Full azimuth OBC acquisition – A Campos Basin pre-salt case study

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Abstract

Improved azimuth sampling is one of the key issues for obtaining adequate seismic imaging in complex structural settings. In the Campos basin a full azimuth OBC survey has been acquired in order to reduce the risk of miss-positioning expensive deep water pre-salt wells. Pre-survey modeling showed that seabed acquisition could significantly improve on the reservoir illumination compared to narrow azimuth technology. The survey was acquired in a challenging environment which included complex oil field infrastructure, simultaneous operations, deep water and strong currents.

Introduction

It is known worldwide that the key for a good imaging of subsalt structures today is working with wide-azimuth seismic data. As summarized by Barley & Summers (The Leading Edge, April 2007), several wide-azimuth seismic surveys were developed by different oil companies around the world, providing better images which have improved reservoir delimitation and reduced the risk of miss-positioning for very expensive wells.

In Brazil, a series of experimental surveys are planned and one of them already took place at the Campos Basin, but the first non-experimental wide-azimuth marine survey in the country happened in 2010/2011. It was an orthogonal survey over a receiver area of 110km^2, and it's main goal was to provide data for a better characterization of a pre-salt field within the basin. With this data, Petrobras expects to develop the optimum strategy for this field's production.

In this paper we discuss the benefits of full-azimuth seismic data and describe some of the operational issues of this orthogonal OBC Survey.

Survey design - Why go wide?

Bouska (The Leading Edge, December 2008) pointed out some of the advantages of wide-azimuth data: better attenuation of noise, source backscattering and – maybe the most important – multiples attenuation.

A wide-azimuth set of seismic data provides new options for pre-stack processing, since each swath (or another subset within the survey) can be treated as a 3D dataset. Besides, since wide-azimuth seismic provides true 3D data, it gives a more consistent sub-surface image.

In 2007 several OBC surveys were planned for the Campos Basin. The key objective for these surveys was to ensure that adequate coverage was obtained for 4D monitoring. In some areas of the Campos Basin the number of surface obstructions and strong currents cause difficulty in obtaining uniform coverage using streamer based techniques. In this environment the simplest and most cost effective method of obtaining a repeatable seismic dataset, which could be used to match with the surrounding streamer baseline data, was to use the narrow azimuth OBC methodology. However, during the OBC campain there were several pre-salt discoveries in Brazil. Although the existing streamer dataset in the area had been successfully used for post-salt reservoir characterization it was clear that pre-salt imaging was non-optimal. There was in an opportunity to image a pre-salt discovery using advanced seismic acquisition techniques.

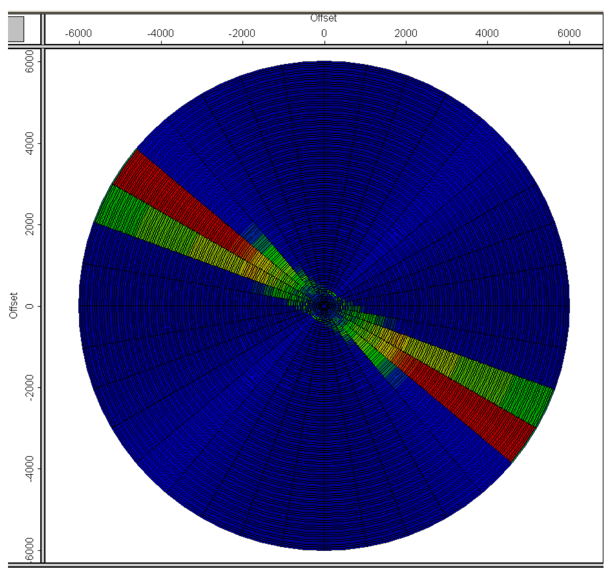

Figure 1. Rose diagram from original narrow azimuth OBC survey design. This design was subsequently changed.

This led the Petrobras Geophysicists to consider whether the original survey parameters were appropriate for pre-salt imaging. It was recognized that seabed acquisition should provide superior imaging through salt due to the low noise environment on the sea floor and improved bandwidth response of the sensors. However the azimuth distribution of the original survey design did not take advantage of decoupled nature of seafloor recording. In narrow azimuth OBC acquisition the split spread recording will effectively register two azimuth sectors of around 7 degrees (figure 1). This compares favorably to conventional streamer acquisition, which only provides a single azimuth, but may still not be adequate to image beneath a complex salt structure.

The new discovery was found underneath a complex salt structure of 1km thickness within carbonatic reservoirs at a depth of 4,460 meters. In addition to the thick salt layer there were dipping post salt beds with faulting above the discovery. The diversity of ray paths associated with the deep and complex structure meant that long offsets and improved azimuth distribution were viewed as vital to improve the pre-salt imaging. This was tested by running a number of illumination modeling tests using the narrow azimuth and full azimuth survey designs. As predicted, the narrow azimuth design resulted in the target being poorly illuminated, particularly over the crestal part of the salt structure (figure 2).

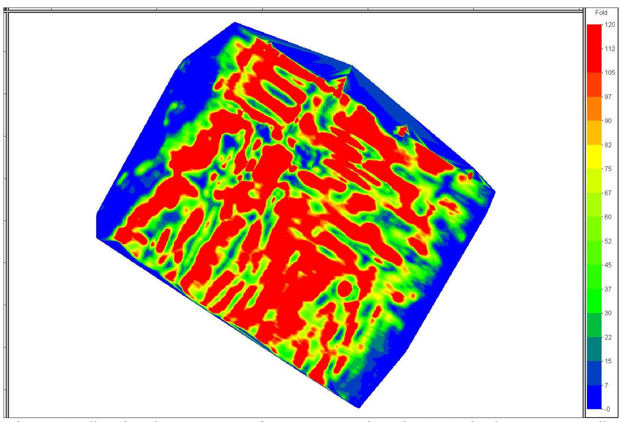

Figure 2. Illumination at target for narrow azimuth OBC design over Marlim pre-salt discovery.

Although improved azimuth distribution was seen as a key objective for the revised survey design there were a number of other factors that had to be taken into consideration. These included:

- Budgetary considerations
- Survey duration
- Long offset requirements
- Undershooting
- Converted wave survey design

After several iterations of survey layout modeling it was decided to use an orthogonal survey design with a 300m shot and receiver line grid (figure 3). This type of sparse orthogonal shooting provides full azimuth distribution whilst still maintaining a high level of acquisition productivity (figure 4).

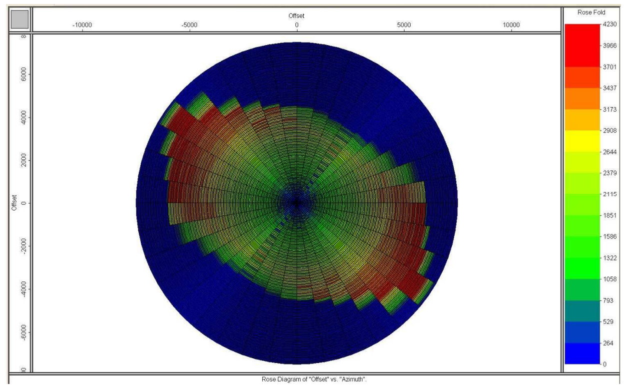

Figure 3. Rose diagram from final survey design layout using 300m shot and receiver line grid.

In order to maximize the coverage area the receiver lines were staggered. This layout resulting in good sampling in the crestal area around the salt structure while still ensuring that longer offset trajectories were captured on the outer areas using the sparser 600m receiver line separation. This type of design results in significantly higher fold in the central areas (400) while dropping to lower levels at the receiver boundaries (figure 6). This was viewed as a cost effective method of achieving the best quality imaging in the core area of the reservoir.

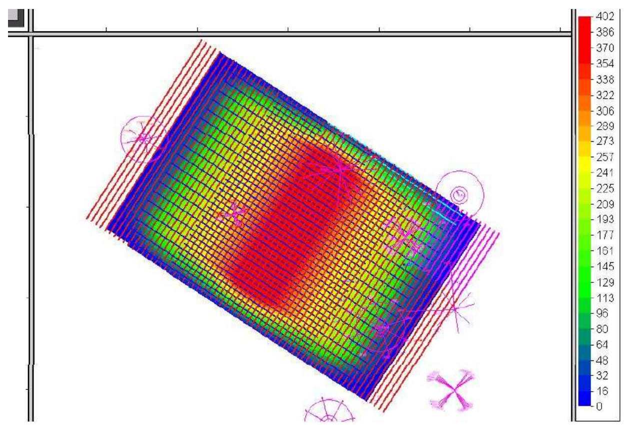

*Figure 4. Coverage display over offsets 0-6000m using 12.5*25m bin*

It was acknowledged that high density shooting such as a 50m grid may have been the optimal scenario for reservoir evaluation however there were constraints in terms of survey duration. In the end the defining factor in choosing the 300m grid had been the improved illumination found at pre-salt target level. The modeling showed that the improved azimuth distribution would significantly improve on the illumination at target (figure 5).

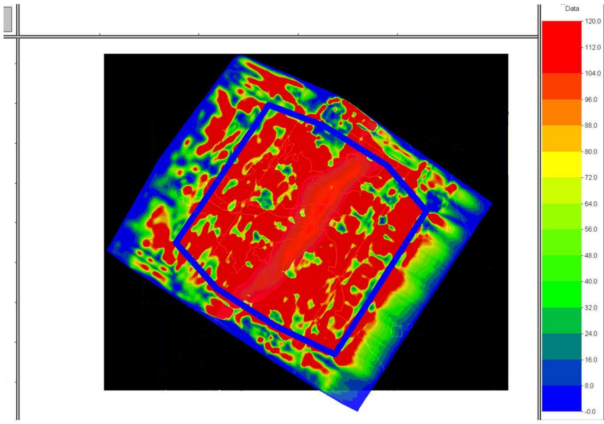

Figure 5. Illumination at target using orthogonal grid. Note the scale is limited at 120 points for comparison with the narrow azimuth OBC design.

OBC survey : Operational aspects

The Full Azimuth OBC geometry consisted of patches with 6.0 km receiver lines with 300 m spacing. As mentioned, these lines were partially unaligned to guarantee long offsets in the interest area and each had 240 active channels. Shot interval was 37.5 m, with 300 m shotline spacing (figure 6). Hence, not an HD acquisition, due to the contract budget and time limitations.

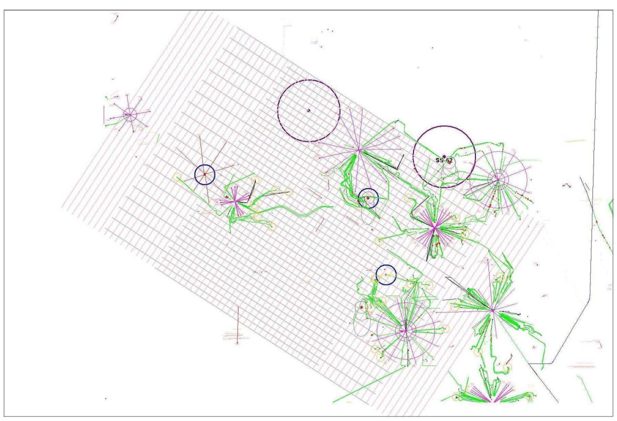

Figure 6. Obstruction scenario for the survey

By the time the survey began, the obstacle scenario was the one shown in figure 6. But since the Campos Basin is the highly productive, drilling and well interventions were common, as well as pipeline deployments. Therefore, the seismic acquisition coordinators had to work together with the Production managers for the basin. Even so, it was sometimes necessary for the seismic crew simply to retrieve cables and redeploy them elsewhere without finishing the area, in order to minimize costs for the company (drilling vessel costs are high above seismic vessel costs).
During the project execution, 7 different drillships have been working inside the survey area, most of them being anchored, and some of them in more than one location. Diving operations occurred around all fixed platforms during all the seismic acquisition operation. For that to work, some shot lines could only be acquired during the day, others only during the night and with permanent communication between the company representative on board and the platforms. Offloading operations from the fixed platforms were a big challenge for the seismic crew too. Also, several pipeline deployments and connections among the field's wells and platforms, requiring that the survey coordinators onshore plan the progress of the operation twice a week, and sometimes change that plan in the same day it would be implemented.
With all these obstacles, the only losses in coverage happened around the fixed platforms and around one of the drillships. The last drilling vessel arrived at the prospect area with a one week notice, and exactly on the only remaining patch, giving the crew no time for adjustments.

Conclusions

The Campos Basin pre-salt discoveries represent a clear opportunity for Petrobras to fully evaluate the advantages of using full azimuth seabed acquisition for pre-salt imaging. In order to provide the best possible imaging result the acquisition geophysicists had to react quickly to change survey design whilst still working within the timing and budgetary constraints. The modeling showed that OBC technology should provide a significant uplift in data quality relative to the current narrow azimuth dataset.
The acquisition phase was successful in terms of matching the coverage requirements and working safely around several highly complex installations. Despite many challenges the crew achieved a consistently high level of performance.

Acknowledgments

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