Reconstitution of the depositional history of the Baleia Azul Field, Campos Basin: The first step for a 1D petroleum system modelling.

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Abstract

Petroleum systems modelling allows to verify the presence of an effective petroleum systems, by considering all the elements it is composed of source rock, reservoir, seal, trap and all the processes responsible for petroleum generation, migration and accumulation in a sedimentary basin. The geological events occurring in the basin from the moment of its formation to the present conditions are evaluated. Factors such as subsidence mechanisms, deposition and compaction phenomena, thermal evolution of the basin, depositional environment, generation of hydrocarbons and the succession of the expulsion, migration, accumulation and preservation processes of the generated oil or gas are considered. Geochemical data, such as the results obtained through Rock-Eval pyrolysis, are also used for the modelling construction and calibration. This approach is of extreme importance to the oil and gas industry because it describes the petroleum system, provides quantitative assessments of the geological scenario and gives consistency to hypotheses made in relation to the observed data. In this way, petroleum systems modelling is a key element in the reduction of the exploration risks. This work is focused in the reconstitution of the depositional history, one of the most important steps of the petroleum systems modelling of the Baleia Azul Field, Campos Basin.

Introduction

The study area is the Baleia Azul Field, belonging to the Parque das Baleias cluster, a set of oil and gas fields in the northern portion of Campos Basin (Fig. 1). The Campos Basin is a passive margin basin formed from a rift, and is located between the Vitória High, to the north, and the Cabo Frio High, to the south, with an area of approximately 100,000 km² (Pereira, 2015).

The Baleia Azul Field (Fig. 2) is located approximately 80km from the coast of Espírito Santo state with an area of 63.69km², where the water depth varies from ca. 1200m in the proximal area to ca. 1500m in the distal area.

This study proposes to build a 1D sedimentary model to reconstitute the burial history at the area of well 4-BRSA-420-ESS. Then, a geochemical interpretation will be done in order to infer the potential hydrocarbon generation in the region. Both stages are important parts of the petroleum systems modelling.

Geological settings

The thermal evolution of the Campos Basin occurred in two main stages of subsidence. The initial stage occurred between 130-68M with a rift followed by a thermal subsidence with a sedimentation rate of 30m/Ma, high crust stretching factor and high heat flow variation (Cardoso, 2007). The duration of the rift opening was 10Ma. The final stage occurred between 68-0Ma with a sedimentation rate of 19m/Ma, a lower crust stretching factor and a drastic drop in the sediment heat flow.

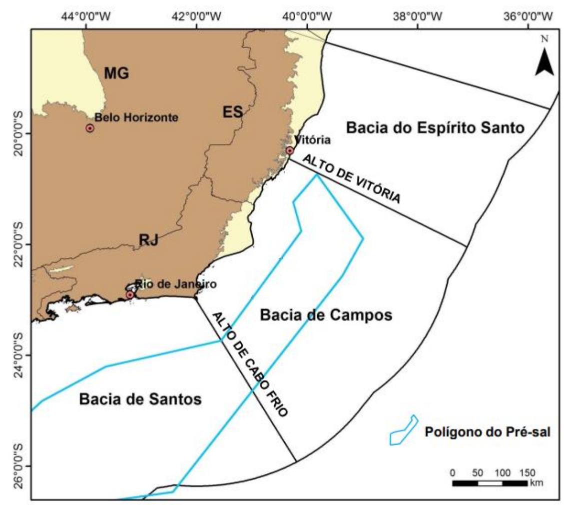

Figure 1: Location map of the Campos Basin, SE Brazil. Modified from Agência Nacional do Petróleo, Gás Natural e Biocombustível (ANP) (Pereira et al, 2015).

The sedimentary deposition in the Campos Basin occurred in 3 main phases (Pereira et al, 2015). The first phase, starting 130Ma ago, was the rift phase with predominantly continental sedimentation over the crystalline basement, composed of medium to high grade metamorphic rocks. The second phase was the transitional phase or sag phase, where the evaporites from the basin were deposited. The third phase was the drift phase, with 3 distinct depositional regimes: carbonate platforms, transgressive marine and regressive marine sedimentation.

The main Pre-salt source rocks in the Campos Basin are the Buracica-Jiquiá shales of the Barremian-Aptian of the Lagoa Feia Group deposited in the rift phase, in a lacustrine environment. The oil generation window in the Buracica-Jiquiá time is estimated between 30Ma and 2Ma, where the depth at the end of the generation window reaches 6500m. Such shales have TOC content of 2-6%, kerogen type I and produce oil ranging from 17-37º API. It is not ruled out the possibility of source rocks among the marine sediments of the post salt (Pereira et al, 2015).

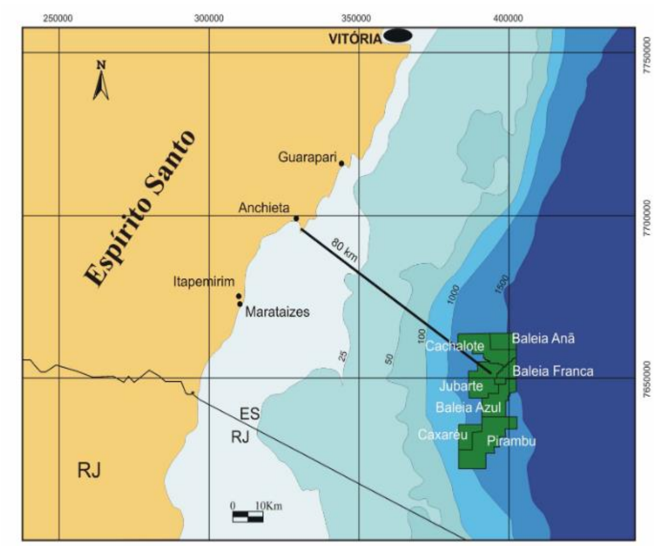

Figure 2: Location map of the Parque das Baleias cluster, Campos Basin, SE Brazil. Modified from ANP/BDEP WebMaps (2019).

The main reservoirs of the Baleia Azul Field are the microbial carbonates of the Macabu Formation (Aptian) and turbidite sandstones of the Carapebus Formation (Santonian-Miocene) with maximum porosity levels varying from 20-32% and permeability between 1D -5D (Pereira et al, 2015).

The seal rocks are shales of the Coqueiros Formation (Aptian), evaporites of the Retiro Formation (Aptian), mudstones and shales of the Outeiro Formation (Albian-Cenomanian), and shales of the Ubatuba Formation (Turonian-recent). The inferred migration pathways are salt windows (where there are no evaporites from the Retiro Formation) or direct or lateral contacts due to faults (Pereira, 2015).

Throughout the evolution of the basin, structural, stratigraphic and mixed traps have been identified: quaquaversal structures, rotated failed blocks, rollover faults, sandy canalized reservoirs (Pereira et al, 2015).

Methodology

The following flow chart was used in this study:

- Bibliographic review concerning the basin evolution and the geothermal data.
- Analysis of the exploration reports.
- Facies determination by well logs interpretation and correlation with 3D seismic data.
- Reconstitution of the depositional model from the seafloor to the basement, based on integration of well logs, seismic data and the geothermal data.
- Reconstruction of the evolution of the basin shape over geological times.
- Calibration of the modelling with geochemical data.

Results and Discussion

Figure 3 shows the depositional and burial history of the sedimentary layers through geological time, using data from well 4-BRSA-420-ESS.

This well reaches the final depth of 3400m in the shales of Ubatuba Formation. For the reconstitution of the model below this depth lithological well data of adjacent wells were used, along with seismic information. The information obtained from the Campos Basin bibliography helped to validate the model. The interval 3530/4260m has the lowest reliability due to large uncertainties regarding integration of well logs and seismic data. For the next step, we are planning to perform a salt restoration for the study area.

Rock-Eval pyrolysis data were only obtained for the interval 2315/2913m and it provided some qualitative analysis about this stretch.

There is signs of oil and gas throughout the interval, according to the well reports. More specifically, oil and gas show in sandstones and only gas shows in shales, marls, and diamictites.

A reasonable TOC content of up to 2% is observed from the analysis of the geochemical logs (Fig. 4). The S2 (generation potential) reaches up to 6 mg HC/g rock and is considered good to poor. Tmax did not reach 440°C in any sample of the sampling interval, showing that it did not reach the oil generation window. It may be considered, at first, that it is an immature section.

Thus, it is inferred that the oil and gas present in the tests and cutting samples from that interval are migrated from deeper sections. However, it is not possible to say for sure because in the 1D modeling the fluid migration study has not been performed.

Figure 5 shows Van Krevelen Type Diagram. High oxygen index (OI) values suggest an organic matter type III. Generally, this type of kerogen has continental origin. Figure 6 shows ''S2 x TOC Diagram'' where was identified, predominantly, a kerogen type II. Generally, this type of kerogen has a marine origin.

Combining the two analysis it can be inferred as probably a marine organic matter with high oxidation level, what would be is consistent with the low TOC values. This oxidation could be due to shallow deposition depth. Another hypothesis is a mixture of continental organic matter brought by rivers and a locally produced marine organic matter.

The next step to be done in this modeling of petroleum systems is to refine the sedimentary model, including a salt evolutionary model, and build the basin thermal conditions. Next, simulations for the model will be performed. Those simulations are going to be recalibrated, using geochemical data, so that it can be accurately confirmed the origin of the oil and gas existing (Pre-salt or Post-salt) and make inferences about the source rocks maturity.

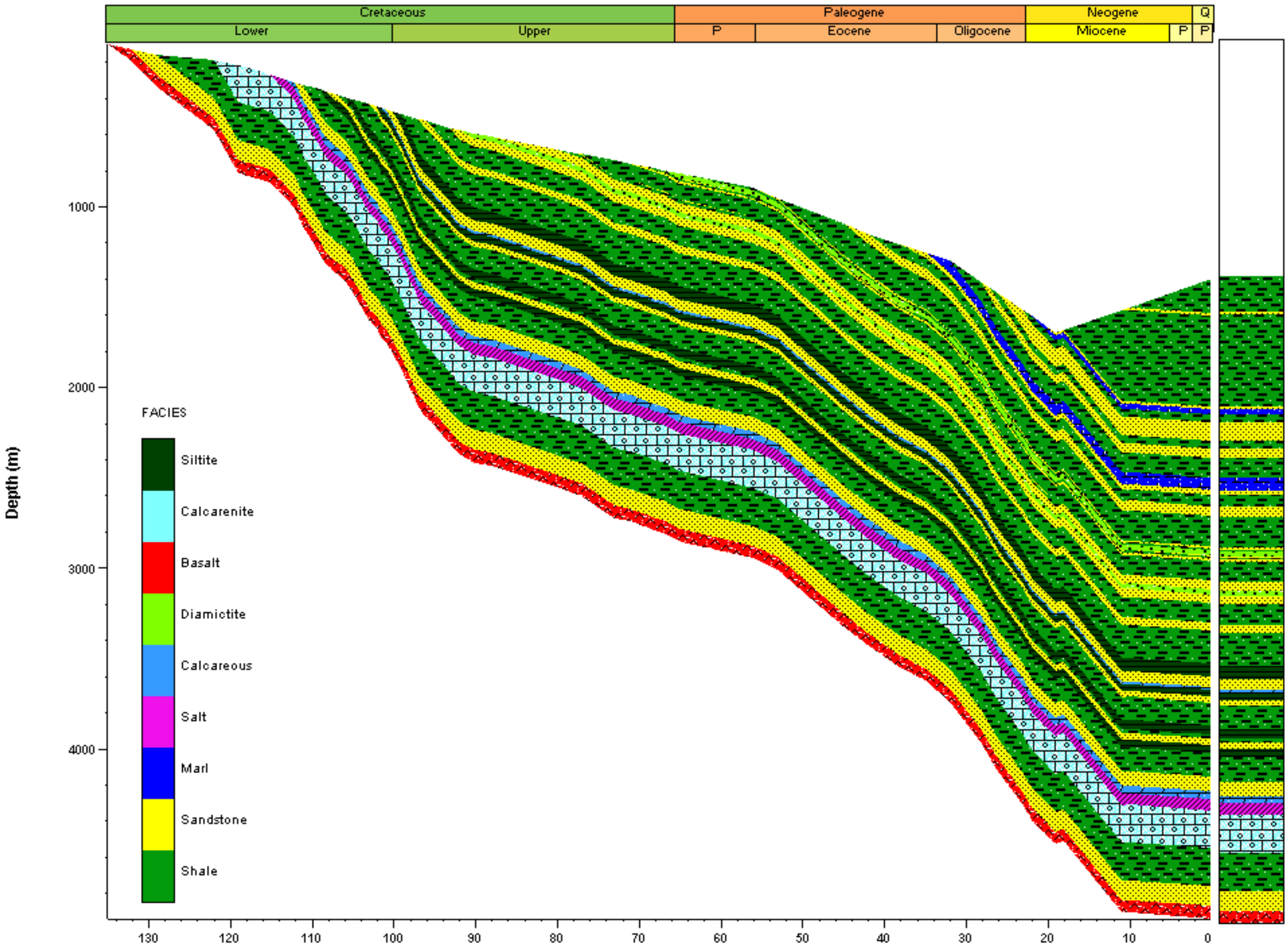

Figure 3: Burial analysis generated from well 4-BRSA-420-ESS. It makes possible an analysis of the evolution basin in a qualitative way. In this burial analysis, the thickness variation of the salt layer was not taken into account. This is a task for the next step.

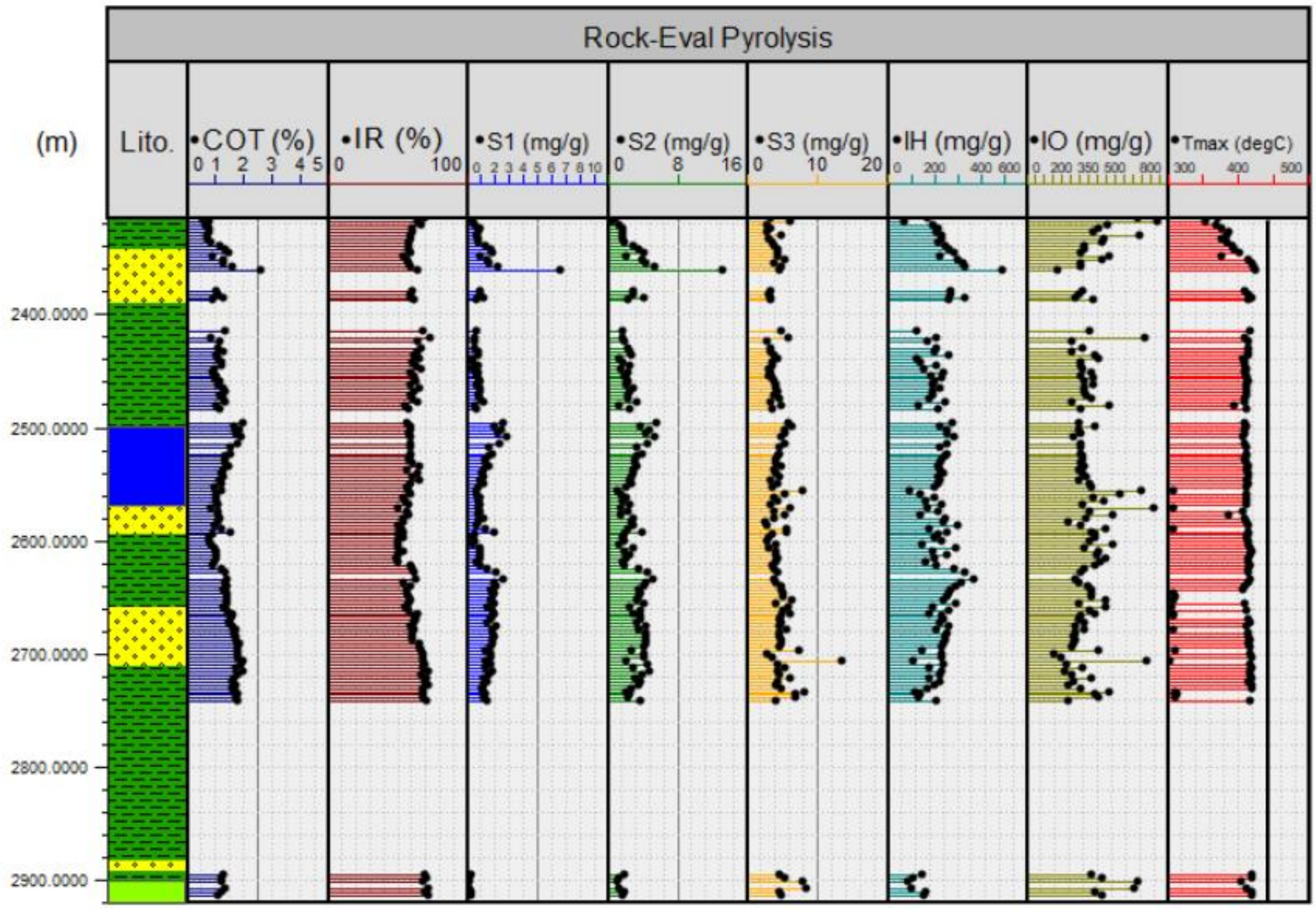

Figure 4: Plot of Rock-Eval pyrolysis geochemical data used in the calibration of the model. The black baseline on the Tmax track represents the beginning of oil generation window (440ºC). This section is considered immature.

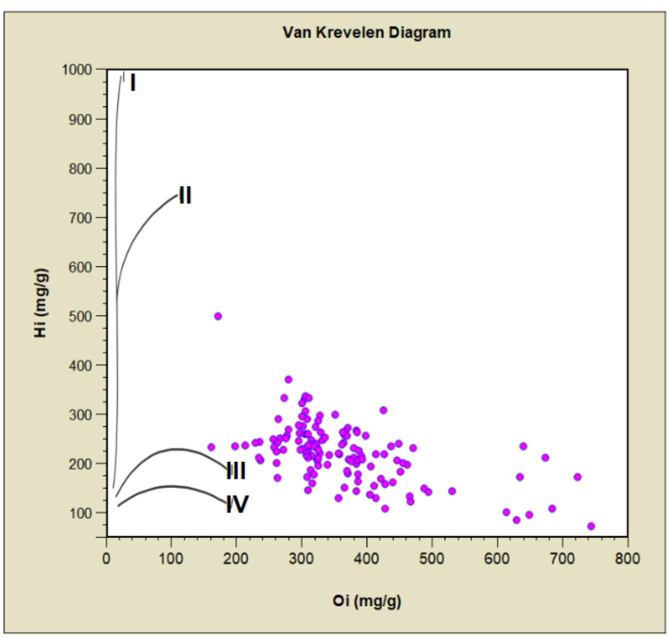

Figure 5: Van Krevelen Type Diagram indicate an organic matter type III. The high oxidation level is indicated by high oxygen index (OI) values.

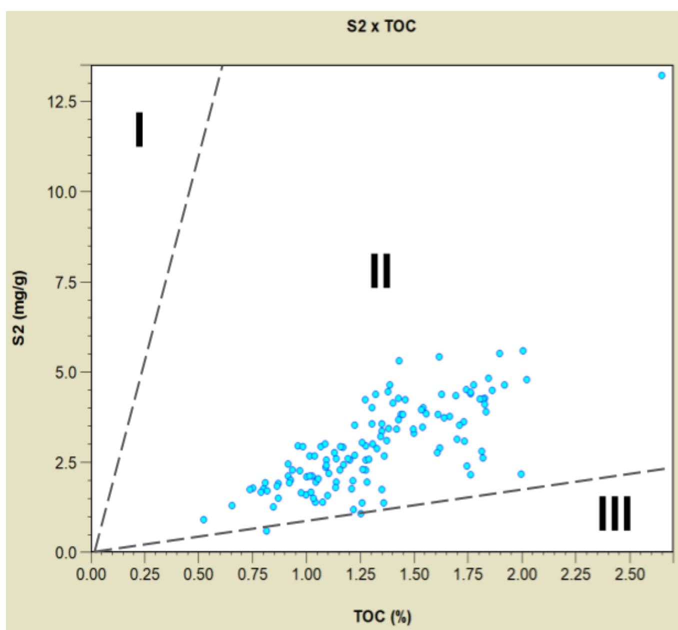

Figure 6: ''S2 x COT'' diagram identifying an organic matter type II for the studied interval.

Preliminary Conclusions

The paleobathymetry has been decreasing due to the sedimentary contribution in this area and to the relative sea level fall. By analyzing the Tmax data it is concluded that the interval 2315/2913 m is immature and did not even enter the oil generation window. The main hypothesis is that the oil and gas present are migrated from lower sedimentary layers. Furthermore, it is necessary to identify the origin of the source rock (Pre-salt or Post-salt). By analyzing the Rock-Eval pyrolysis data the main hypotheses are that the kerogen has a marine organic matter with high oxidation level.

Acknowledgments

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