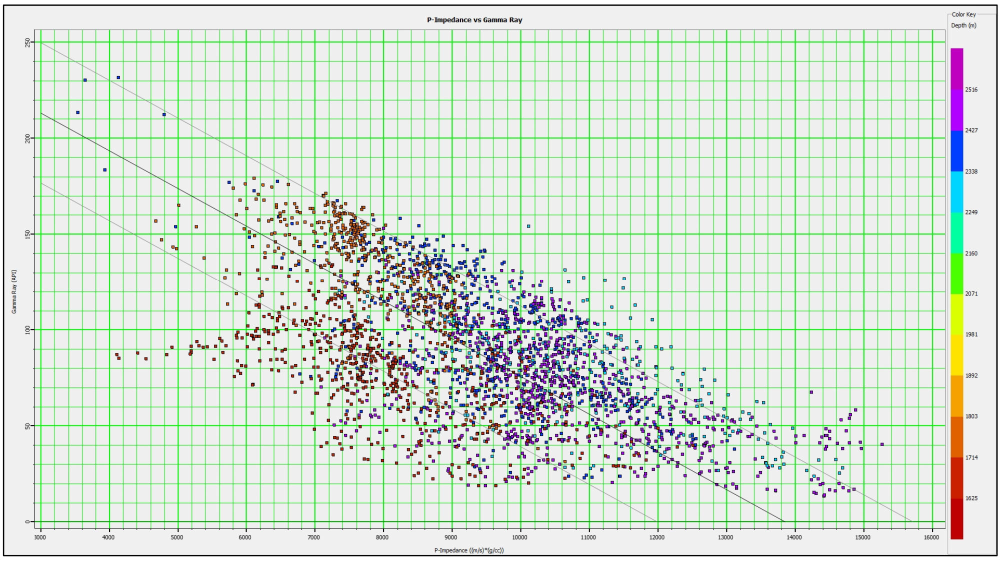

Figure 8: Cross plot Impedance Acoustic and Gamma Ray.

Conclusions

The workflow presented, supports the seismic interpretation showing good correlation with the data inverted.

Seismic inversion methodology integrates post-stack seismic inversion, well log and stratigraphic horizons for providing a better understanding of the rock properties in reservoir scale. Consequently, contribute to reservoir characterization in high resolution by in identifying facies distributions and shale probability volumes.

In target zone, shale facies from 3-D cube inverted with gamma ray curve data high (69-101 API) shows a correlation between the impedance acoustic of 10151 to 11371.

The results corroborate probable Coqueiro Seco Formation shale as a possible sweet-spot in Sergipe Basin.

Acknowledgments

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