Using VSP in a directional well to help understanding of carbonate banks in Pampo Field

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Abstract

We evaluate the capabilities of VSP in a directional well to image a complex system of carbonatic sand accumulation to help reservoir characterization studies of Albian Carbonates of Pampo Field, Campos Basin.

While interpreting a carbonatic bank system on a marginal environment, a doubt appeared that urged us to run a VSP, able to generate an image with better resolution than the surface seismic. We had the opportunity of running it in the deviated path of an horizontal well, directed to the Eocene sand reservoir located above the carbonate reservoir.

The geologic model for the VSP acquisition simulation was taken from the seismic volume that had already been depth-converted with good precision.

The neat image generated from the VSP data provided a definition of the carbonatic sands bodies that allowed us to solve the problem.

Introduction

The Pampo Field is located to the south of Campos Basin, 80 km offshore with 100 m. water depth. This field was discovered in 1978, and in 1980 started its commercial production. The maximum production happened in 1986, after which it started declining and increasing water production. Due to the complexity and heterogeneity of the reservoir, the recovery factor was very low, and a new reservoir characterization study was requested.

A new seismic data was acquired and processed in 1999, to support the study of a new flow model. Using geostatistic to integrate velocities of wells and stack velocities, a new velocity field was generated and used to convert the seismic volume data.

In order to clear up and confirm a feature in the interpretation, we got the opportunity of acquiring the VSP in an horizontal well that was drilled in an Eocene sand reservoir.

Well Seismic

The VSP in a directional well is a powerful tool for imaging discontinuities in a reservoir, at a low cost and with improved resolution.

As a consequence of the deviation of the well, starting vertical and reaching the target horizontal, there were two possibilities of running the survey:

a.- Wireline Operation (WL): for deviations up to 40deg the CSI™ (Combinable Seismic Imager) tool can go down by its own weight.

b.- Tough Logging Conditions Operation (TLC): to reach larger depths with inclinations above 40deg. the

CSI™ has to be pushed by drilling casing.

As the total operation time and costs are different for each alternative, it was very important to evaluate the cost/benefit for each case by means of a seismic modeling, which provides the expected image extensions.

The next two figures show the results of the ray tracings generated with Bormod™.

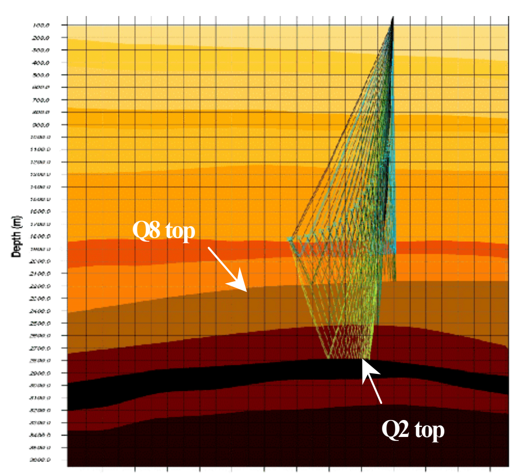

Figure 1 – Modeling of TLC operation.

The figure 1 shows the extension of the image generated by the VSP for a TLC operation. The CSI™ was supposed to reach 2109m MD (measured depth), and the operation with consists of 56 levels. The maximum horizontal length of the image would be of 560 m for the Q8 zone, while for the deepest zone would be of 250 m.

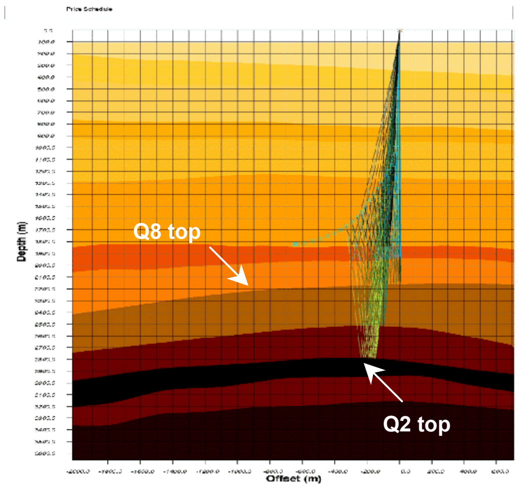

Figure 2 – Modeling of WL operation.

The figure 2 shows the result for the WL operation. The CSI™ was supposed to reach 1744m MD, and the survey would consist of 40 levels. The maximum horizontal length would be 220 for the Q8 zone, while for the deepest zone we would get 100m.

The WL option provided a faster operation (about 20hs less than a TLC one), but the extension is very narrow (less than 50% of the TLC operation). Thus, it was decided to run the VSP survey as a TLC operation.

VSP Processing

Due to the well trajectory and the raypath geometry a triaxial preocessing on the X,Y,Z components of the CSI™ was performed, figure 3.

The key steps of the processing sequence on Borseis™ soft. were:

- Model velocities adjusted by inversion of VSP transit times.
- Triaxial processing: generation of horizontal components HMX (on the incidence plane) and HMN (normal to the incidence plane).
- P and S Wavefield separation.
- Up going and Down going P-waves separation.
- Deconvolution.
- Image generation by migration of Up going P-waves after Dcon,, in Z[m] (shown in figure 3) and in T[sec].

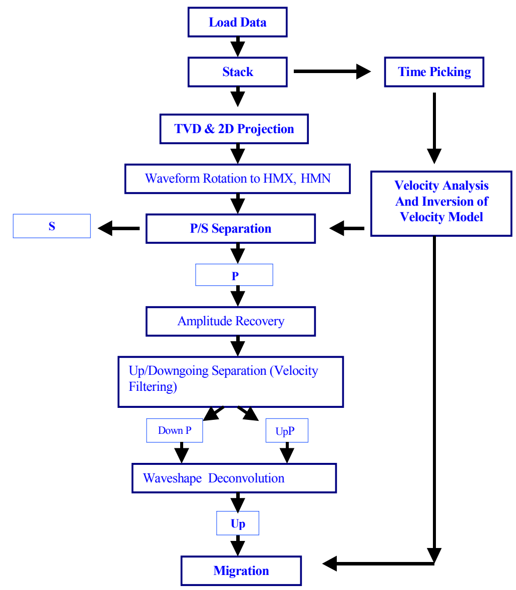

Figure 3 – VSP processing flow

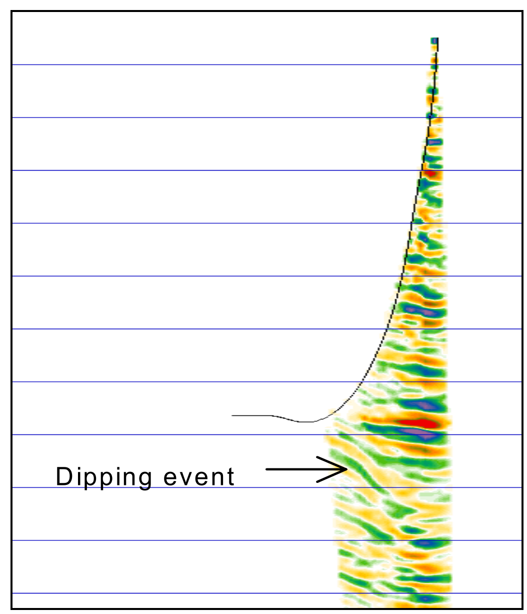

Figure 4 – VSP image in Z.

Well Tie and Interpretation

Reservoir studies of Pampo Field had been made in a LandMark platform, thus the image had to be loaded in this platform. But we found problems to load the VSP path in order to overlay the VSP image on the seismic data. The solution found was to load the VSP data as seismic 2D line and overlay it as wiggles over the seismic line. As the seismic 3D data of Pampo Field was already depth converted, we didn't have any problem to tie the VSP image.

We can see at figure 4 some dipping events related with the geology. In figure 5 we can see a seismic line with the real well trajectory, with the horizontal path at Eocene reservoir, on which we run the VSP. Due the structural and stratrigrafic complexity of carbonates (Quissamã members), the seismic signal had a karstic characteristic. The interpretation of all the depositional elements in such environment, particularly in this part of the reservoir, may be difficult. We reduced the uncertainties about the model integrating the surface seismic and VSP information.

The seismic line shows discontinuities on reflectors associated to a fault system that can be interpreted as gaps or simple deformations in the time lines. It is important to solve this uncertainty because we need to define the flow unit we are mapping.

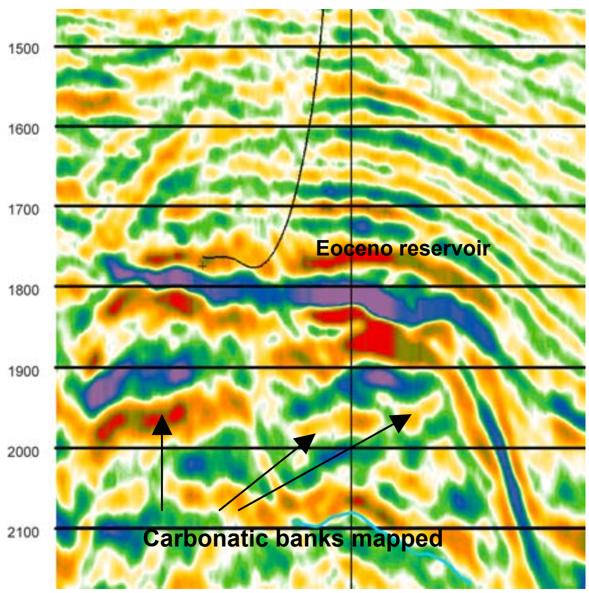

Figure 5 – Seismic line with the horizontal well.

In figure 6 we can see the same seismic line, with the VSP interpreted image overlaid. According to the interpretation, the higher energy part of the bank was rebuilt and launched to a deeper part, created as the system of faults was developing. The rebuilt carbonate facies had already been interpreted by core analysis, confirming the model.

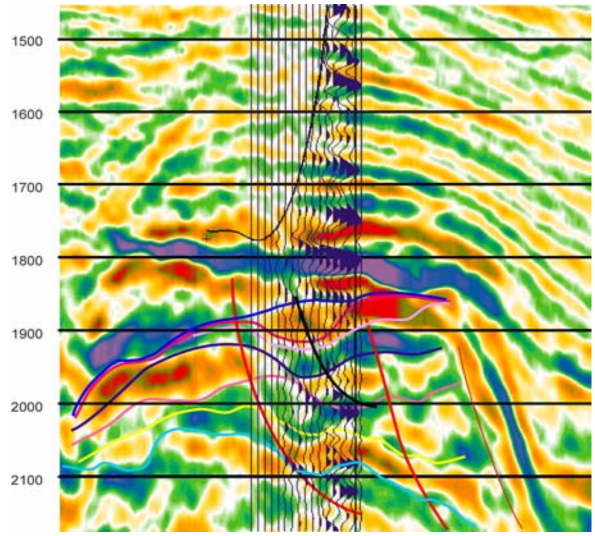

Figure 6 – Seismic line with the interpreted VSP image overlaid.

Conclusions

This work shows how powerful the VSP can be when it is adequately used. It is an example of a cheap way of obtaining high resolution information by running a VSP in a directional well, besides an offset or walkway VSP. A proper modeling is fundamental to evaluate the effectiveness of the survey, by analyzing operational limitations and image extension.

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Acknowledgments

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