Combining seismic facies analysis and well Information to guide new interval velocity models for a Pre-Salt study, Santos Basin, Brazil.

Talles Barsanti Meneguim* (Petrobras), Soraia Carlos Mendes (Petrobras), Alexandre Rodrigo Maul (Petrobras), Lívia Falcão Fernandes (Petrobras), Maria Gonzalez Farias (Paradigm) and Gerardo Gonzalez (Paradigm).

This paper was prepared for presentation during the 14th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, August 3-6, 2015.

Abstract

Since 2006, several extraordinary hydrocarbon discoveries occurred in the pre-salt section of Santos Basin, Brazil. During this period, the good quality of the seismic data exerted a fundamental role to the rather impressive exploratory results obtained.

The reservoir characterization process to field development purposes requires a higher precision and resolution of the seismic data, to better image the reservoirs and reduce project uncertainties. With this goal, several efforts are made to improve the seismic acquisition and processing consistency.

In this paper, we will show an approach that used the sonic and density logs and cutting samples in order to build a 3D probabilistic facies model to create a velocity model with a stratified salt layer.

This better salt modelling can allow several applications, as following: i- perform a more accurate illumination study; ii- do a better uncertainty analysis regarding depth positioning; iii- improve geomechanical modelling, once there are several different salt types and a good positioning of them inside the salt section; and iv- reprocess the seismic data (PSDM, RTM) with a more realistic velocity model.

Introduction

In Santos Basin, Brazil, several oil and gas discoveries took place in the pre-salt section in the last few years.

Discoveries were based on high technology seismic datasets. Currently, in order to obtain the best reservoir characterization, discoveries are taking advantage of new acquired data.

During the appraisal stage, the seismic interpreters use all the available seismic data in order to build the best seismic reservoir scenario. Besides, they start to evaluate the possibility to acquire a new seismic survey with any improved seismic reservoir parameter.

The first thing to do in order to have this new data is perform a good illumination study to simulate the best geological image derived from the seismic data.

The reservoirs from the pre-salt section of Santos Basin, Brazil, normally are in a complex environment, mainly due to structural aspects, below the salt section, and salt stratification in salt section, impacting seismic velocities.

Most of the velocity models used for the existing seismic data can be improved regarding the heterogeneities within the salt section (Falcão *et al*, 2014 a, b). Therefore the illumination studies using these models will not return an accurate image as the way-path used did not represent the geological reality (Figure 1). Jardim *et al*, 2014 and Maul *et al*, 2015 have shown the importance of including salt stratification in order to obtain the most realistic result from illumination study.

In this paper we will present a probabilistic approach to generate a heterogeneous salt section using seismic facies analysis to guide an interval velocity model for a pre-salt section in Santos Basin.

As conclusion, it would be easy to verify that we can not use any simple velocity model for such complex area in order to perform illumination study, depth positioning analysis, seismic inversion, geomechanics studies and to reprocess the data (PSDM, RTM).

Methodology

The proposed method is a derivative approach based on Maul & Falcão (2014). These authors have suggested this technique when they were try to identify and also to quantify the differences among the forecast and the obtained results after drilling the wells for the Pre-Salt reservoirs in Santos Basin (Maul et al, 2014).

The adaptation here presented suggests the usage of frequency support as constrains for the velocity modeling (Figures 2 and 3).

Besides, this paper also considers a facies study analysis in order to build this stratified velocity model.

As we will show, this technique allows us to generate a good stratified velocity model using a probabilistic approach, which is a key point for the illumination study (Figures 4 and 5) for complex areas, as well as three interval velocity models taking the average, the minimum and maximum interval velocity for each rock type allowing to perform the uncertainty analysis regarding gross rock volume above the oil-water contact.

Example

One example of this method is shown through the following images, where it is possible to see the way-path results delivered from two velocity models: a homogenous/constant one (A) and with salt stratified (B).

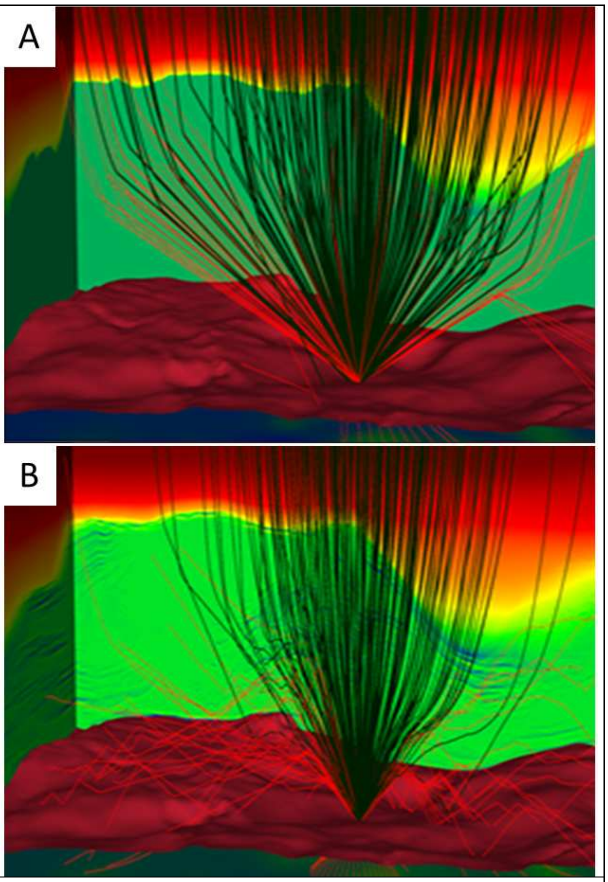

Figure 1: Ray tracing (A) Homogenous Velocity Model; (B) Stratified Velocity Model (Courtesy of Paradigm®).

Results

The sonic log (in the log frequency) and the described cutting sample are presented showing a good match between them. The same match is observed applying any filtering process in the sonic logs (Figures 2 and 3).

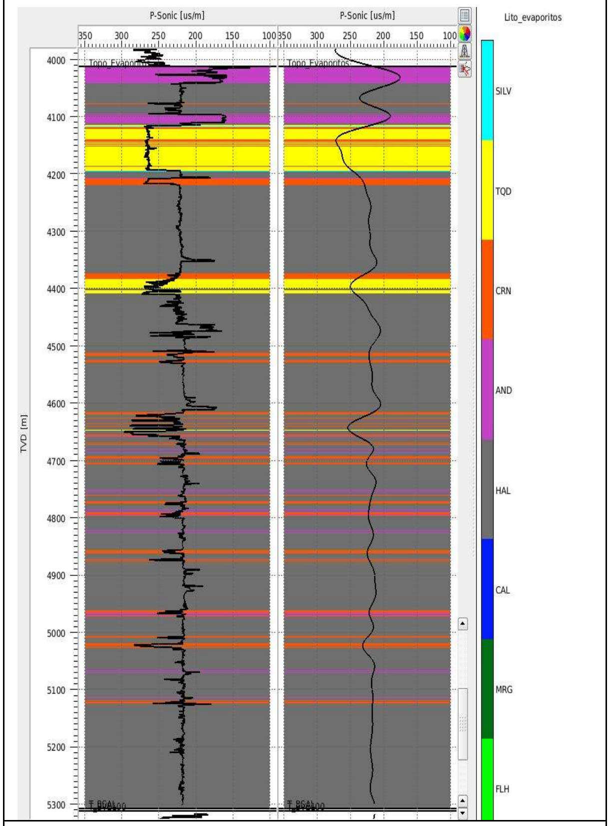

Figure 2: The response regarding the well log and seismic frequency supports against the cutting sample description illustrating a great similarity for both supports.

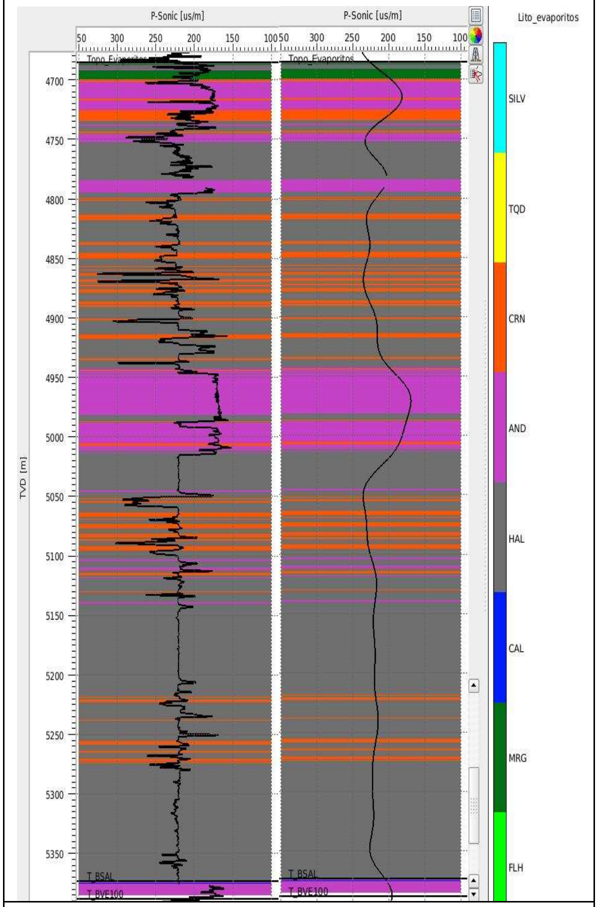

Figure 3: Another well showing also the high similarity between both supports for the response regarding the well log and seismic frequency supports against the cutting sample description.

In both wells is possible to verify the correlation between sonic log and cutting samples. This correlation is preserved over the logs (original sample rate and the lower seismic frequencies) against the cutting information.

After re-sampling the well logs in the seismic frequency, it would be possible to discriminate four velocity classes and those having the average (base case or P50), the pessimistic scenario (P90) and the optimistic one (P10), regarding only the Gross Rock Volume (GRV) above the oil-water contact (Figure 4).

The average value for each class was used to generate the input for the illumination study as well as to generate the P50 scenario for the GRV. For the P10 scenario was used the minimum velocity values and for the P90 one was used the maximum velocity values.

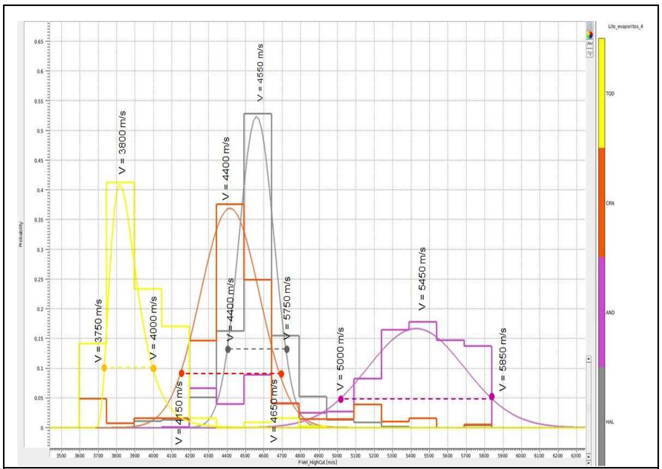

Figure 4: The Probability Density Function of the well log velocity in the seismic support emphasizing the used velocity for the three built interval velocity models.

In order to illustrate the results, it is presented the difference between: the original salt-section velocity model, which represents a homogenous or constant velocity model for the salt section (Figure 5); and the seismic section obtained for stratified velocity model applying the suggested methodology (Figure 6).

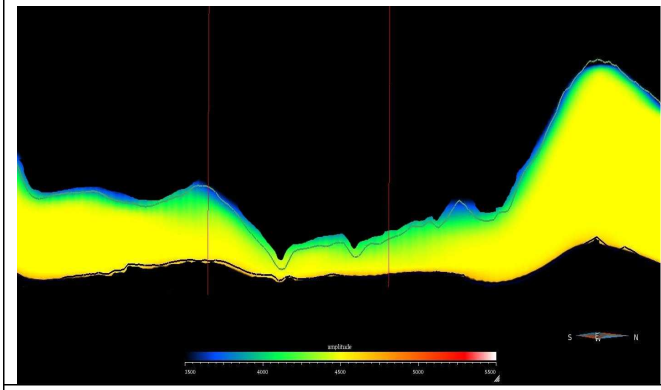

Figure 5: Original salt-section velocity model.

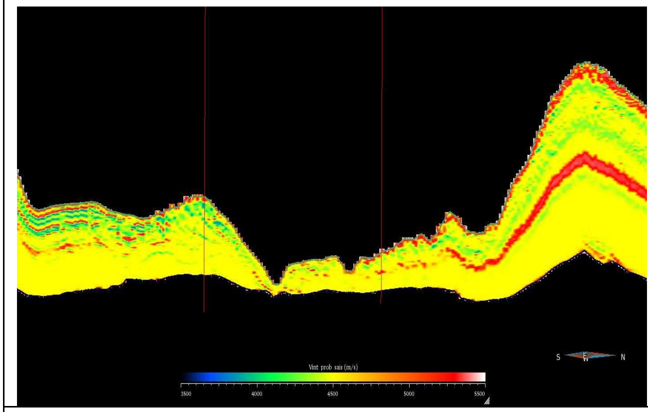

Figure 6: Stratified salt-section velocity model.

Conclusions

As expected, the obtained results provide a more realistic velocity model for the salt-section in the studied area.

This model reflects the salt heterogeneity within the salt-section as found when drilling wells in this areas as well as in several other areas in Santos Basin.

The generated scenarios, regarding gross rock volumes used in this methodology, seem to be more realistic for uncertainty analysis than using the original velocity model as input only.

Acknowledgments

The authors would like to express their gratitude to Petrobras to give all needed support to this study as well as to allow its publication. Special thanks must be given to Rubens Caldeira Monteiro and Walter Becker Maciel for his time and valuable comments when preparing this paper.

References

Falcão, L., Maul, A.R., Novellino, V.S. & Gonzalez, G., 2014 – Construção de Modelos Geológicos de Velocidades. Aplicações em: Estudos de Iluminação, Reprocessamento e Geração de Cenários de Reservatórios. XIV SIMGEF (Simpósio de Geofísica da Petrobras – Internal Publication), Vitória – ES – Brasil.

Falcão, L., Maul, A.R., Novellino, V.S. & Gonzalez, G., 2014 – Construção de Modelos Geológicos de Velocidades e suas Aplicações. Seminário: Métodos e Metodologias Aplicados à Geomecânica (CENPES/Petrobras – Internal Publication), Rio de Janeiro – RJ – Brasil.

Jardim, F. Maul, A.R., Falcão, L. & Gonzalez, G., 2014 – Análise de Incertezas de Reservatórios da Seção Pré-Sal utilizando Estudo de Iluminação (Hit-Maps). XIV SIMGEF (Simpósio de Geofísica da Petrobras – Internal Publication), Vitória – ES – Brasil.

Maul, A.R. & Falcão, L., 2014 – Velocity Analysis from Sonic Logs, Cutting Samples and Seismic (Petrobras Internal Report).

Maul. A.R., Falcão, L., Oliveira, F.C. & González, M. L. A. 2014 – Modelagem Geológica de Velocidades Sísmicas Utilizando o GoCad/SKUA (Petrobras Internal Handout).

Maul, A.R., Jardim, J.S., Falcão, L. & Gonzalez, G., 2015 – Observing Amplitude Uncertainties for a Pre-salt Reservoirs Using Illumination Study (Hit-maps). 77th EAGE Conference and Exhibition 2015 in Madrid, Spain.