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Brazilian Pre-Salt Gross-Rock Volume Uncertainties: Integration Between Velocity Model and Seismic Resolution

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Summary

The reservoir characterisation and project development in Pre-Salt reservoirs in Santos Basin, Brazil, represent big challenges to the geoscientists. This is mainly due to the lack of well information, its quality and resolution support related to the seismic data, generating depth uncertainties regarding velocity modelling. Aiming to analyze and quantify the impact of parameter uncertainties in the structural model, two different approaches to build velocity models were applied. The first scenario utilizes a constant velocity value of 4,500 m/s in all salt section. The second scenario considers different velocities of the stratified salts to build the velocity model. For each scenario, a set of 300 realizations was created, to account for the uncertainties in the structural modelling and were analyzed based on their Gross Rock Volume (GRV). The differences between the pessimistic and optimistic realizations were close to 1.6% and 2%, for scenarios 1 and 2, respectively. These differences represent considerable GRV volumes variation of approximately 3.109 m3. Additional parameters such as Net-to-Gross (NTG), porosity and oil saturation, can also influence oil reserve calculations, and should be included in future uncertainty studies.

Introduction

The Pre-Salt reservoirs in Santos Basin, Brazil, represent new exploratory and production frontiers for E&P projects, not only due to the huge related accumulations, but also to the complexity of both the structures and the faciology of the microbial carbonates. In this sense, the reservoir characterisation and project development represent big challenges to the geoscientists. This is mainly due to the lack of well information, its quality and resolution support related to the seismic data, generating depth uncertainties regarding velocity modelling. Thus, significant effort has been made to handle part of those uncertainties early in the structural modelling by analyzing the uncertainty parameters in the velocity modelling (Amaral et al., 2015; Meneguim et al., 2015; Yamamoto et al., 2016; Barros et al., 2017), and in the seismic interpretations (Leahy and Skorstad, 2013; Leahy et al., 2014; Pinto et al., 2017). Depending on the uncertainty parameters, even small variations can dramatically affect the shape of the top reservoir surface, i.e., adding or reducing reservoir volumes. Which again can mask the project economics driving to wrong decisions.

Aiming to analyze and quantify the impact of parameter uncertainties in the structural model, two different approaches to build velocity models were applied. The first scenario utilizes a constant velocity value of 4,500 m/s in all salt section. The second scenario considers different velocities of the stratified salts to build the velocity model. Both models were calibrated to well markers and analyzed regarding the ambiguities present at the position of the top reservoir, due to the limited seismic resolution. For each scenario, a set of 300 realizations was created, to account for the uncertainties in the structural modelling. The 600 realizations were analyzed based on their Gross Rock Volume (GRV), enclosed by the top reservoir surface, and a bottom surface represented by the Oil-Water Contact (OWC). Finally, the presented methodology can guide geoscientists through the analysis of different velocity models, as well as several sets of seismic interpretations, to evaluate the impact on E&P projects.

Methodology

Due to the complexity of the salt section, lateral velocity changes are perceived in the data. Therefore, the Pre-Salt seismic data demands depth migrations to better locate the position of the structures (Yan et al., 2009; Jones and Davison, 2014). The Pre-Stack Depth Migration (PSDM) aims to enhance the seismic imaging, however it might not necessarily respect the true depth of the structures. When comparing the markers from drilled wells to the interpreted surfaces, it is common to find deviations of approximately 1%. This misfit complements the reservoir characterisation (Roque et al., 2017). Additionally, the seismic interpretation is always a tricky procedure, due to the inherent limited seismic resolution and low signal to noise ratio.

The methodology presented in this work comprises the analysis of uncertainties on GRV due to variations on velocity modelling scenarios and seismic interpretation, as following:

PSDM (D) >> Seismic Interpretation (D) >> Converted Seismic Interpretation (T) >> <u>Velocity Model Selection (T)</u> >> Avg. Velocity Calibration (T) >> <u>Calibrated Seismic Interpretation (D)</u> >> Uncertainty Analysis >> GRV Realizations

The "(D)" and "(T)" denote the respective data domains, i.e., depth or time, and the underlined words refer to where uncertainty analysis was applied.

The seismic data and interpretations were converted from depth to time, using the final tomography velocity model. The velocity models (scenarios 1 and 2) consider both the tomography updating in the Post-Salt section. For the scenario 1, the salt section presents a constant value (4,500 m/s). This is a common workflow for seismic migration of Pre-Salt reservoirs projects (Figure 1– top left).

On the other hand, the presence of different evaporite minerals, such as, halite, anhydrite, carnallite, tachyhydrite and sylvite has been observed when analyzing samples from wells (Amaral et al., 2015; Barros et al., 2017). Thus, a stratified salt model with the respective velocities for each identified mineral was built (scenario 2). Acoustic inversions, performed using all available well log information, were used to locate the salt stratifications (Figure 1 - bottom left). Afterwards, a Bayesian facies classification using probability density functions (PDF) to achieve the probability mineral cubes as suggested by Meneguim et al. (2015) was performed (Figure 1 - right). The average velocity of each facies/mineral was then selected to represent each facies.

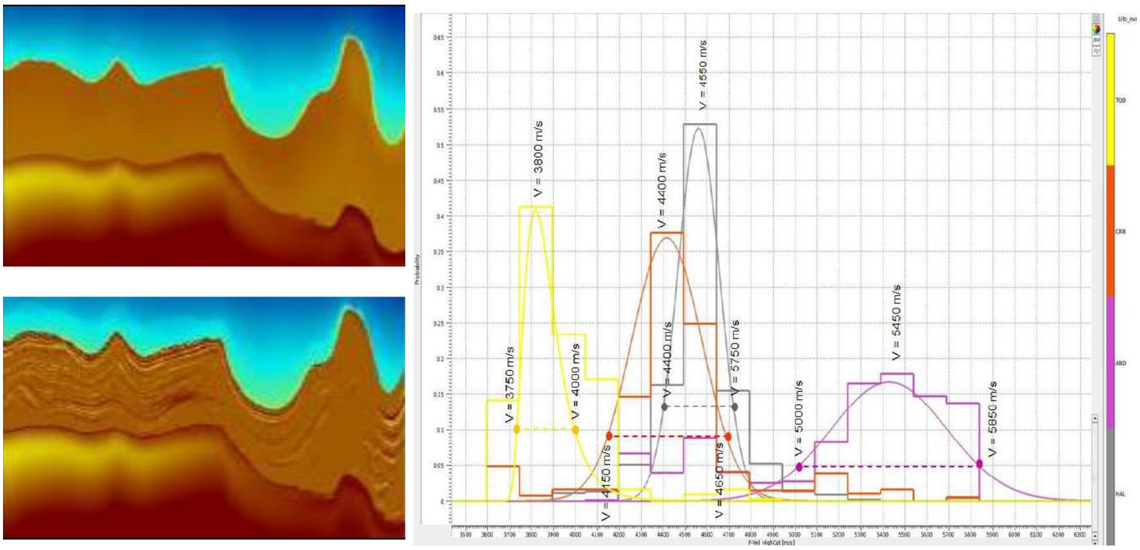

Figure 1: ***Left***: *Differences of the velocity models from scenarios 1 (top) and 2 (bottom). Scenario 1 uses the tomographic velocity, and scenario 2 incorporates the salt layers inside the evaporitic section. Modified from Barros et al. (2017).* ***Right***: *PDF of salt velocities from well data. Extracted from Meneguim et al. (2015).*

After a well-to-seismic-tie, Time-Depth (TD) relations for each well were created. These relations were then used to calibrate the average velocity model for both scenarios. The seismic data and interpretations were then converted from time to depth, ensuring that the interpretations matched the well markers. For the regions away from the wells, an external drift kriging technique was used, considering the average velocity as the soft data (both scenarios), and the tied well velocity (markers) as the hard data.

Two GRV scenarios were made using the converted top surfaces for both calibrated velocity models: scenarios 1 and 2, respectively. Following the workflow, each top surface was submitted to stochastic Monte Carlo simulations producing realizations for the used surface. In each realization, the resulting surface is the original surface added by a Gaussian residual map produced in the simulation process. The generated surfaces respect the range of uncertainties based on the seismic resolution, considering it as an envelope surrounding the converted surface. The seismic envelope is calculated according to Pinto et al. (2017), where the dominant frequency and interval velocity attributes are combined into one map and weighted by the RMS amplitude map. The envelope can be displayed as a map for the region of study, or as a depth section (Figure 2). The values found for the seismic envelope ranged from 70 m (+/- 35 m) to 200 m (+/- 100 m). The values in this map represent a distance, above and below, from the original surface, where the new surface could be probabilistically located according to the seismic resolution. The assumption of being above and below from the surface rely on the fact that there is no previous hypothesis about where the top surface could be located. With additional information, such as alternative interpretations, data from different methodologies, well log data, core samples, and others, many assumptions could be made and other bias can be introduced.

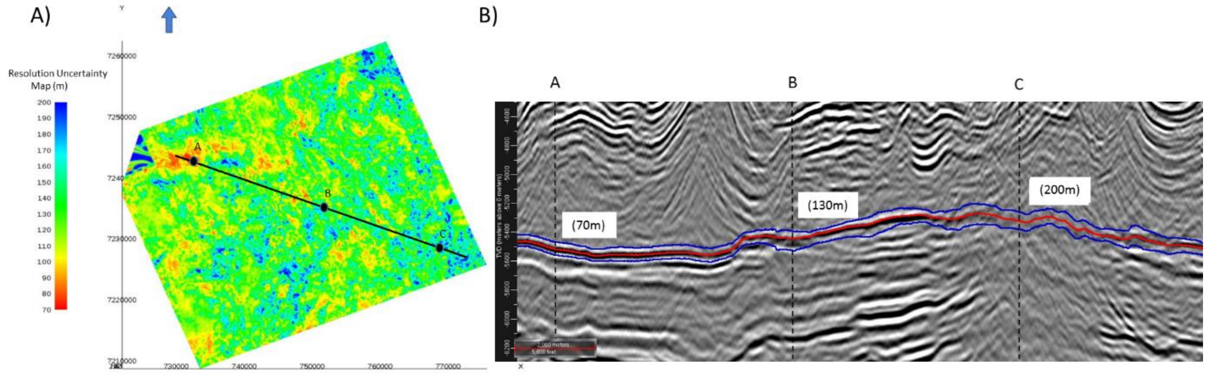

Figure 2: A) *Uncertainty map utilized in the stochastic simulations. B) Seismic section with top reservoir (red) and the uncertainty envelope (blue). The vertical range of the uncertainty envelope is shown for wells A, B and C.*

The reservoir covers an area of approximately 1000 km^2, with an oil column varying between 300 m and 400 m. When comparing the GRV from scenarios 1 and 2, an increase of 0.5% is observed for scenario 2. Although the percentage is small, the difference can represent considerable changes in reservoir volumes. As an example, Meneguim et al. (2015), mention in their work a variation around 3%.

Results, Conclusions and Future Works

Two scenarios, with 300 realizations each, were investigated. Stochastic stimulations were run on reference structural models for each scenario. The reference GRV parameter, for each scenario, was used to compare the realizations for each scenario. In all the 600 realizations, the top surfaces were calibrated to the well markers. The misfit at the well locations, driven by the calibration algorithm, is zero. At other locations, the surfaces were free to move respecting the velocity modifications in each scenario, and according to the seismic uncertainties described in Figure 2A and 2B. In Figure 3, a subset with 15 realizations for each scenario is shown, displaying the character of the structural models along the simulations. By analyzing all realizations, it is possible to identify the pessimistic (lower GRV value) and optimistic (higher GRV value) realizations for scenarios 1 and 2 (Figure 4). The differences between the pessimistic and optimistic realizations were close to 1.6% and 2%, for scenarios 1 and 2, respectively. These differences represent considerable GRV volumes variation of approximately 3.10^9 m^3. Additional parameters such as Net-to-Gross (NTG), porosity and oil saturation, can also influence oil reserve calculations, and should be included in future uncertainty studies. Investigations may also include the possibility of performing velocity modelling considering not only the average velocities (P50) for the salt facies (scenario 2), but also the P10 and P90 for the PDF displayed in Figure 1.

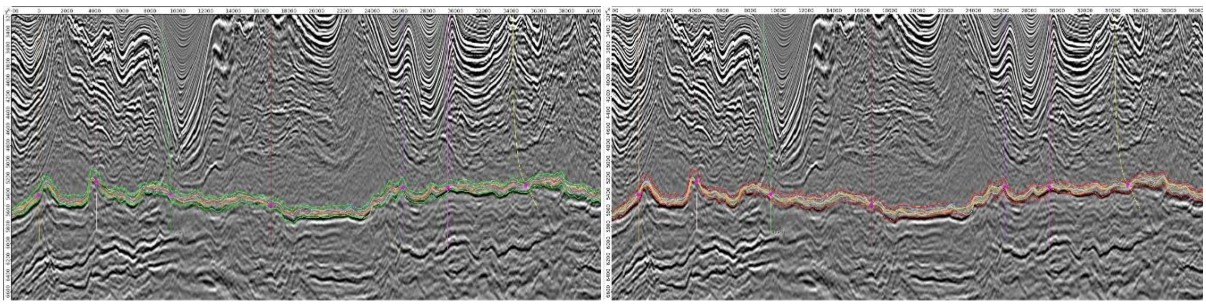

Figure 3: *Subset with 15 realizations for each scenario (scenario 1 – left; scenario 2 – right). The green and red envelopes denote the seismic uncertainty envelopes. The pink points are the well picks.*

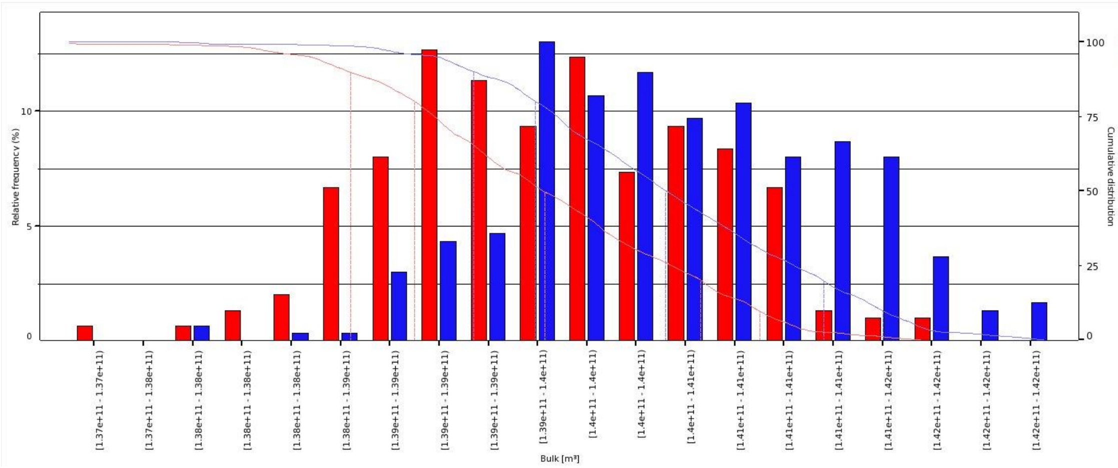

Figure 4: *Histogram with all 600 GRV values for both scenarios (blue – scenario 1; red – scenario 2). Scenario 2 is slightly more optimistic than scenario 1.*

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