Multicomponent offset VSP to detect gas reservoirs

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Abstract

The occurrence of gas filled, complex reservoirs, in Miranga field on Reconcavo onshore basin was the motivation to evaluate the seismic response of borehole seismic in that area. The target was to investigate if we could solve the thin reservoirs of Candeias formation and, at the sime time, use that information as a feasibility study to orientate the future aquisition of surface multicomponent seismic. Although the VSP results were not able to discriminate the reservoirs, they showed a higher frequency content than can observed on the 3D surface seismic, either using a lower frequency energy source (airguns). Another very important result was the difference in response of compressional and shear wavefields what demonstrate that multicomponent borehole seismic can be used as a explotatory tool in similar circumstances.

Introduction

The onshore Miranga field, on the central part of Reconcavo basin (Figure 1) has two production intervals. The deeper reservoirs are the gas filled lake turbidites sandstones from Candeias formation. These turbidites, known as Caruaçu layers, have a very complex geometry with the stack of successive sedimentary cycles and fast lateral variation in faciology and petrophysical characterístics.

A 3D surface seismic survey was acquired in 1998 to try to characterize those reservoirs, but the results showed that, at the target interval, the resolution was still not good enough to solve the reservoirs. That unsatisfactory result showed that conventional surface seismic could not be used to help with the development strategy on the field as can't serve to preview the occurrence of Caruaçu Sandstones and to define its geometry and mainly, to anticipate if the reservoirs can be expected to contain gas .

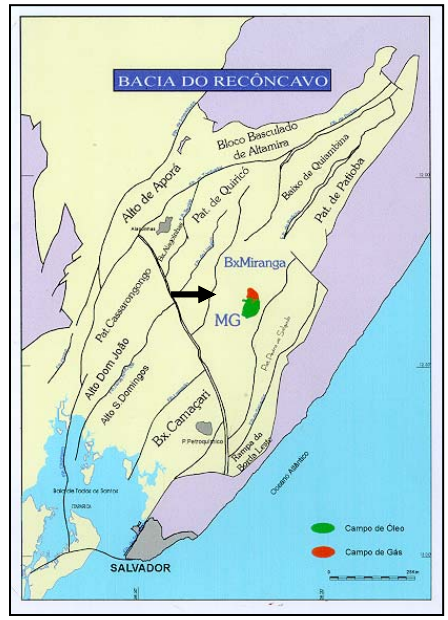

Figure 1 - Localization of Miranga field on the Central portion of Reconcavo basin.

VSP modeling and acquisition

To define the VSP acquisition parameters it was built a 3D elastic model (Figure 2) based on the 3D seismic interpretation developed in a Landmark plataform converted to depth using the RMS velocities defined during the processing step. The model was then evaluated to choose the source positions and receivers interval that could generate the maximum illumination at target level with the minimum lateral drift. The modeling phase used the ray trace method with both 2D and 3D models generated in the GX-II and Norsar-3D softwares. The advantage of 3D modeling is that it can define with more precision the expected lateral drift to both wavefields. That is an important aspect when trying to correlate those different data. Another advantage was to anticipate that the reservoir lenses would not be solved by the VSP acquisition, either choosing the smallest feasible geophone interval.

The modeling resulted in the definition of two offsets aligned with the receiver well, placed 1200 m Southwest and 860 m Northeast from the well MGP-46 (receiver well) as can be observed in Figure 3.

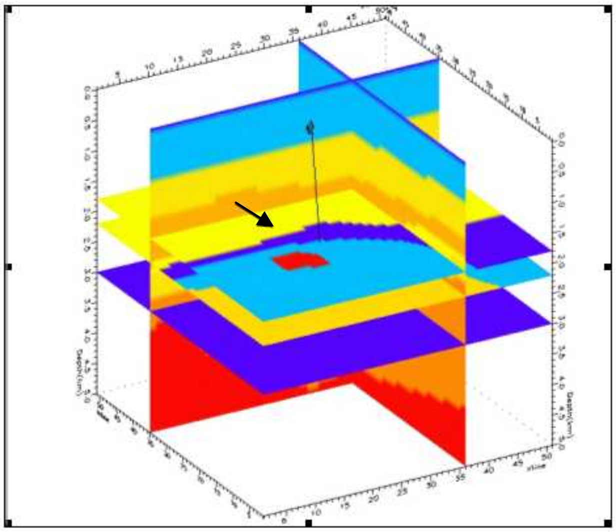

Figure 2 – Geometry used in the 3D ray trace modelling. The arrow indicates one of the lens included in the model.

So, the acquisition direction was chosed perpencicular to the structural strike in order to avoid much lateral drift. Either with a gentle dip in the area that could cause a drift in the acquisition plane. Another important point is tha as the receiver well was not cased (the well was being drilled at acquistion time) we could expect a good coupling between the geofone (CSAT) and the sampled interval (Figure 5).

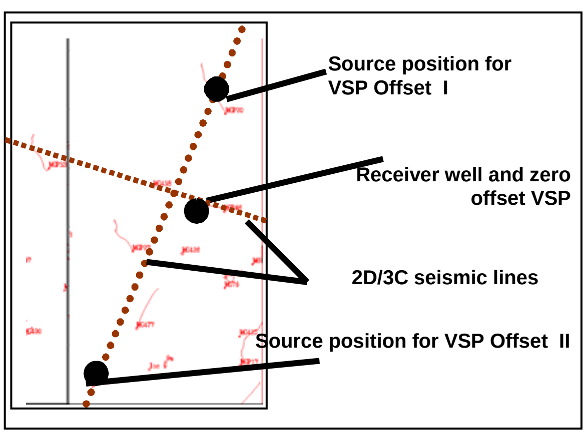

Figure 3 - Map showing the position of receiver well (MGP-46) and the points where the two offsets sources where placed. The dotted lines are two 2D-3C surface seismic lines that where acquired in the area and are still on evaluation.

Although dynamite is the recomended source to land VSP acquisitions (most of surface seismic on Reconcavo basin were acquired with explosive) as the services companies do not operate with dynamite in Brazil, we used airguns once more. As it was Petrobras responsability to prepare the area and pits to place the airguns we decide to experiment the use of metallic pits to avoid the colapse of sidewalls what could interrupt the acquisition (Figure 4). The operation lasted for three days (zero offset plus two offset VSP) and was carried out by Schlumberger that was either in charge of the processing.

Figure 4 - Metálic pit used to shoot the airguns. Note the stability of the set, either after more than five hundreds shots.

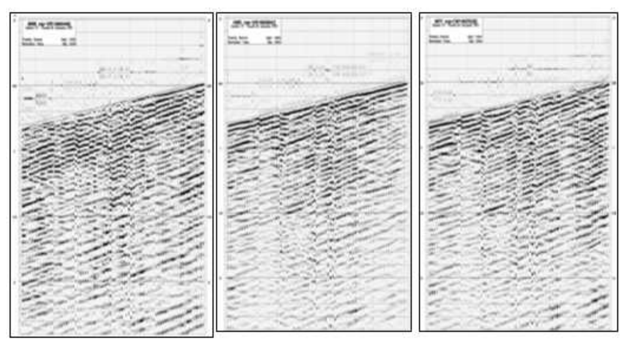

Figure 5 - Records from zero offset VSP.Observe the high signal/noise ratio in the 3 different components: vertical(left), radial(middle) and transversal(right).

Processing

The processing was performed by Schlumberger on its regional office in Buenos Ayres. The workflow applied the conventional sequence used to process offset VSPs, but the wavefield separations was revisited sometimes to evaluate its impact on the final compressional and shear stacks. To the migration step it was used the finite difference algorithm that produces some side effects but is not so "model dependent" as the VSP-CDP transform. One approach to evaluate the result of the zero offset processing is its comparison with the synthetic seismogram what is shown in Figure 6. The match is considerably good and the differences can be justified by the variation in AVO and horizontal sampling (different Fresnel zones of VSP and surface seismic).

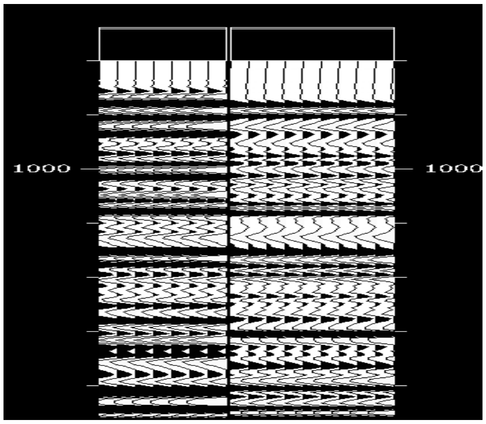

Figure 6 - Comparison between the synthetic seismogram (left) and the zero offset VSP.

Interpretation and Conclusions

Although the borehole seismic was not able to discriminate the thin reservoirs either if we could have used higher frequency source like dynamite, the result showed clearly higher resolution than surface seismic as we can see in Figure 7. That suggest a 3D-VSP could be used as a tool to get better definition of the structural behavior of that area. The higher frequency of shear waves at target interval (Figure 8) suggest its capability to discriminate thin reservoirs and the simple difference between the compressional and shear responses at the gas interval proves that the VSP could be used as a explotatory tool to characterize gas reservoirs (Figure 9). A radial shooting pattern could be used to a series of offset VSPs to continue the development of that area.

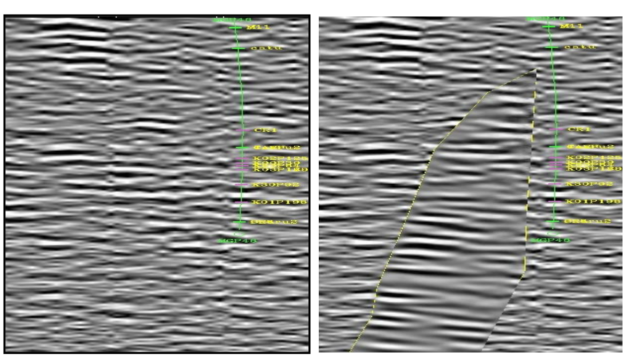

Figure 7 - Comparison of 3D surface seismic without (left) and with the offset VSP superimposed.

As the target depth in the area is around 2200m it would be possible to investigate using a offset VSP till 1000m. Considering that the drainage grid is around 600 m the use of offset VSP with multiple azimuths would make it possile to investigate the neighborhood of the well to orientate the development strategy. The economical feasibility depends on the drilling costs and the number of sucessive borehole seismic acquisitions.

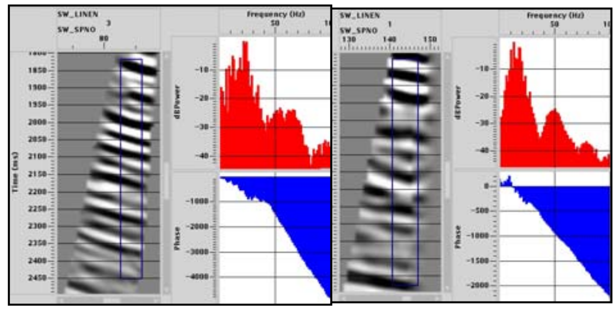

Figure 8 - The shear response (left) shows higher frequency than compressional wavefield at the gas interval.

Optionaly the walkaway technique could be used to extend the coverage in the direction one wants to investigate. According to that possibility it will be important to evaluate the technique that would be used to define the shot position shear static correction because it has a very high magnitude and could severely corrupt the shear stacking.

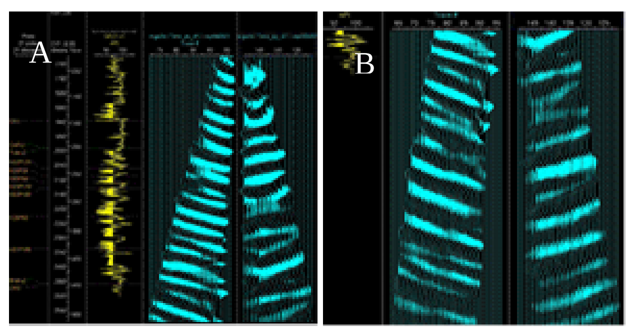

Figure 9 - The interference of the gas filled reservoirs (A) explain the observed difference between the compressional (right) and shear (left) images on the offset VSP. In the side (B) the results are more similar as that reservoir interval is filled with water.

Acknowledgments

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