Reservoir Characterization by Acoustic Inversion – Marlim Field

Tatiane M. Nascimento[1], Paulo T. L. Menezes[2], Igor L. Braga[3]. FGEL/UERJ-Invision Geophysics; DGAP/FGEL/UERJ-PETROBRAS; Invision Geophysics.

Abstract

In the present paper we present the results of an acoustic impedance study of the Marlim turbidites reservoirs in Campos Basin. The proposed workflow divided into three main stages: 3D seismic data pre-conditioning; well-tie, and finally, inversion/interpretation of the results.

The final acoustic impedance cube showed higher resolution compared with the original amplitude data and provided a better visualization of the geological framework of the Marlim field. Besides, the correlation with well data also provided porosity estimation for the reservoirs facies.

Introduction

Reservoir characterization studies allow a more detailed lithology-fluid prediction in the various stages of the reservoir life cycle. In these complex processes, geophysicists usually handle a huge amount of data. That, when properly integrated, can improve the appraisal or flow monitoring of a particular oil field. Of course, due its high resolution, 3D seismic data is of great importance to build geological models with great accuracy (Martins *et al*., 1995; Kelamis *et al.*, 1995).

To quantify the various petrophysical parameters of a reservoir as realistically as possible, we also need to integrate several datasets with different degrees of accuracy, like well logs, 3D seismic data and geological conceptual models.

Inversion of seismic data for acoustic impedance has proven to be an excellent tool to estimate petrophysical parameters of reservoir (Sancevero *et al.*, 2006; Kelamis *et al.*, 1995). Frequently, by applying inversion procedures one can increase the frequency content of the seismic data, which is band-limited. (Buxton Latimer *et al*, 2000). Furthermore, the result of inversion also allows the lithology differentiation and estimation of the fluid content, not only the interface geometry as given the amplitude attribute (Avseth, *et al*., 2005). Since the acoustic impedance is a property related to the layer, the inversion process adds information to the seismic interpretation, enabling greater inference of subsurface geology (Bacon *et al*., 2003).

Usually deep-water turbidite reservoirs show a complex distribution of sand bodies with thicknesses many times smaller than the vertical resolution limit of the seismic data (Ribeiro, 2012). Thus, the inversion for acoustic impedance is an essential tool for a more detailed analysis of reservoirs with such characteristics, such as Marlim.

In this paper we present the results of an acoustic inversion scheme applied to 3D seismic data in the Marlim field (Campos Basin). Our results were calibrated with logs of four available wells. That was necessary to estimate the low frequency model in accordance with our previous stratigraphic knowledge of Marlim field. As expected our proposed approach allowed a better interpretation of the complex geological structure of the Marlim turbidites.

Marlim Field

The reservoirs in Marlim field (Figure 1) consist of an Oligocene/Miocene deep-water turbidite system forming a series of amalgamated sandstone bodies (informally called "Marlim Sandstone") (Peres, 1993). These were interpreted as a prograded system, indicated by standard downlapping as seen in seismic sections (Lopes, 2004b).

The Marlim sandstone is easily recognized in the seismic amplitude data with the reservoirs boundaries being notably stratigraphic west, north and south, given by pinch out takes place from layers of sand; eastward accumulation has its limit against a normal listric fault, generated by the moving salt. This fault is responsible for limiting the eastern portion of the block, and considered the main route of oil migration from the pre-salt reservoir (Tinoco & Corá, 1991 in Bizzi *et al*., 2003).

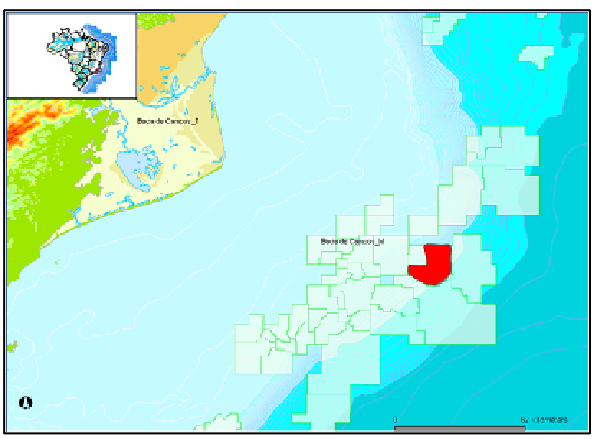

Figure 1: Location of the Marlim field in red, Campos Basin.

The high amplitude seismic response (common feature of complex turbidite unconfined) is attributed to the impedance contrast between the high porosity reservoir, and the relatively low speed of the overlying shale (Fainstein *et al*. 2001).

Dataset and Methodology

Our dataset consists of a 3D seismic amplitude cube (TWT) and the composite logs (sonic, density, porosity and gamma rays) of four available wells. The seismic data was processed following the standard post-stack time migration.

We established a three main stage interpretation workflow: pre-conditioning of the data, calibration with wells and inversion for the absolute impedance.

In the first stage, data pre-conditioning, we filtered the seismic data to enhance the resolution and continuity of the trace amplitude. To this end, we applied a filter for random noise attenuation using the curvelet transform.

In the second stage, well tie, we initially correlated the well stratigraphy with the herein interpreted main stratigraphic horizons. Then, we used the sonic and density logs to extract wavelet and create an acoustic impedance curve for each well. As result, the corresponding synthetic seismograms were generated. This step is essential for calibration of the seismic inversion response to the well data. In parallel, the seismic data was inverted to acoustic impedance. We followed the model-based approach, where the interpreted horizons define the inversion domain. The first inversion results are then quality controlled with the well-tie and mapped horizons.

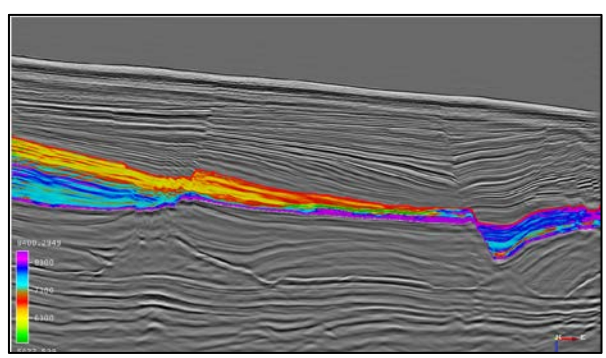

Figure 2: Figure 2: AI resulting from the summation of the low frequency model with the seismic data inverted.

In the third stage, we created a horizon-cube from the four main interpreted horizons to build a low frequency model consistent with the local stratigraphy. This model is constrained, in the 0 to 10 Hz frequency range, by the available well-log information, and then extrapolated from the wells positions to whole horizon-cube, resulting in the low frequency model. With the low frequency model in hands we were able to estimate the final absolute acoustic impedance (AI) volume. (Figure 2).

Figure 3 shows the good correlation between the impedance curve of the well 219A-1RJS-RJ (filtered in the original seismic band) with the recovered absolute impedance curve (IP-abs).

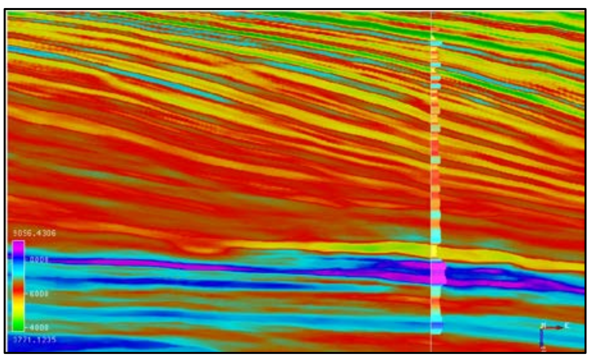

Figure 3: Correlation between IP-abs and well impedance constraints in the seismic band.

As expected, the final IP-abs cube shows higher resolution than original data, with depositional features within the turbidites not seen in the amplitude data being highlighted in the inversion (figure 4).

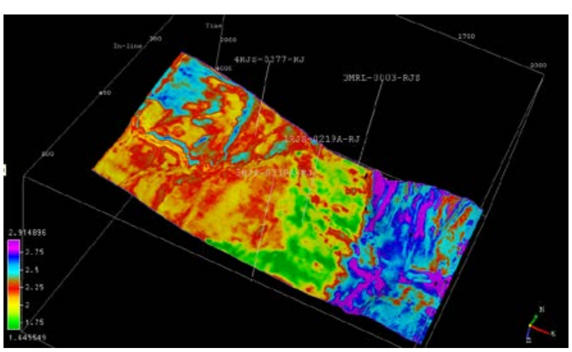

Figure 4: Marlim turbidite surface (lower impedance values).

As seen in Figure 4, the lower impedances values correspond to the reservoir facies of Marlim turbidites. When we cross plot IP-abs x φ, it is possible correlate these lower values to porosities in the 30 and 40% range (Figure 5).

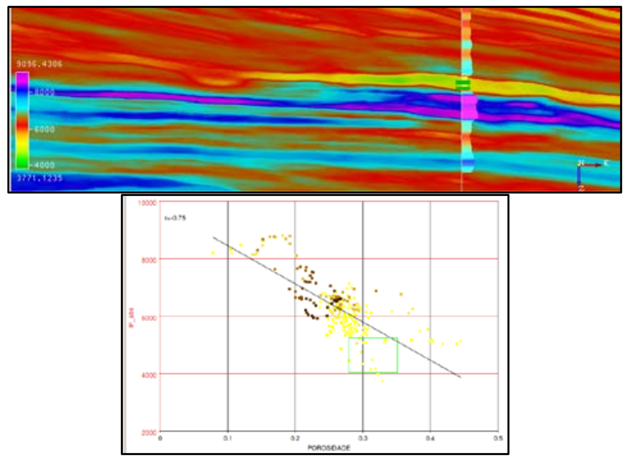

Figure 5: Crossplot with IP values x abs porosity values for well 1RJS-219A-RJ. The values assigned to the lithology data are consistent with gamma rays.

From the IP-abs volume we estimated the porosity of the Marlim reservoir facies by correlating, in the available wells, IP-abs x φ (Figure 6).

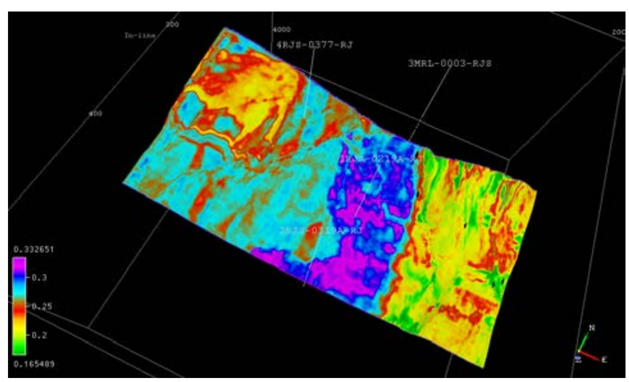

Figure 6: The highest porosity values correspond to the turbidite body of the Marlim field.

Conclusions

We demonstrated the importance of the role of seismic inversion for reservoir characterization. Higher resolution images were obtained in the Marlim turbidite reservoirs, thus allowing a better interpretation of the geology. Besides, we also predicted from the cross-plot of the recovered acoustic impedance with available porosity well-logs, the porosities along the whole Marlim reservoir. This can be very important for flow simulations/modeling in the appraisal and monitoring stages of the reservoir life cycle.

Acknowledgments

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