Sand bodies distribution prognosis combining seismic inversion and rock physics properties – A case study from the Peregrino field

Marisa Makler (Statoil), Eliane Costa Alves (UFF), Raquel Teixeira (Statoil)

Abstract

A significant challenge within the E&P industry is to quantify and reduce the uncertainties in the reservoir description. One of the main goals of reservoir description and modelling is to quantitatively describe petrophysical and geological reservoir properties in three dimensions.

This paper describes how seismic inversion and rock physics models have been combined to better understand the reservoir in the Peregrino Field. The final product is lithology cubes that indicate the distribution of sand and shale bodies.

Introduction

The Peregrino field is located in the southernmost area of the Campos Basin, 85 km offshore Cabo Frio, and about 120 km from Macaé (Fig 1). The first hydrocarbons where discovered by PETROBRAS, in the Carapebus Formation in 1994. The Plan of development and operation was approved in 2007. The field is currently operated by Statoil do Brazil and the production started in April of 2011.

In this part of the Southern Campos Basin, Carapebus sandstones are Cretaceous-aged. It has been interpreted as a deltaic and shallow marine depositional environment and the reservoir intervals consist mostly of gravity driven deposits, intercalated with shales (Avseth, 2008). The reservoir is filled with heavy oil (14º API) with low gas content (13 Sm^3/Sm^3) (Plan of Development, 2007).

The 3D seismic data is used to describe the structural features as well as the geometry and size of the container that contain the reservoir. Conventional seismic amplitude data is difficult to use quantitatively to describe the complex distribution of sand and shale bodies within the reservoir. 3D prestack seismic inversion has been applied in order to calibrate the seismic data to well information. The resulting elastic properties and the combination of these such as acoustic impedance (AI), P-velocity, S-velocity, density, or *Vp/Vs* can then be related to the reservoir properties through petroelastic models.

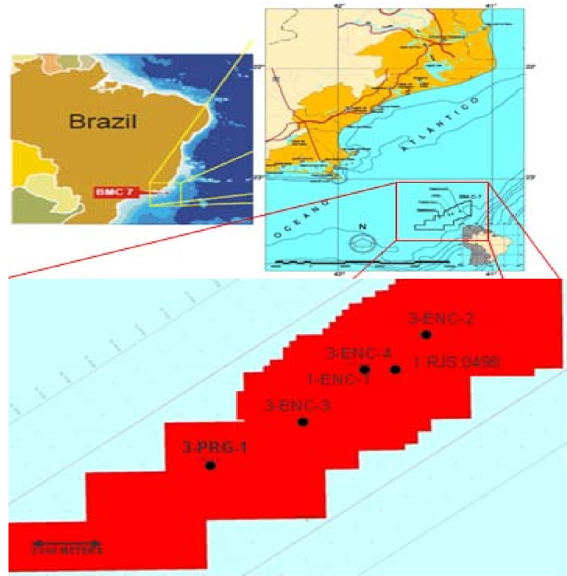

Fig 1 *– Peregrino Field Location*

The objective of this work is to show how seismic inversion can support and improve the characterization of the reservoir, by generating so-called 'lithology' cubes that describe the sand and shale distribution.

Input Data and Methodology

The input data used in this study were a 3D seismic prestack data over the Peregrino Field, seismic inversion (acoustic impedance (AI) and *Vp/Vs* ratio), 5 exploration wells and seismic horizon interpretations. A rock physics model was developed internally in Statoil, specifically for Peregrino field. For the detailed analysis, an area of 67 km² around some exploration wells was selected. The location of the exploration wells and the seismic interpretation of Top Carapebus are shown in Fig 2.

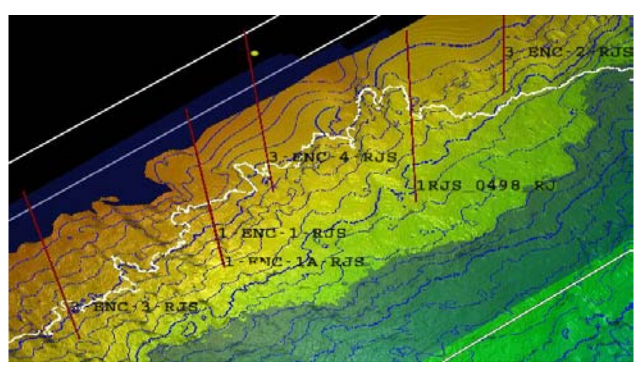

Fig 2 *– Top Carapebus seismic interpretation and location of exploration wells.*

The simultaneous inversion method used here is base on Dillon et al., 2004, where different angle stacked volumes are inverted simultaneously to obtain P and S wave impedance using Zoeppritz or Aki e Richards. This procedure was applied in this work to generate elastic attributes allowing the interpretation of Formation Carapebus sands.

The rock physics model that was developed for Peregrino field is shown in Fig 3. The blue lines curves represent the porosity. The upper curve represents the shale trend; the circles connecting the middle and lower line represent saturation change from 100% water filled to 100% gas filled sands. Better and cleaner reservoir would also tend towards the lower line. As Peregrino reservoir is heavy oil content we use the trend line close to the brine case. The pink circle represents the sandstones, the green marks the shales and the blue marks the cemented material and carbonates. The well points in the cross plot are color coded by Gamma Ray, the well log to the lefit in the figure is the acoustic impedance..

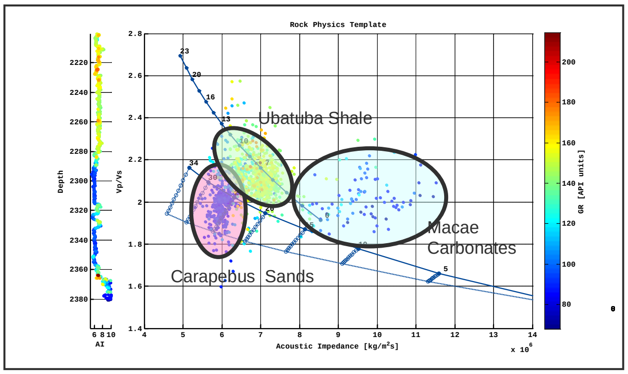

***Fig 3** – Peregrino rock physics template (RPT)*

In this study, the use of a rock physic template (RPT) shows that there is a good separation of sand and shale responses based on a crossplot of the elastic parameters: acoustic impedance and *Vp/Vs* (Peiro, 2009). The crossplot shows that the discrimination between sand and shale is better when including both AI and Vp/Vs compared to using only one of the seismic parameters.

Development

In order to identify the different lithologies present in the exploration wells, polygons corresponding to different lithologies were defined based on the RPT model and well logs information. In the Fig 4, the orange polygons are associated with high porosity sands (over 22%) and low AI (lower than 8000 (m/s)*(g/cc)). Moreover, the dark orange indicates better sand than the bright orange. The dark green polygon indicates shales, characterized by high Vp/Vs, and the bright green is a transition zone between sand and shale. Finally, the beige polygons represent cemented rocks and carbonates. The RPT model was superimposed the well data in Fig 4 to verify the correlation with these polygons.

A quick, but effective, quality control of this classification is done by checking the results in each well using GR, density, AI, Vp/Vs and porosity logs. (Fig 5)

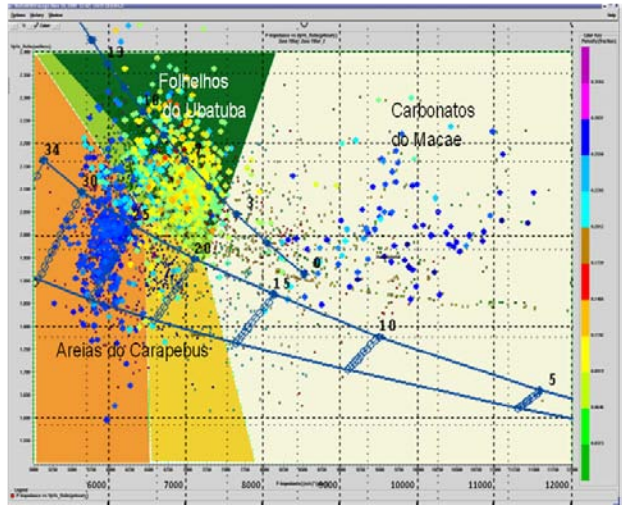

***Fig 4** – AI vs. Vp/Vs crossplot. Lithology polygons are superimposed the RPT model. The points are wells log information and the color scale is porosity values.*

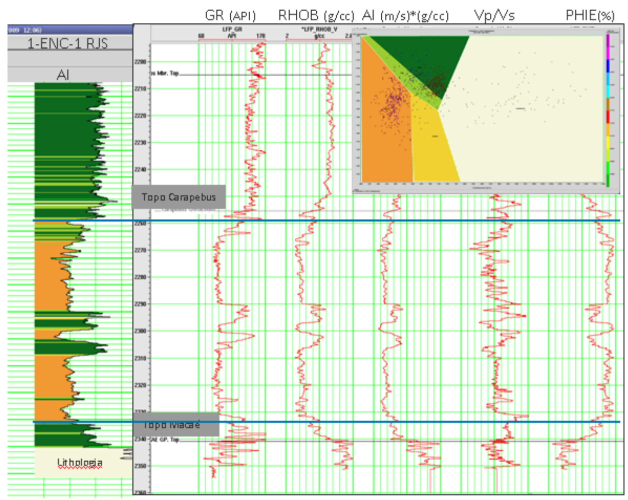

***Fig 5** – Quality Control for 1-ENC-1.*

Fig 5 shows that the polygons that were selected distinguishes very well the two sand intervals with a thin shale layer between them in the 1-ENC-1 well.

The next step consisted in generating a seismic inverted AI versus Vp/Vs crossplot. The lithology polygons were classified based on the porosity curves from the RPT model. These polygons have different limits compared to the ones based on the well information because we have less confidence and resolution on the cube resulting form the inversion. Therefore we need to include uncertainties ranges that weren't present on the previous polygons definition. The seismic polygons were classified as different qualities of sand and shale. (Fig 6 and 7)

Results

As a general result (Fig 7), it was noted that upper sand package was well described by the seismic model, while the lower sands are not predicted as well. This is partly caused by the strong impedance contrast to the high acoustic Macae formation below which causes tuning effects, and smearing of the AI, but also the lack of sufficient seismic resolution (Fig 8).

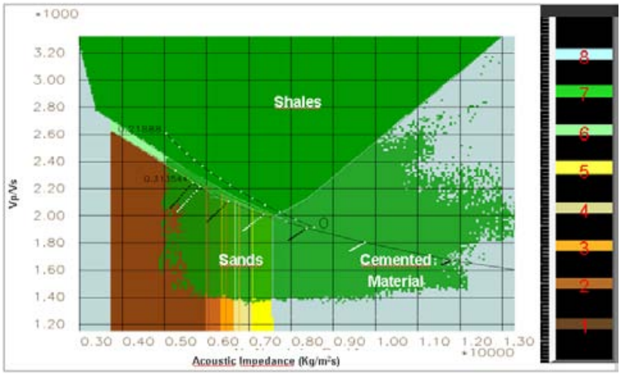

***Fig 6** – Seismic AI vs Vp/Vs Classification. Facies 1 – 5 represent sands, 6 is a transition zone, 7 is shale and 8 is cemented material.*

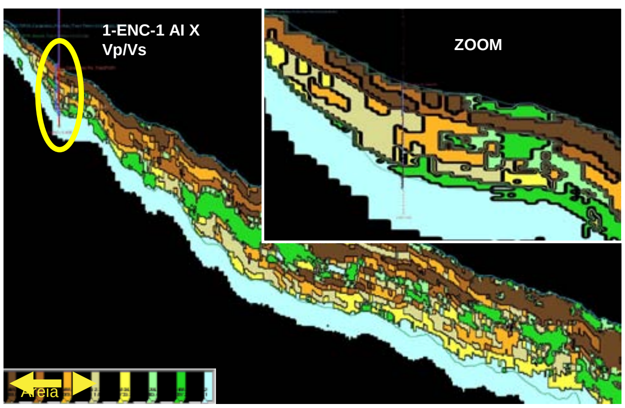

***Fig 7** – RPT model applied in a Dip direction Crossline through 1-ENC-1 well.*

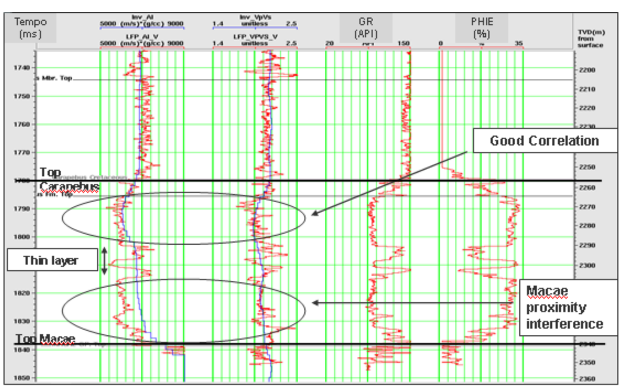

***Fig 8** – Comparison between 1-ENC-1 logs and seismic inversion information.*

A second model was developed as an alternative and simpler classification more in line with the geological facies. This model is based on the facies description obtained from well logs, where it was classified regarding cutoff of porosity and Vsh (Table 1) and seismic inverted volumes.

	Porosity	Vsh	Lithology
Facies 1	> 22%	< 0.15	Sands
Facies 2		< 0.50	Bioturbated sands
Facies 3		> 0.50	Non Reservoir

***Tab 1** –Cutoffs for reservoir facies determination.*

Fig 8 shows a crossplot of AI vs. Vp/Vs well logs data colored by facies classification. Facies 1 is highlighted in Fig 9 characterized with low AI and low VP/Vs ratio. Facies 2 and 3 both have higher AI and higher Vp/Vs.

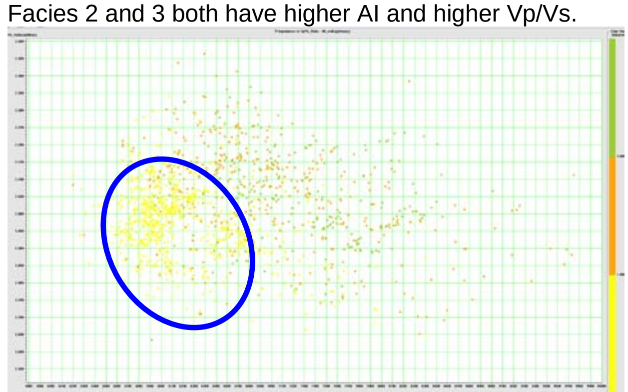

***Fig 9** –Well logs AI x Vp/Vs colored by facies classification*

The AI vs. Vp/Vs crossplot shown in Fig 9 was taken as an initial point for generating a facies volume. Beyond the facies 1, 2 and 3, it was classified an intermediary area and a carbonated and cemented material area (Fig 10).

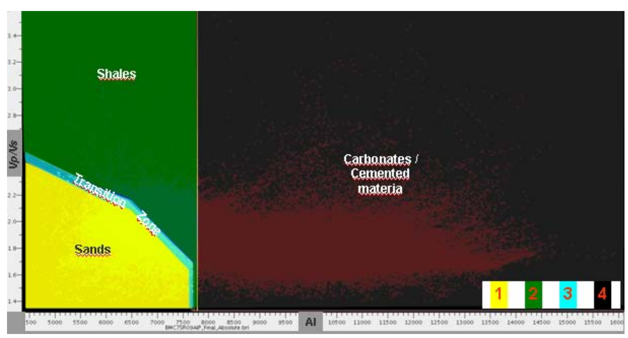

***Fig 10** – Facies polygons representation superimposed on AI vs. Vp/Vs seismic data.*

This facies model was also compared to the RPT in a similar way as before.

The final facies volume obtained from this classification is shown Fig 11. The crossline passing through 1-ENC-1 well shows the both upper and lower sand package and the thin shale layer in between. It's also possible to see that in the lower sand there is an area classified as transition zone which again shows the difficulty modeling the zones adjacent to the Macae formation.

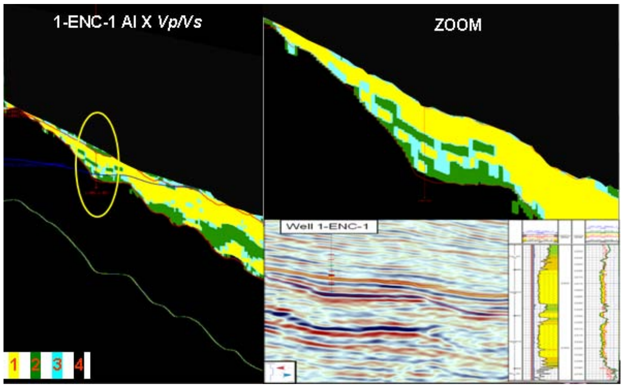

Fig 11 *– Facies model applied in a Dip direction Crossline through 1-ENC-1 well.*

Conclusions

The integration of a rock physics template and seismic inversion data have been used successfully to classify facies in Peregrino upper Carapebus sand reservoir.

The current seismic inversion and the high impedance contrast of the Macae formation limits the accuracy of facies prediction in the lower part of the reservoir.

The facies classification in combination with other data is actively used in the planning of new wells on the Peregrino field.

Acknowledgments

The authors are grateful to the Peregrino licence owners: Statoil do Brasil and Sinochem for allowing this paper to be published, and Laboratório de Geologia e Geofísica Marinha (Lagemar, UFF) for technical support.

References

AVSETH, P. Peregrino RPT Analysis. STATOIL (relatório interno). 2008.

DILLON, D.L, VASQUEZ, G.F. SCHWEDERSKY, N.G. & VELLOSO, R.Q. Atributos DHI (Indicadores Diretos de Hidrocarboneto) obtidos a partir do dado sísmico pré-empilhamento:uma análise integrada da rocha à sísmica B. Geoci. Petrobras, Rio de Janeiro, v. 12, n. 1, p. 149-173, nov.2003/maio 2004.

PEIRO, M. Peregrino – Statoil Simultaneous Elastic Inversion. Oslo Processing Center - Reservoir Services Department CGGVeritas Project Nº103n1qf. 2009.

PLAN OF DEVELOPMENT – Peregrino, STATOIL (relatório interno). CONTRATO ANP Nº 48610.003887/2000. 2007.