Seismic interpretation of the main Turbidites at Enchova and Bonito oil fields (Campos Basin - Brazil)

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Abstract

The goal of this research is to evaluate the tectonic-stratigraphic features at Enchova and Bonito oil fields, located at the Southwest of Campos basin (Brazil). The main objective is to characterize the main turbidites reservoirs at these fields. The results were obtained based on geophysical interpretation of the different turbidites reservoir levels at both analyzed regions. The job was developed through the analysis and correlation of four-wells profiles, as well as the interpretation of approximately 1250 km of 2D seismic sections. The elaborated stratigraphic sections allowed the identification and correlation of the main turbidites seismic interest´s horizons; and the interpreted seismic data, in association with structural/stratigraphic contour and isopach maps were generated, and used in the characterization of stratigraphic features, and in the understanding of the Albian-Cenomanian turbidites arrangement.

Through the construction of the maps, it was verified the existence of oil reservoirs in different stratigraphic layer in the Enchova and Bonito fields as Albian (structural traps), and an Albian-Cenomanian turbidites with petrophysical characteristics like "Namorado turbidite".

Introduction

The Campos Basin is located in the Southeastern region of Brazil, occupying the Northern coast of the state of Rio de Janeiro and South of Espírito Santo. The Campos Basin extends over an area of approximately 100,000 km² and it is considered the most prolific in the country, responsible for 57% of the national oil production in November 2016 (ANP, 2016). The limits of the basin are to the North with the Espírito Santo Basin, by the Vitória High and to the South, with the Santos Basin by the Cabo Frio High (Rangel et al., 1994).

The rupture of the Gondwana supercontinent occurred at 200 Ma with consequent origin of the Atlantic Ocean around 130 Ma, resulted in the formation of the Brazilian and African marginal basins. The Campos Basin is a typical basin of divergent margin, coinciding in its general aspects with the evolutionary history of the other basins of the Brazilian East coast. It is considered that the ocean opening started the development of the South-Atlantic Rift (Bueno, 2004).

The evolutionary history of the sedimentary basins of the Brazilian East margin is subdivided into three Supersequences: Rift, Post-Rift and Drift (Winter et al. 2007). The stratigraphic chart of the Campos Basin showing the geological ages of interest of this study area (figure1).

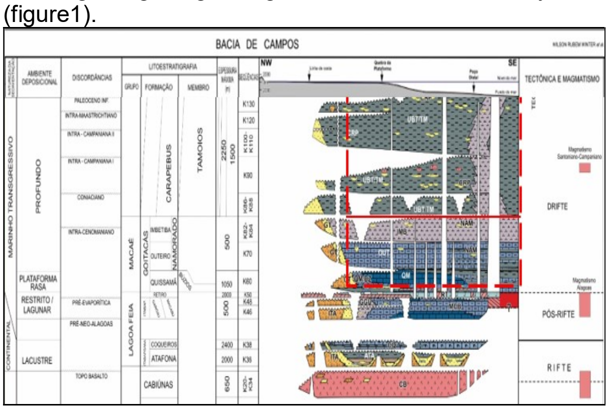

Figure 1 - Stratigraphic chart of the Campos Basin (Winter et al. 2007). The interest Interval is highlighted by the red square.

The Cabiúnas Formation was proposed by Rangel et al. (1994) to designate the basaltic spills, embedded with volcanoclastic and sedimentary rocks, which constitute the floor of all the sedimentary fills of the Campos Basin. Over the Cabiúnas Formation, the Lagoa Feia Group comprises different kinds of terrigenous rocks such as: conglomerates, sandstones, lacustrine carbonates, and black shales (Dias et al. 1988). The Retiro Formation corresponds to the evaporation sequence of the Lagoa Feia Group, playing the role of seal rock for the Pre-Salt reservoirs. The Macaé Group was defined by Schaller (1973) to designate the calcirrudites, calcarenites and calcilutites deposited during the Albian. Based on its lithological characteristics, the unit was subdivided into three formations: Goitacás, Quissamã and Outeiro Formations. Laying over Macaé Group, the Campos Formation was proposed by the same mentioned author. The region focus of this study is located in the Southwest portion of the Campos Basin, including the Enchova and Bonito oil fields. The region inserted in the yellow rectangle of Figure 2 corresponds to the research area. The yellow dots denote the oil wells (1RJS_0131_RJ, 1RJS_0029_RJ, 4RJS_0038_RJ, 3BO_0003_RJS) studied and correlated. The well 1RJS_0131_RJ belongs to Enchova field and the other three wells are located within the Bonito field.

The commercial production of hydrocarbons from the Campos Basin began in 1977, at the Enchova field. The Enchova field shows its main producer levels from post-salt stratigraphic layers. In the case of Enchova, the highest production of hydrocarbons comes from Albian

Quissamã Formation, and, secondarily, Eocene turbidite sandstones from the Carapebus Formation (Lopes, 2004), Bonito oil field also produce from this level.

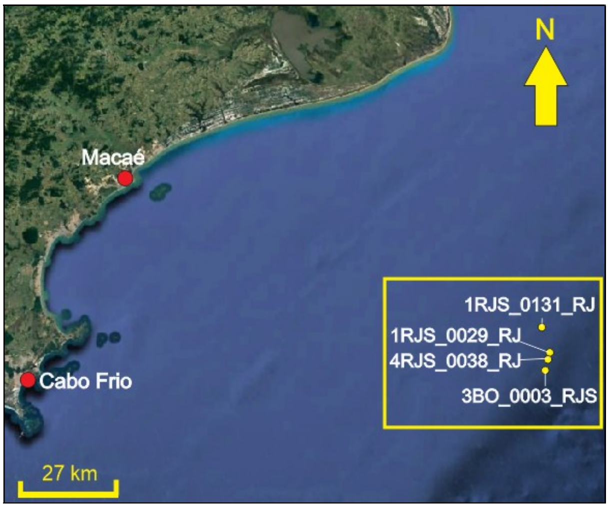

Figure 2 - Satellite image with study area location (modified from Google Earth, 2017).

The oil accumulations, in the study area, occurs mainly in sandstones of the Carapebus Formation (Campos Group), calcarenites (Macaé Group), coquinas (Lagoa Feia Group), and less commonly in the basalts of Cabiúnas Formation (Baumgarten, 1985).

The main objective of this work is the tectonic-stratigraphic characterization of the main reservoirs of the Enchova and Bonito fields, located in the Southwest portion of the Campos basin, through the use of geophysical data and construction of geological maps. This work makes possible the analysis and correlation of well profiles, as well as the seismic interpretation applied to hydrocarbon exploration. Also is possible to analyze the intervals of the study area that constitute potential reservoirs, and to understand the oil arrangement in different rocks in the fields of Enchova and Bonito.

Method

The database used for the research was acquired from the BDEP – "Banco de Dados de Exploração e Produção" of ANP – "Agência Nacional do Petróleo". The provided data is public and free for academic use. The well data obtained for the survey consists of digital ".las" files of the profile records. The set of profiles available for this work is composed of Gamma Ray (GR), Density (RHOB), Resistivity (ILD) and Sonic (DT). The organized database consists of the geophysical profiles of four wells and 1250 kilometers of 2D seismic lines, all of them distributed as showing at the figure 3.

In the following step was carried out the organization and treatment of the data provided by BDEP/ANP to the graphic construction of the well profiles. The files in ".las" were used to make the display of wells profiles (GR, RHOB, ILD, DT). With the profiles available, the process of well correlation was started with the objective of identify the regional distribution of the main stratigraphic layers. Figure 4 denotes the profiles constructed from the ".las" files of the well 1RJS_0131_RJ.

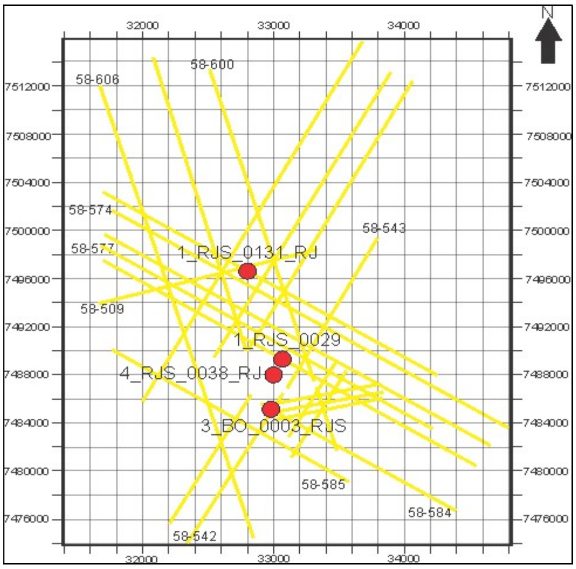

Figure 3 – Geophysical data distribution along the study area. 2D seismic sections (yellow traces) throughout the region covered in this work.

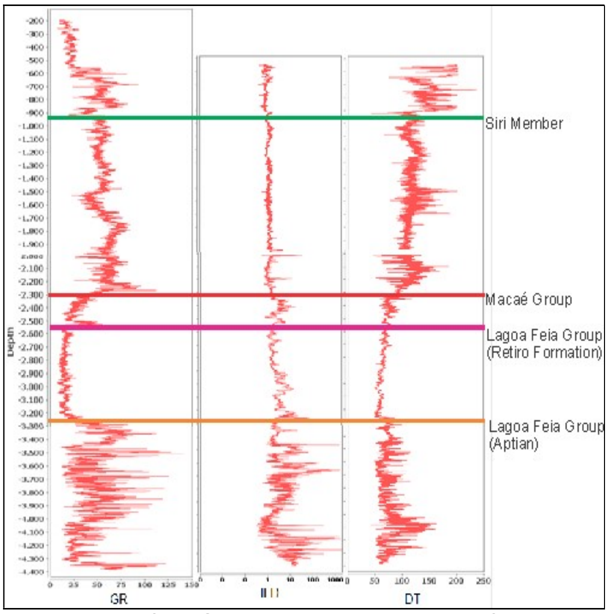

Figure 4 - Profiles GR, ILD and DT generated for the well 1RJS_0131_RJ.

The seismic interpretation has as main objective to deduce information about the behavior of the rocks and their geometric arrangement in subsurface, from the observation of the travel times of the seismic waves. Before the seismic interpretation, the seismic data are calibrated with the profiles of the wells studied. Calibration is required because of the units in which each file is measured. The seismic data are obtained as a function of time (in milliseconds) while well profiling is defined in meters. The time-depth conversion was performed by the calculation of stratigraphic layer depth using the velocity and depth measured on the sonic profile DT.

The well profiles used in the calibration were taken from the well 3BO_0003_RJS and the seismic section used was at 58-584. Figure 5 shows that the well and the seismic section are intercepted; with the aim of map all the horizons along both studied fields.

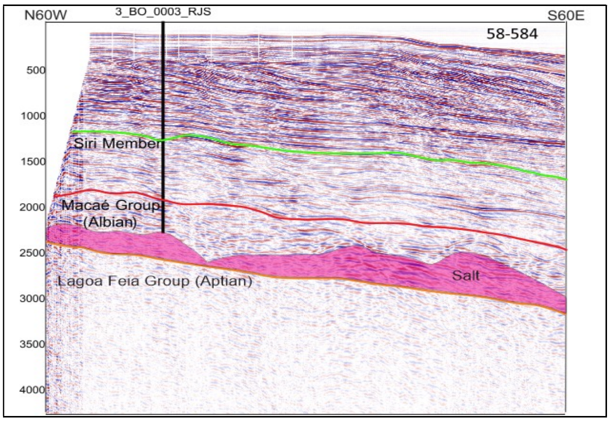

Figure 5 - Seismic section and well used for calibration.

The stratigraphic correlation based on the stratigraphic sections, together with the interpretation of the seismic data, allowed the preparation of contour structural maps of the interest stratigraphic levels: Lagoa Feia Fm., Macaé Gr., Albian-Cenomanian turbidite, Siri Member, and Sea Bottom; and isopach maps for the main turbidite level was created. These products were obtained through the use of the software Surfer 13.

Results

In the stratigraphic section the tops of: Lagoa Feia Fm., Macaé Gr., Albian-Cenomanian turbidite, and Siri Member were correlated as show at the figure 6.

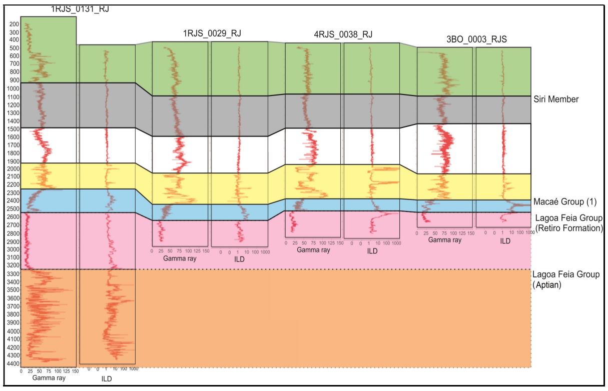

Figure 6 - Enchova-Bonito stratigraphic section.

The yellow portion denotes possible turbidites from Albian-Cenomanian ages. The blue package represents the carbonates of the Macaé Group (Albian). The pink portion of the stratigraphic section can be inferred as salt from the Retiro Formation. The layer with orange color corresponds to the portion below the salt of the Lagoa Feia Group. The top of the orange package represents the Aptian boundary. The layers above Macaé Gr. may denote the presence of turbidites which are potential oil reservoirs as well as the carbonates of the Macaé Group.

In order to illustrate the main features and horizons interpreted along the analyzed seismic sections, section 58-600 was selected to denote such aspects, starting at the North-West at Enchova field and ending at South-East in the middle of the Bonito field (Figure 7).

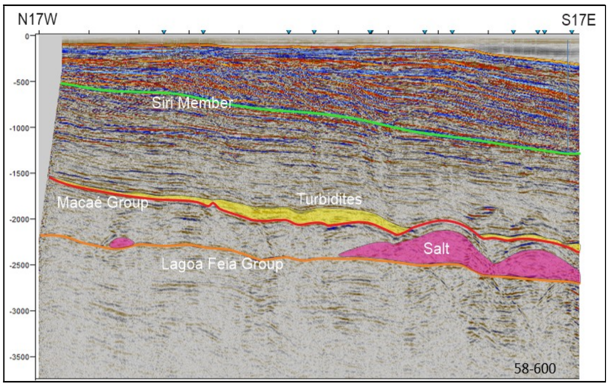

Figure 7– Interpretation of seismic line 58-600.

Few fault systems were observed at the area, some Albian deformation associated with halokinetics were observed, and over the Albian horizon a turbidite of approximately 140 meters was interpreted (yellow body at the figure 7), maybe it would be a main reservoir target at this region.

The contour structural map of the Lagoa Feia Group (Aptian – Figure 8) shows a discontinuity contours between Enchova and Bonito fields that may indicate the presence of a main fault that could represent the boarder of both oil fields.

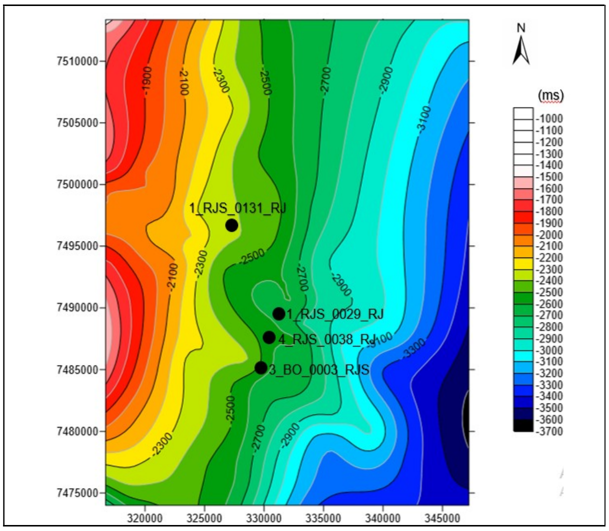

Figure 8 - Structural contour map of the Lagoa Feia Group (Aptian) in time scale.

The structural contour map related to Macaé Group (Albian - Figure 9) shows a local structural trap in Bonito oil field, this kind of oil trapping is not evident on the region of Enchova oil field at North-West, where maybe more seismic data is necessary to identify the main producer carbonatic bank reported for this field.

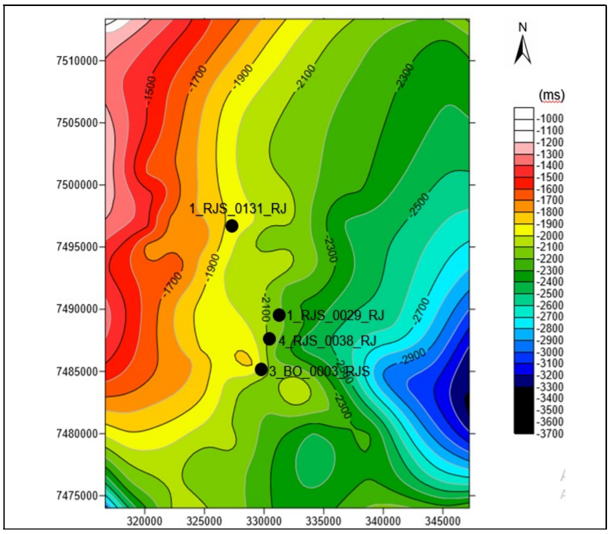

Figure 9 - Structural contour map of Macaé Group (Albian) in time scale.

The structural contour maps of the Albian-Cenomanian turbidite (Figure 10) show a regional dip from the East to the Southeast; and the Isopach map of Albian-Cenomanian turbidites (Figure 11) was also elaborated in order to highlight the turbidites bodies. The Figure 11 shows that the turbidites are not homogeneous along the study area, showing a big lobe over Enchova oil field at the North of the well 1_RJS_0131_RJ; and smaller turbidite lobe at the East of the Bonito wells (1_RJS_0029_RJ, 4_RJS_0038, 3_BO_0003_RJS). This job does not consider the biggest thickness of the isopach map to the Southeast because that information is the result of the extrapolation map, without geological control.

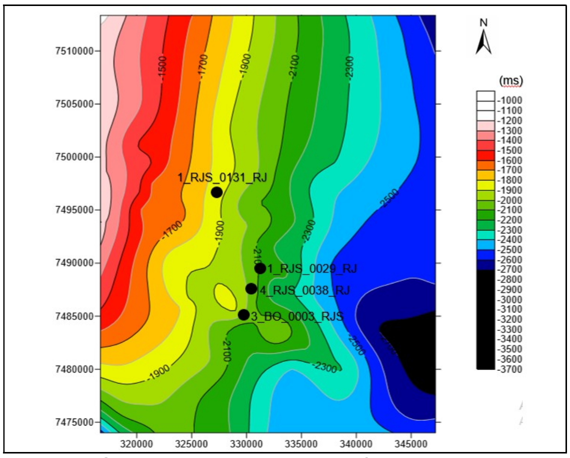

Figure 3 - Structural contour map of the turbidites above the Macaé Group in the Enchova and Bonito fields in time scale.

It was also observed that Macaé Group show great variation of thickness in the region of Bonito field, presenting considerably smaller thicknesses than the adjacent regions. While in the field of Enchova the thicknesses of the carbonates of Macaé Group shows approximately a constant thickness (800 meters); this previous fact indicates that Enchova is a better area to trap hydrocarbon at Albian levels as confirmed by its production history.

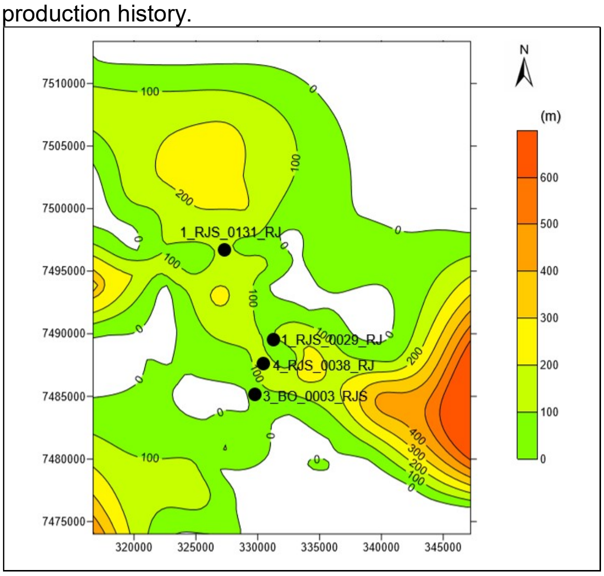

Figure 11 - Isopach map of the turbidite deposits above the Macaé Group in the Enchova and Bonito fields.

Conclusions

Differences were found between the main reservoir levels of the Enchova and Bonito fields. Enchova shows a good distribution of the main reservoir levels identified by this study: Albian-Cenomanian turbidites and calcarenites from Quissamã Formation; both identified reservoir are smaller at Bonito field, it is possible that turbidites younger that Albian-Cenomanian will be reservoirs for Bonito oil field but it was not possible to define it with the available dataset.

The rocks of the Macaé Group show great variation of thickness in the region of the Bonito field, presenting considerably smaller thicknesses than the Enchova field region. While in the Enchova field the thicknesses of the carbonates of Macaé Group present almost a constant thickness (800 meters), representing a good area to trap hydrocarbon for this stratigraphic level.

Acknowledgments

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