Structural and Stratigraphic characterization of Eocene Turbidites in the Southwest portion of Campos Basin, Brazil.

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This paper was prepared for presentation during the 15th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, 31 July to 3 August, 2017.

Abstract

This work aims to approaches the trapping mechanisms that act in the Eocene turbidites of Carapebus Formation, at the Southwest portion of Campos Basin. 2D and 3D seismic data were analyzed, as well as wirelogs from wells distributed along six oil fields: Pampo, Trilha, West Enchova, Enchova, Bicudo and Bonito. The main Eocene deposit was observed in 16 of the 19 analyzed wells, showing highest thicknesses between 90 m and 100 m in the South-central region of Bonito Field. Two main areas with economic potential were found: one at the Western area of Bicudo field, structural traps are dominant, while the border region between Enchova and Bonito fields is characterized by an association of structural and stratigraphic traps.

Introduction

Responsible for about 60% of Brazilian hydrocarbons production in 2016 (National Petroleum Agency ANP), the Campos Basin is located on the Southeastern Coast of Brazil, limited to the North with Espírito Santo Basin by the Vitoria High, and to the South with Santos Basin, by Cabo Frio High. It contains a total area of 115,000 km², of which only 500 km² are onshore.

Oil and gas production in the region began in 1977, from Albian carbonates, located in Enchova field. (Bruhn et al., 2003). Currently, the main reservoirs of the basin consist of Albo-Cenomanian to Miocene turbidites, including the deposits of Eocene age focused in this work. The main objective of the present study is to characterize oil occurrences among the Eocene turbidites found in the Southwest portion of the Campos Basin, in an area that covers six mature oil fields: Pampo, Trilha, West Enchova, Enchova, Bicudo and Bonito (Figure 1). Data from well logs associated with 2D and 3D seismic were used, aiming at describing the mechanisms that conditioned the existence of the traps.

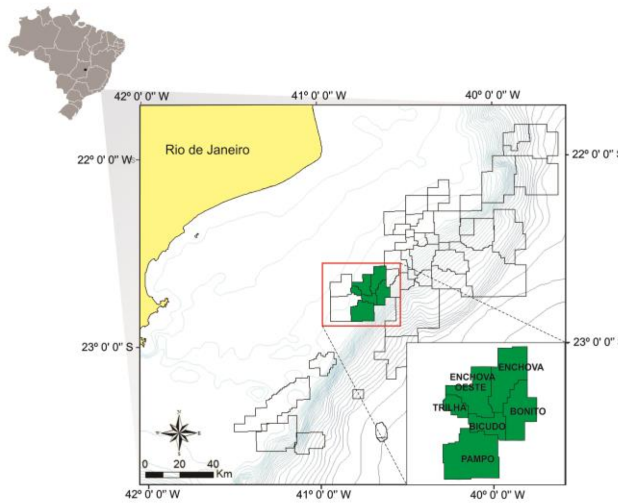

Figure 1: Location map for the six oil fields studied

Data Setting

The data used in this work consist of 19 wells and their respective Gamma Ray (GR), Sonic (DT), Resistivity (ILD) and Density (RHOB) logs, as well as a 3D seismic volume (in yellow) with 90 km² and 25 2D seismic lines, shown in Figure 2. For the interpretation of the data, the Decision Space Desktop software (Landmark) was used.

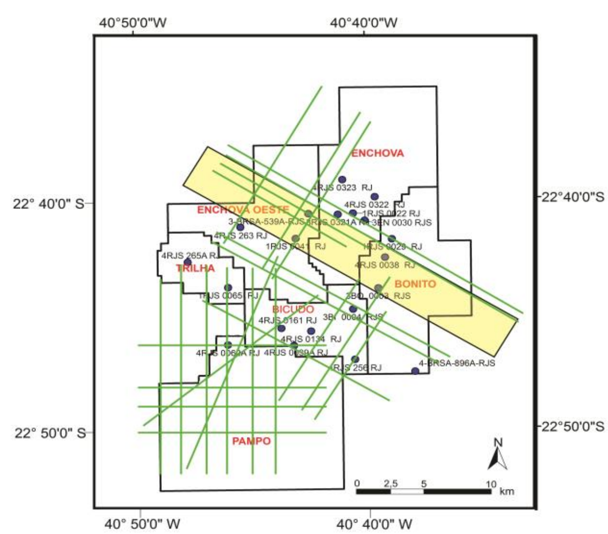

Figure 2: Spatial arrangement of interpreted data.

Methods

The methods and work steps adopted in this work are:

I - Well log interpretation and correlation: The main stratigraphic levels of interest were interpreted and delimited on the basis of patterns and information observed in well logs. Then, these levels were correlated along three stratigraphic sections, expressed in Figure 3.

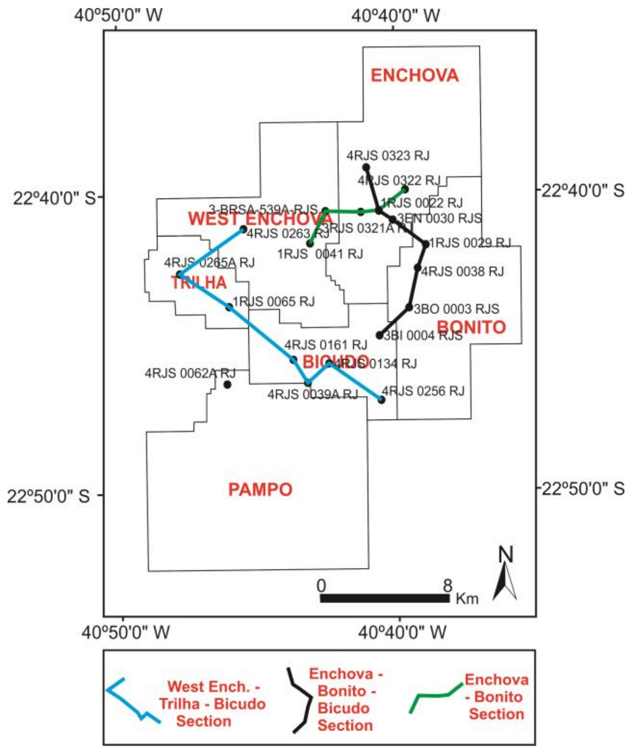

Figure 3: Location of Stratigraphic sections on the studied area

II – Seismic data interpretation: 3D seismic volume and 2D seismic lines were interpreted in the time scale, enabling the identification of stratigraphic horizons and structural features. The top and bottom of the Eocene Carapebus Formation were interpreted, in the midst of the 3D seismic data, in a regular 3 x 3 mesh.

III - Structural and isopach maps: structural and isopach maps related to the Eocenic Carapebus Formation were generated from the subtraction of surfaces interpreted on seismic data, in a meters equivalent scale from the original milliseconds. The objective was reveal the main structures and dominant patterns in this stratigraphyc layer. It is important to mention that the interval velocity of 2680 m/s was applied for Carapebus sandstones.

IV - Structural-Stratigraphic Analysis: The last step is the integration of all collected information and generated results, in order to complete the analysis of the structural and stratigraphic arrangements that controlled the possible accumulations of hydrocarbons present in the stratigraphic level approached.

Results

Stratigraphic Analysis

Three geological sections were used as the base for stratigraphic analysis, all of them being described below.

The West Enchova - Trilha - Bicudo Section (Figure 4) shows the existence of a main turbidite reservoir of Eocene age, defined as EO – I (color yellow in the correlations), that occurs in six of the seven wells of this section. It is characterized by a low Southeast dip and thickening in the same direction, varying from 35 m to 90 m. The Carapebus Formation occurs inserted among pelites of the Ubatuba Formation. The Gamma Ray logs illustrate the contrast between the box pattern presented by the turbidite deposits, which reach mean values of 45-50 API, and the mean of 85 API presented by shales and marls. In this section, it was also verified the presence of an erosive surface that truncates the Carapebus Formation at the NW end of the correlation. This feature developed during the Upper Oligocene, corresponding to Enchova Canyon, detailed by Antunes et al. (1988).

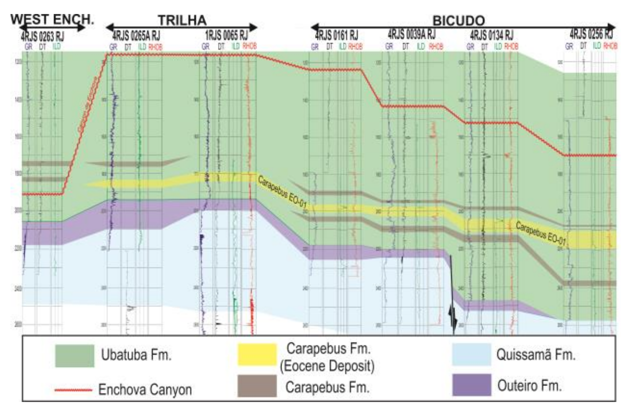

Figure 4: Section West Enchova – Trilha – Bicudo

The analysis of the Enchova - Bicudo - Bonito Section (Figure 5) reveals the presence of two listric faults, wich define the deepening of Carapebus Formation towards the central portion of the correlation (Campo de Bonito), where the largest thicknesses (around 100 m) of sandy deposits occur. The Enchova Canyon truncates the Carapebus Formation in the limit between the Bicudo and Bonito fields, and it is filled by Oligocene-Miocene shales and sandstones.

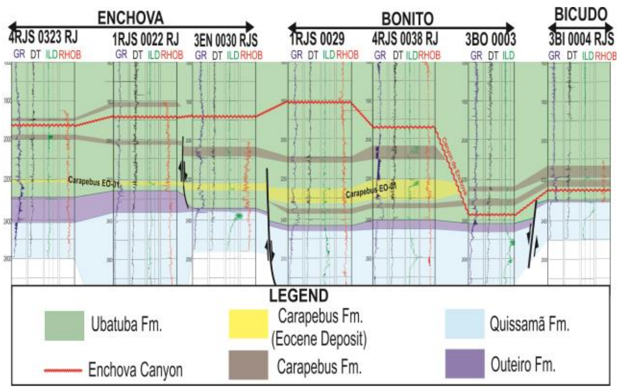

Figure 5: Section Enchova – Bonito - Bicudo

A similar situation occurs in Section Enchova – West Enchova (Figure 6 - strike section). The turbidite deposit shows thickening towards the Northeast portion of the section, where it reaches 50 m. The Enchova Canyon promotes the erosion of the Eocene Carapebus Formation in the West Enchova field region, as observed in well 1RJS_0041.

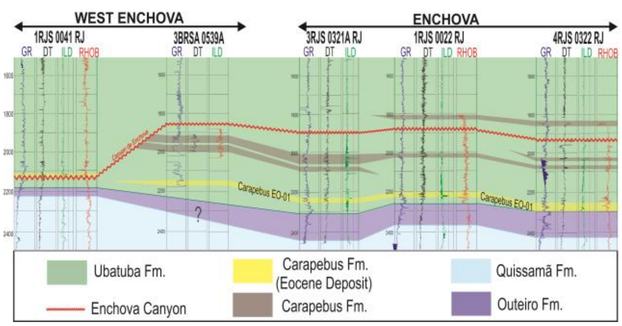

Figure 6: Section Enchova – West Enchova.

Seismic Interpretation

The 2D and 3D seismic interpretation ranges from the economic basement of the basin (Cabiúnas Formation), dating from the Halterivian, to the Siri Member (Emborê Formation) related to Oligo-Miocene age. The horizon that reflects the Cabiúnas Formation corresponds to the last well-marked reflector in the seismic data, while the Lagoa Feia Group is characterized by a succession of plane-parallel reflectors, with alternation between maximum and minimum amplitudes.

The top of the Retiro Formation is represented by evaporites with a well-marked reflector, which geometry is quite varied, related to the saline movement initiated during the Lower Albian (Demercian et al., 1993). The horizons corresponding to the Quissamã Formation reveal diverse amplitude and geometry, reflecting the morphology of the carbonate banks and their faciological variation, as well as the influence of the halokinetic movement on the spatial distribution of this unit. The top of the Outeiro Formation follows a similar pattern as to the shape of the reflectors, with lower variation of amplitudes, generally minimal.

The Eocene deposits of the Carapebus Formation are characterized by reflectors of amplitudes that vary laterally. The changes in amplitudes may be related to the greater or less presence of pelitic lithologies in the middle of the sandy deposit. The upper limit of these deposits is marked by reflectors of minimum amplitude, which represent the shales of the Ubatuba Formation. The top of the interpreted sequence is delimited by the Siri Member (Emborê Formation), represented both at its base and top by continuous reflectors and linear geometry, predominating minimum amplitudes.

As shown in the stratigraphic correlation, the sloping erosive surface representing the Enchova Canyon truncates the Eocene turbidites of the Carapebus Formation in the Northeast portion of the Bicudo field and Southwest of the West Enchova, Enchova and Bonito fields. Figure 7 illustrates, in the latter field, the surface representing the Canyon in the 3D seismic data.

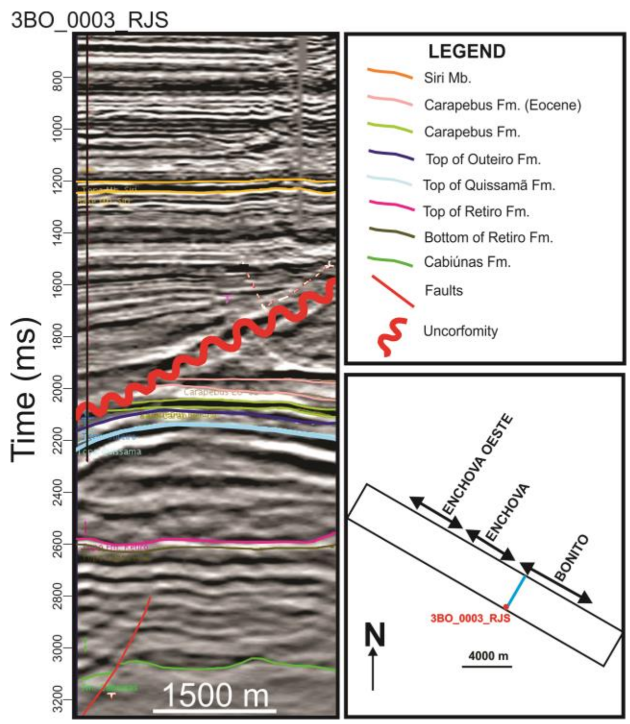

Figure 7: 3D seismic section showing the erosion surface of Enchova Canyon, expressed in red.

Structural and isopach maps

Figure 8 represents the structural contour map, in time, of the main Eocene Carapebus deposit, which occurs along the fields of Trilha, West Enchova, Enchova, Bicudo and Bonito. It shows a low southeast dip, with the hanging wall corresponding to the fields of Bicudo and Bonito, due to the presence of normal fault systems NE-SW, also active in the lithotypes of the Macaé Group.

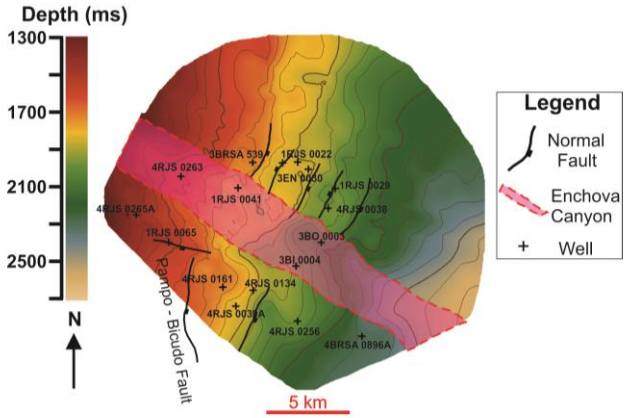

Figure 8: Structural map of Eocene Carapebus deposit, expressed in time (ms).

The association of synthetic and antithetic faults promotes the generation of a horst in the Enchova field and a dome structure in the Bonito region. In pink, the approximate contour of the Enchova Canyon is expressed, inferred from the inflections presented by the isochrones in the central region of the generated map.

The isopach map of the Eocene Carapebus turbidite, exhibited in Figure 9, shows that the thicker sandy deposit occurs in the central-East region of the covered area, in the middle of the Bonito field. The distribution of isopachs lines allows us to interpret two main turbiditic lobes, delimited in yellow (EW lobe) and orange (NW-SE lobe) in Figure 9. For both features, a source area would be situated in the Northeast portion of the sandy deposit, equivalent to the South of Trilha field. It is also important to highlight the area of zero thickness of the Carapebus Formation, expressed in gray color at Figure 9. This zone represents a more accurate delimitation of the Enchova Canyon, which exhibits an erosive channel with a width greater than 3 km.

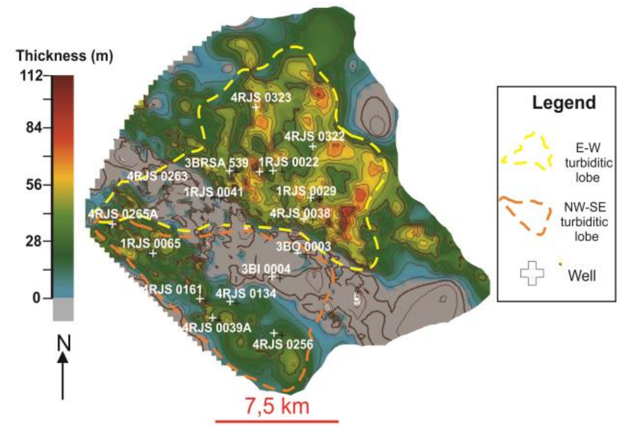

Figure 9: Isopach map of the Eocene Carapebus turbidite, expressed in meters.

Structural-Stratigraphic Analysis

The main Eocene Carapebus turbidite shows its occurrence confirmed in 16 wells, six of which are producers or have economic potential in this interval, according to their respective resistivity logs and well folders: 4RJS_0161, 4RJS_0039A (Bicudo), 1RJS_0022, 3EN_0030 (Enchova), 4RJS_0038 and 1RJS_0029 (Bonito). The integration of geophysical and seismic data allowed the distinction of two main regions with hydrocarbon accumulation, where different trapping mechanisms dominate it.

The first corresponds to the Western portion of Bicudo field, near the boundary with Pampo field, marked by a major fault. Wells 4RJS_0161 and 4RJS_0039A are located in the lower block of this fault. However, as shown in Figure 10, which illustrates a 2D seismic line covering the Northeast portion of Pampo and West of Bicudo, well 4RJS_0039A is situated on the crest of an anticlinal *rollover,* a structure that would have allowed local trapping of hydrocarbons. The spatial proximity between the wells 4RJS_0039 and 4RJS_0161, as well as the constant structural position of the top of Quissamã Formation in both (approx. 2050m), suggests the same context for the oil accumulations in each of them. In this way, the structural character of the traps acting in this region is confirmed.

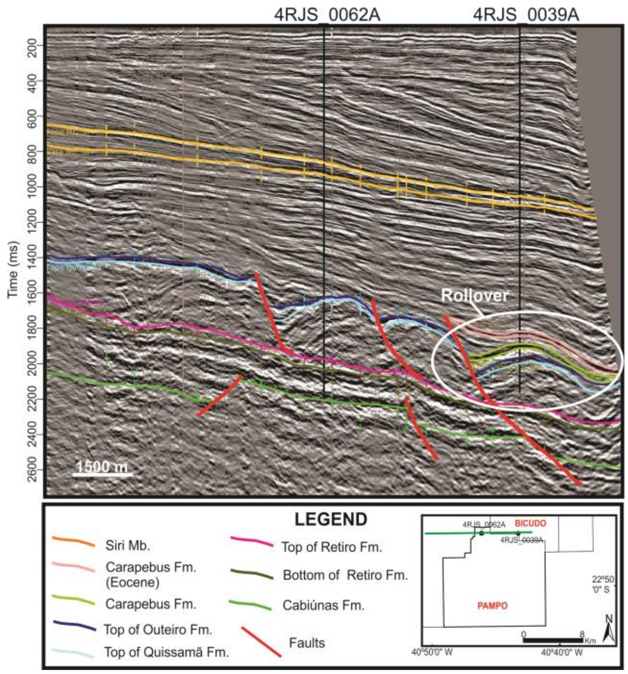

Figure 10: 2D seismic section between Pampo and Bicudo, showing the rollover structure next to the fault separating the fields.

Another area that presents commercial hydrocarbon occurrences is the border region between Enchova and Bonito fields. Two production wells are located in each of these fields; in Enchova, the wells 1RJS_0022 and 3EN_0030 are located inside the horst found in the structural map of the Eocene Carapebus reservoir. In the middle of the Bonito field, the domic feature observed in the same map contains the wells 4RJS_0038 and 1RJS_0029. Figure 11 shows, in detail, the contour map for the aforementioned areas.

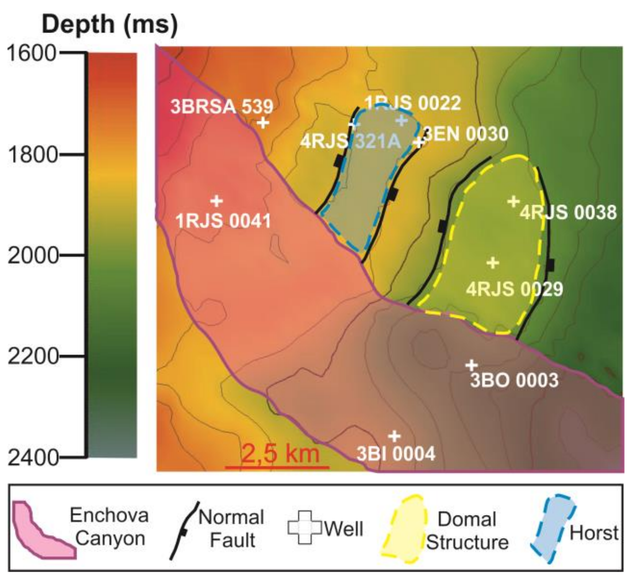

Figure 11: Detailed structural map of Eocene Carapebus deposit, located at the boundary area between Enchova and Bonito fields.

In both cases, the structural context generates elevated features (horst and dome), propitious to the hydrocarbon trapping. The Southern portion of these structures are delimited by the Enchova Canyon, wich erosive surface of Oligocene age truncates the sandy deposits of the Carapebus Formation, as shown in Figure 10. The filling of the channel by pelites from the Upper Oligocene prevented the lateral migration of hydrocarbons, generating a stratigraphic trap. Thus, the combination of structural elements (horst and dome) and stratigraphic (erosion caused by the Canyon) generates a mixed hydrocarbon trap in the area.

Conclusions

The main turbidite deposit of the Carapebus Formation, of Eocene age, occurs in 16 of the 19 wells analyzed, covering the fields of West Enchova, Enchova, Bicudo, Bonito and Trilha. The largest recorded thicknesses of this stratigraphic layer are located at the South-Central portion of the Bonito field, reaching almost 100 m. In the Gamma Ray logs, the sandstones of the Carapebus Formation are characterized by a box pattern, with mean values between 45 and 50 API degrees.

Normal faults of the NE-SW trend are the main structures that affect the Carapebus Eocene Formation, deepening the stratum towards the Bonito and Bicudo fields. Local fault systems generate a horst in the Southern portion of the Enchova field, associated to the East with a dome, located in the Bonito field. The configuration of the isopach lines shows two main turbidite lobes, oriented NW-SE and EW, with probable source area located in the Southern portion of the Trilha field.

Two regions show important petroleum occurrences in the Eocene Carapebus Formation: Eastern portion of the Bicudo field and in the border area between Enchova and Bonito. At first, a structure of the rollover type, located on the lower fault block that separates Pampo and Bicudo fileds, acts as a structural trap for accumulation of gas and oil in two of the wells studied. In Enchova and Bonito, elevated structures (horst and dome) occur associated with the erosive surface of the Enchova Canyon in the Southern portion of these fields, generating a hybrid hydrocarbon trap in four of the studied wells.

Acknowledgements

This research was development at UNESPetro, Center of Geosciences Applied to Petroleum, UNESP, IGCE, Rio Claro – SP – Brazil. We thank Petrobras for the financial support for the execution of this work, and the Landmark for making the Decision Space Desktop software license available. We also extend our thanks to LISG (Laboratory of Integration of Seismic and Geological Data).

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