Geophysical characterization of Exploratory Plays in the central portion of Espírito Santo Basin.

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Abstract

In Espírito Santo Basin, accumulations of oil and gas are provided by different mechanisms, such as structural and stratigraphic traps and structures sealed by salt bodies.
The objective of the research is to perform a tectonic-structural analysis at the region Cangoá and Peroá fields, through data of well profiles and interpretation of 2D seismic lines, identifying the top of the Urucutuca Formation and the chronostratigraphic levels of the Miocene, Oligocene, Albian and Aptian.
From this analysis, it is evaluated the potentiality of two identified exploratory plays: Urucutuca turbidites play and structured Albian play. The first one is characterized by turbidite reservoirs of the Urucutuca Formation located closed to salt domes, which are responsible for trap the hydrocarbon. The second one are reservoirs formed due to the presence of rollover structures that trap the hydrocarbon.

Introduction

The Espírito Santo Basin is located on the Southeast margin of Brazil and its offshore portion has an area of 200.000 km^2. To the South, it is bordered by the Campos Basin due to the Vitória Structural High and, to the North, is separated from the Cumuruxatiba Basin by the Abrolhos Volcanic Complex (VIEIRA et al., 1994).
The study area is around the Peroá and Cangoá oil fields at the central portion of EspÍrito Santo Basin (Figure 1), 42 km - 26 miles - from the coast. The average water depth in these fields is 60 meters (BDEP, 2016) and the oil density is around 50° API (ANP, 2016).
Cangoá field was discovered in 1988 (well 7-CAN-001D-ESS) and covers an area of 20.17 km². Peroá field is located 8.6 km east of Cangoá field and was discovered in 1996 (well 1-ESS-077 ESS).
The main importance of Cangoá and Peroá fields lies in the production of natural gas, which is several times higher than the production of oil. The reservoir rocks occur with a wide regional distribution in the basin, defining different exploratory plays, including the Cricaré Formation, Jaguaré Member (Valanginian / Barremian), Mariricu Formation, Mucuri Member (Aptian), São Mateus and Regency Formation (Albian) and Urucutuca Formation (Upper Cretaceous/Paleogene/Neogene).

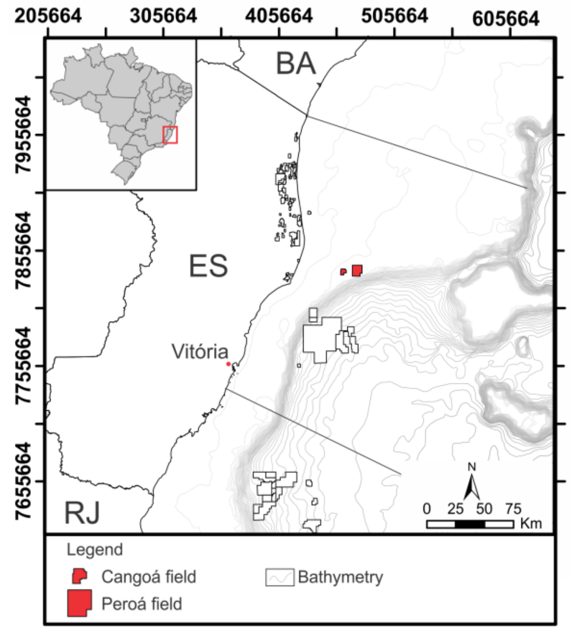

***Figure 1** – Location of the Espírito Santo Basin with emphasis on Cangoá and Peroá fields.*

The main known reservoirs consist in Oligo-Miocene lenticular turbidite sandstones of the Urucutuca Formation (VELOSO, 2013). These turbidite bodies are complex channels oriented approximately in the North-South direction, with an average thickness of 30m, porosity around 14% and maximum water saturation (Sw) of 35% in the Peroá field (Morais, D. S., 2014).
In Espírito Santo Basin, accumulations of oil and gas are provided by different mechanisms, such as structural and stratigraphic traps and bodies of salt. The proeminent structural styles of the basin is characterized by grabens and horsts (rifte sequence), anticlinal rollovers and normal faults and listric faults associated with the rise of saline domes by halokinesis (Figure 2).

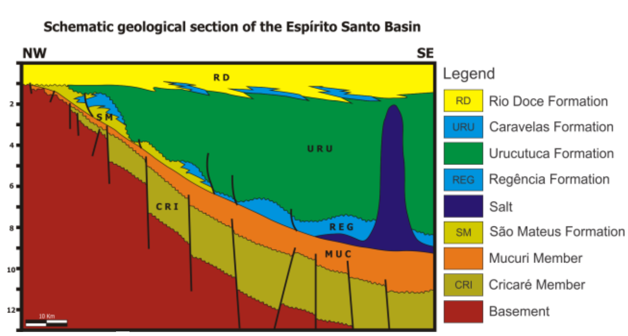

***Figure 2** – Schematic geological section of the Espírito Santo Basin. (Source: Modified from ANP, 2007).*

Objective

The objective of the research is to perform a tectonic-structural analysis of Cangoá and Peroá fields, through data of well profiles and interpretation of 2D seismic lines, identifying the top of the Urucutuca Formation and the chronostratigraphic levels of the Miocene, Oligocene, Albian and Aptian. From this analysis, it is expected to evaluate the potentiality of the identified exploratory plays.

Method

The project was developed using a set of wells and seismic data provided by the Agência Nacional do Petróleo (ANP) through the policy of providing data to public universities. The project was executed in four main stages:

1) Database acquisition, organization and processing.

In this phase occurred the research and compilation of several studies from the Espírito Santo Basin, with emphasis on Cangoá and Peroá fields. The main topics studied were the stratigraphic and structural characteristics of the basin, as well as its evolutionary geological model and the geophysical principles involved in the execution of the project.
In addition, the data set was properly organized and processed, consisting of 1450 kilometers of 2D seismic sections in .SGY format and 14 wells with their composite profiles, operational characteristics, historical production and basic curves in .las format (3-BRSA_0160_ESS, 3-BRSA_0169_ESS, 4-BRSA_0066_ESS, 6-ESS_0085_ES, 3-ESS_0082_ES, 1-ESS_0077_ES, 1-ESS_0012D_ES, 1-ESS_0076_ES, 3-ESS_0079_ES, 4-ESS_0075_ES, 1-ESS_0067_ES, 3-ESS_0074_ES and 3-ESS_0068_ES).
All the seismic sections were used in the analysis. The well–seismic calibration were done using the 3-ESS_0068_ES well and this allows the seismic identification of stratigraphic interest´s horizons (Figure 3).

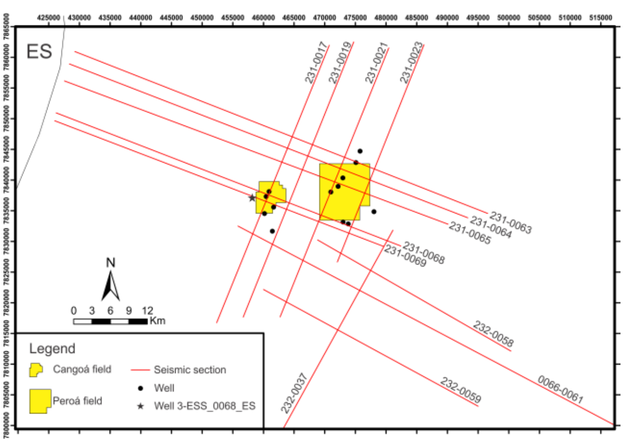

***Figure 3** – Localization of 2D seismic lines and Wells, highlighting the well 3-ESS_0068_ES, used for calibration.*

2) Well analysis

Using the basic curves in .las format, it was made profiles for the analysis of four parameters: gamma ray data (GR) Resistivity (ILD), density (RHOB) and velocity (DT). The integration of this graphics with the composite profiles and data well allowed the interpretation of five horizons, corresponding to the top of the Urucutuca Formation and the chronostratigraphic levels of the Miocene, Oligocene, Albian and Aptian.
The correlation of the wells was made through the lateral correlation of layers with the same physical properties between the profiles of the wells, as shown in Figure 4, to define the general features of the analyzed horizons.

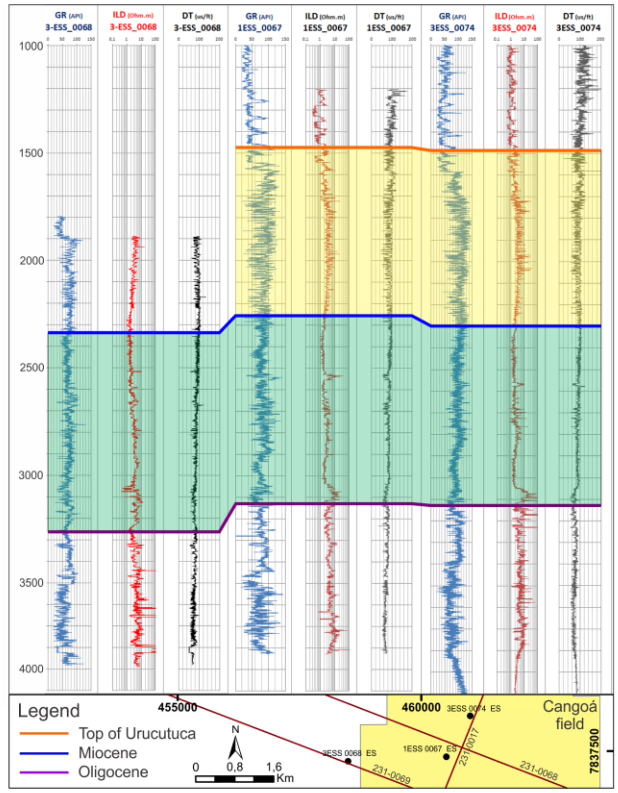

***Figure 4** – Correlation between the wells 3-ESS_0068_ES, 1-ESS_0067_ES and 3-ESS_0074_ES on Cangoá Field using the profiles of gamma ray (GR), Resistivity (ILD) and sonic profile (DT).*

Also, in this phase was made the wells calibration with seismic using the well 3-ESS_0068_ES. With the principle that seismic lines are obtained as a function of time, in milliseconds, and the well profiles are in meters, it was necessary to do the time-depth conversion. This conversion was done by calculating the velocity measured in the sonic profile (DT) for the interval of interest and the corresponding depth in the well. Once the time of travel of the wave was found, this measurement was converted to double time, in milliseconds, for calibration of the seismic (Figure 5).

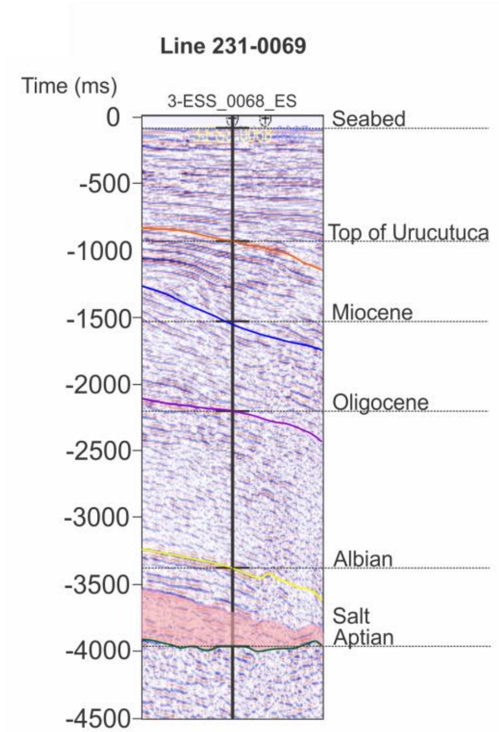

***Figure 5** – Calibration using the well 3-ESS_0068_ES and seismic line 231-0069 trhough time-depth conversion.*

3) Seismic interpretation

In the third phase, after calibration, the main horizons were defined and correlated along the other 2D lines, one by one, considering the intersection of the other seismic lines with each other.
After this, with the intervals of interest interpreted, the lines were compared in order to understand the structural context of the study area and the indicators (traps) of possible accumulations of oil and gas, such as faults, folds and elements related with halokinesis.

4) Maps generation

Finally, contour surface maps in 2D and 3D of four interpreted horizons were generated, as well as isopach maps comparing two distinct chronostratigraphic intervals: Miocene and Oligocene; and also Albian and Aptian.
The isovalues maps were made in Surfer® 13 software for the different situations evaluated, using the ordinary kriging interpolation method.

Results

Five horizons were correlated along Cangoá and Peroá Fields, as showed in the dip sections 231-0061 (Figure 6) and 231-0063 (Figure 7), both in the NW-SE direction. From this analysis, it was verified that the Espírito Santo basin was exposed to different deformation patterns.

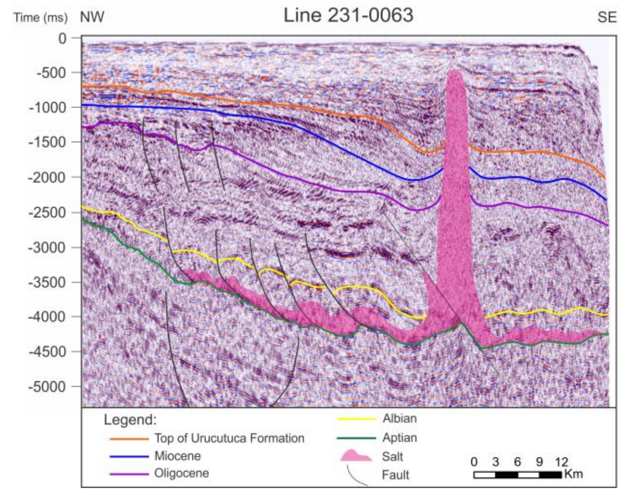

***Figure 6** – Seismic interpretation of section 231-0063.*

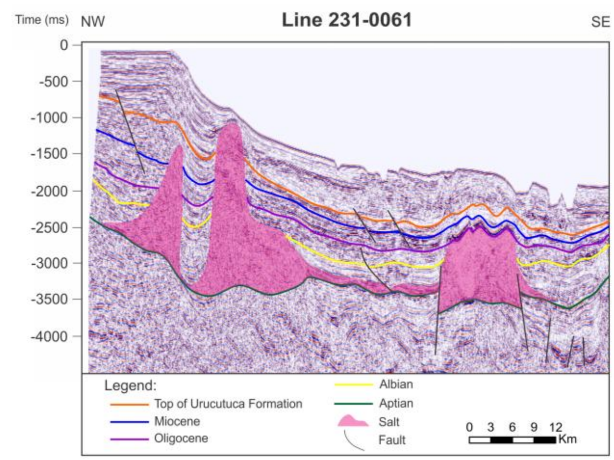

***Figure 7** – Seismic interpretation of section 231-0061.*

The base of the evaporite sequence, corresponding to the Lower Aptian (green line), is characterized by the extensional tectonic style. In this domain, relative to the continental phase of the evolution of the basin, there are normal faults, horsts and grabens.
At the top of Albian (yellow line) is observed the saline tectonic style, in which the deformations are controlled by halokinesis. The evaporites of the Itaúnas Member move by intruding on the upper rocks in the form of extensive salt domes (represented in pink color) that reach kilometers of thickness. The space generated by the displacement of the salt results in the abatement of the upper blocks, which results in the formation of listric faults with associated rollover folds. Halokinesis is also responsible for the formation of normal faults reaching the rocks of the Urucutuca Formation.
The horizons interpreted for the Oligocene (purple line) and the Miocene (blue line) belongs to the drift phase of the basin. It is precisely in the interval between these two levels that there are thick turbidite sequences that constitute the main oil reservoirs. The top of the Urucutuca Formation (orange line) exhibits small variation when not affected by the salt, being only occasionally displaced by normal faults.

Besides the seismic interpretation, 2D surface contour maps were generated in milliseconds for the four chronostratigraphic levels interpreted: Miocene, Oligocene, Albian and Aptian.

The four maps are relatively similar, showing variations mainly in relation to the deep, represented as a function of time for the different horizons. Nevertheless, each level has particular characteristics. The Aptian map (Figure 8A), for example, contains the greater structural variation, attributed to the occurrence of grabens, horsts and the reactivation of the rift system.

In general, the maps show that the regional dip of the area is oriented towards SE, with depocenter of the basin in this direction, as we can see in the Miocene map (Figure 8B).

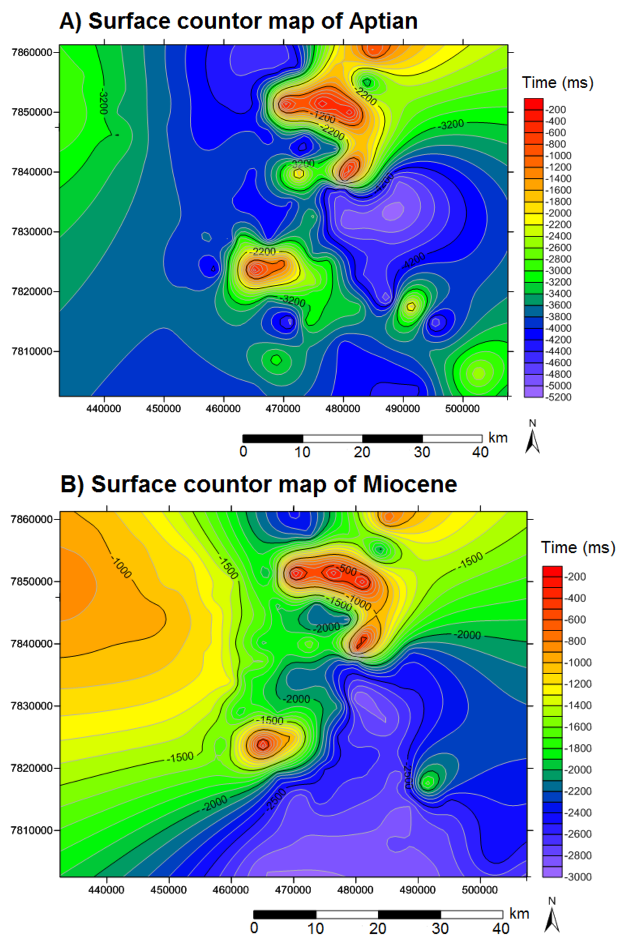

***Figure 8** – Surface coutor maps for Aptian (A) and Miocene (B). The scale is negative and in milliseconds*.

In order to visualize the general configuration of the basin in the study area and the variation of the intervals between each interpreted layer, 3D surface contour maps were generated for Miocene (Fig. 9A), Oligocene (Fig. 9B) and Albian (Fig. 9C).

In these maps is quite evident the disposition of the salt domes, that are distributed mainly in the Eastern region of the Fields of Cangoá and Peroá, possessing a slight tendency of alignment in the NNE direction.

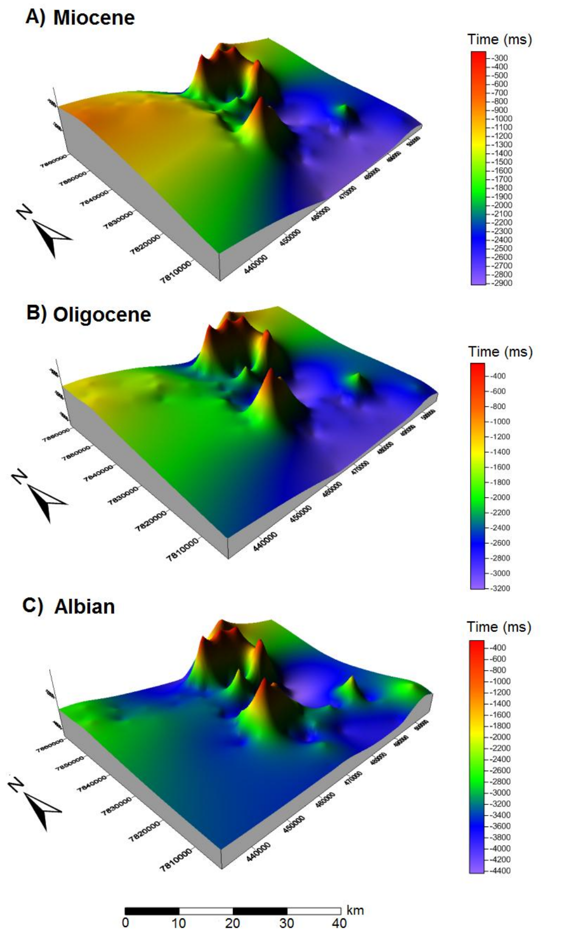

***Figure 9** – 3D Surface coutor maps for Miocene (A), Oligocene (B) and Albian (C). The scale is negative and in milliseconds.*

Apart from the structural contour maps, two isopach maps, in meters, of the interval between the Miocene and the Oligocene (Figure 10) and the interval between the Aptian and the Albian (Figure 11) were generated.

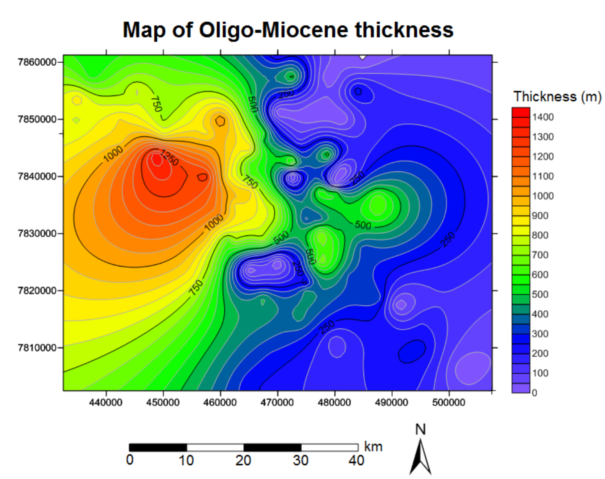

***Figure 10** – Isopach map showing the Oligo-Miocene thickness. The scale is in meters.*

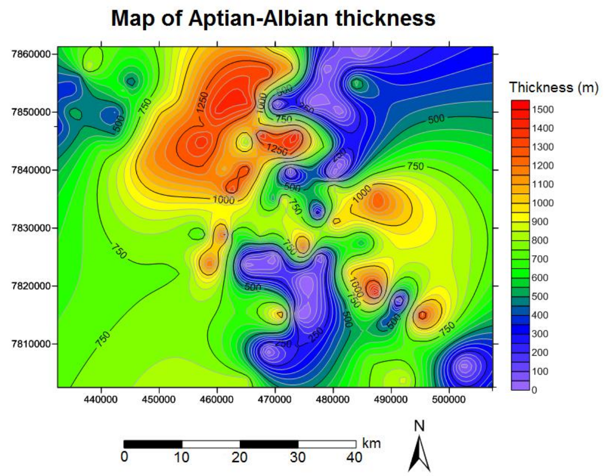

Figure 11 – Isopach map showing the thickness of the interval between Aptian and Albian horizons. The scale is in meters.

An analysis of the structural and isopach maps suggests two potential oil plays in the study area: Urucutuca turbidites play and structured Albian play.
The Urucutuca turbidities play correspond to the reservoirs of turbidite sandstones of the Urucutuca Formation, from Cenomanian to Recent. These turbidites are structured as a effect of halokinesis and may be associated with faults that serve as a hydrocarbon conduit (ÁVILA, 2015).
As shown in Figure 10, the thickness of the Oligo-Miocene is large in the reddish-yellow regions and small in the blue-purple portions of the map. In general, the thickness of the layer decrease from Northwest to Southeast, following the dip of the basin, and also in the presence of salt domes, which obliterate the layers through which they intrude. As we can see, in the NNE direction of the map there are several places where the Oligo-Miocene becomes very thin, which is a reflection of the presence of large saline domes, well represented in the 3D surface contour maps.
Aware of this, it is expected that the region adjacent to the salt domes constitute an excellent exploratory play, once the salt acts as a trap for the turbidites and also as a sealant rock. In figure 12, for example, a schematic representation of this exploratory play is shown, based on the interpretation of the seismic line 231-0061.
The second recognized exploratory play that occurs in the area is the structured Albian play. In this case, the Albian horizon, especially the Regency Formation, is structured by the action of halokinesis, which is responsible for the formation of listric faults that generate rollover structures. Additionally, the shales of the Urucutuca Formation act as sealant rocks, allowing the hydrocarbon accumulation.
As we can see in figure 11, the largest thickness of the Aptian-Albian range is in the reddish regions, while the salt domes are in the purple areas, where the thickness of the layer is small. Considering that the salt movement is responsible for the formation of the rollover structures, it is expected to find these folds precisely in the areas of greater thickness, which accommodated the deformation caused by the salt.

Therefore, potential reservoirs of the structured Albian play can be found in red areas of the map, as illustrated in figure 13.

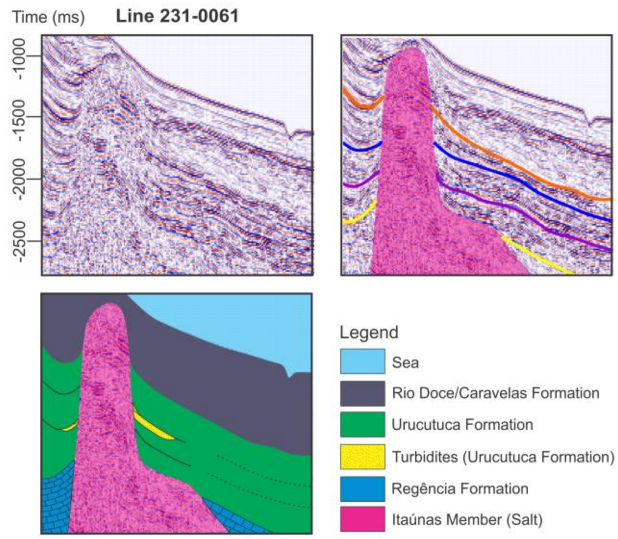

***Figure 12** – Schematic representation of Urucutuca turbidites play based on the line 231-0061.*

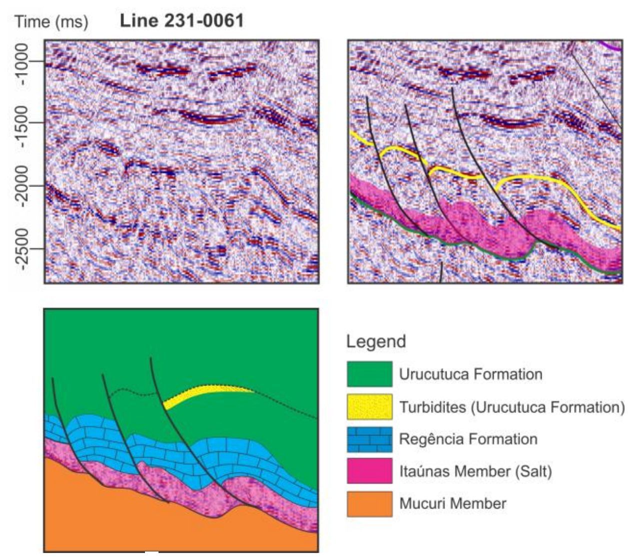

Figure 13 – Schematic representation of structured Albian play based on the line 231-0063.

Conclusions

The central portion of Espírito Santo Basin, near Cangoá and Peroá fields, has different deformation patterns. The extensional tectonic style predominates in the basin, as observed in the interpreted structures, like horsts, grabens, normal faults, listric faults and rollover folds.
It is also concluded that the regional dip of the basin is oriented towards SE and several salt domes are distributed in the region, showing a slight tendency of alignment in the NNE direction.
Moreover, there are two recognized Exploratory plays in the study area: Urucutuca turbidites play and structured Albian play. The first one is characterized by turbidite

reservoirs of the Urucutuca Formation located closed to salt domes, which are responsible for trap the hydrocarbon. The second one are reservoirs formed due to the presence of rollover structures that trap the hydrocarbon.

Acknowledgments

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