High-resolution multiazimuth towed-streamer seismic acquisition and processing – a case study from the Campos basin offshore Brazil

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This paper was prepared for presentation during the 12th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, August 15-18, 2011.

Abstract

This paper describes the acquisition and early-out processing of a two-survey towed-streamer multiazimuth experiment over Chevron and partners Frade field in the Campos basin, carried out in 2010. Improvements in signal-to-noise ratio, thin bed resolution and reflection event continuity are shown when compared to existing conventional narrow-azimuth data over the area.

Introduction

Multiazimuth (MAZ) refers to a survey where two or more conventional narrow-azimuth (NAZ) towed-streamer surveys are acquired over the same area with different sail-line azimuths. This technology has been used successfully over the years in different basins, perhaps most notably in the Nile delta where surveys using up to six different azimuths significantly improved illumination and signal-to-noise ratio in the data (Keggin et al 2006).

The Frade field sits some 120km offshore Rio de Janeiro State in water depths between 1000 and 1250m, in an area characterized by seafloor canyons, gas clouds and fault shadows. Figure 1 shows a map of water-depths over the survey area. Narrow-azimuth data with both time- and depth-migration processing exist over the area.

The key objectives for this project were to improve the imaging and resolution of the internal architecture of the Oligocene channel system where the reservoir sits, to enable reliable stratigraphic and structural mapping.

Processed seismic volumes were required in a rapid turnaround time to impact well placement and horizontal drilling of thin beds in early 2011.

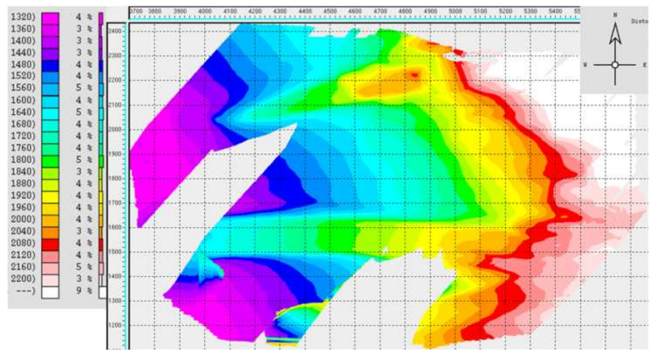


Figure 1 – Water-bottom map in two-way time (ms) note the canyons running East-West

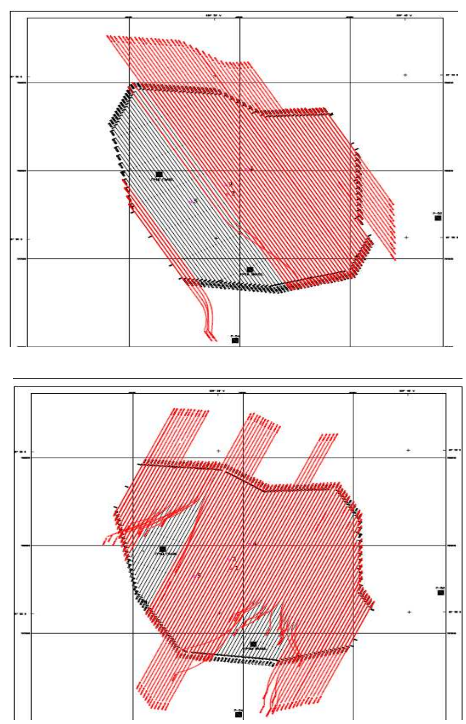


Figure 2 - Post-plot map (red lines) of the 150 degree azimuth survey (top) and 24 degree azimuth survey (bottom)

Acquisition

The survey was designed with two azimuths, one broadly perpendicular to the Oligocene channel (24°) and the second azimuth broadly parallel to the Oligocene channel (150 °) with the intention to improve illumination of the complex channel system. It was carried out between March and May 2010 by the WesternGeco Amundsen Q-Marine vessel, and each azimuth covers approximately 100 km^2. Some of the key acquisition parameters are summarized in Table 1.

Table 1 – Acquisition parameter summary

Streamers	12x6000m
Cable separation	50 m
Cable depth	7 m
Sources	2x5085 in^3
Source depth	6 m
Source separation	25 m
Shotpoint interval	18,75 m (flip-flop)
Group interval	12,5 m
Inline bin size	12.5x12.5
Nominal fold	80

A particular challenge during the acquisition was the presence of two obstructions that allowed acquisition of only limited coverage in one part of the survey area. The effect of these obstructions can clearly be seen on the post-plot maps in Figure 2.

Data-processing

In general, data-processing for MAZ datasets is similar to conventional processing, and in some ways can be considered similar to processing for time-lapse analysis; we want to minimize sources of non-repeatability (such as geometry, water-velocity variations and multiples), but in the MAZ case, we want to retain differences due to illumination which will improve the result when the different azimuth volumes are combined. In this case, important elements of the processing sequence included;

Single-sensor processing; One of the key benefits of the point-receiver Q-Marine system is the recording of the raw sensor data at 3.125 m intervals along the streamer. At this sample interval, noise in the form of streamer vibrations caused by swell noise or cross flow is sufficiently well sampled to attenuate using coherent noise filters, providing data with improved signal-to-noise characteristics, important for optimizing bandwidth for high-resolution processing.

3D surface-related multiple attenuation (3D SRME); The complex nature of the seafloor and near-surface reflectors and refractors (especially in the areas around the canyon) meant that the multiple wavefield was also complex, and required 3D SRME to sufficiently attenuate the multiples. A true-azimuth implementation of 3D SRME was used, 3D general surface multiple prediction (GSMP) described by Dragoset and Moore (2008), that provided sufficient attenuation of diffracted multiples even with modest apertures (350x500m). To minimize turnaround time for this compute-intensive step, the 3D GSMP was run onboard using the Amundsen's compute facility, providing a high-quality multiple model that was then delivered to the Rio de Janeiro data processing-center for subtraction from the input data. Figure 3 shows the result before and after subtraction of the multiple model.

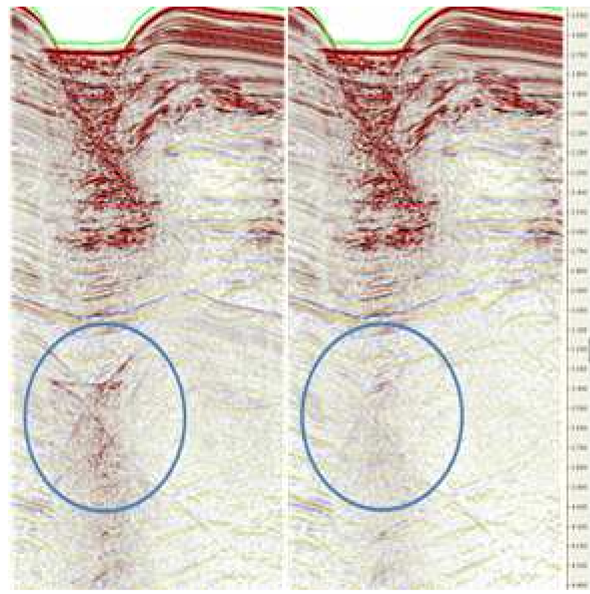


Figure 3 – Inline stack section before onboard multiple attenuation using 3D GSMP (left) and after (right). Complex multiples generated around the canyons (circled) are well attenuated.

Imaging; Given the turnaround requirement for this earl-out cube, and the fact that a full multiazimuth model building and depth imaging project would follow, a relatively simple approach was taken to the velocity model building and migration. Kirchhoff prestack depth migration was run, but using a two-layer model where the first layer is an accurate depth model of the water column, and the second layer is populated with velocities derived from from prestack time migration of the 24° azimuth volume (which has the larger coverage area). It was anticipated that using the depth migration algorithm would better handle the velocity contrasts introduced by the canyons that are poorly handled by the 1D velocity field assumption of time imaging.

Multiazimuth combination; The two azimuths were processed separately through migration, using a common velocity field, however some differences in moveout and imaging still exist due to uncompensated differences in raypaths between the two azimuths. Two statistical processing steps were used to address these issues. Firstly, residual moveout was addressed using a cross-correlation technique ('time-variant trim statics') where moveout corrections are made to flatten gathers across the desired offset range. Secondly, the datasets were matched poststack in time and space using a 3D nonrigid matching technique (Aare 2008). Figure 4 shows a schematic of the combination workflow.

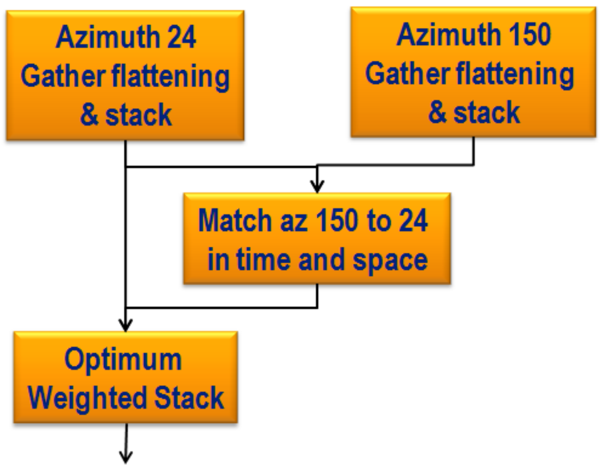


Figure 4 – MAZ matching and combination workflow

As discussed by Manning et al. (2006), when combining MAZ datasets with different illumination characteristics, it is undesirable to simply sum the volumes to provide the 'average' result. Manning proposed an optimization scheme based on adding back coherent energy in the difference. In this case, an alternative scheme was used where weights are computed from the cross-correlation of the sum and difference of the two volumes. The weights generated by this 'optimum weighted stack' technique are then applied before stacking the two azimuths together.

Resolution enhancement; The high signal-to-noise ratio data provided by point-receiver Q-Marine MAZ data allowed shaping of the spectrum to improve high-frequency content, bandwidth, and therefore data resolution, without boosting up excessive noise. Figure 5 shows an inline section before and after the poststack application of amplitude-only inverse Q filtering; improvement in the resolution of thin beds and fine details can clearly be seen. A value of 80 was used for Q, with a maximum amplitude boost of 36dB.

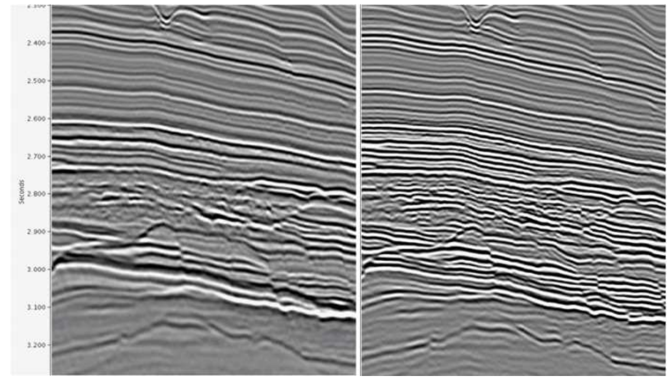


Figure 5 – Inline section before (left) and after (right) inverse Q filtering shows improvements in resolution without noise boosting

Results

Figure 6 shows a comparison between the early-out MAZ combination volume and the existing NAZ dataset over this area, acquired and processed in 2005, which is currently being used for interpretation.

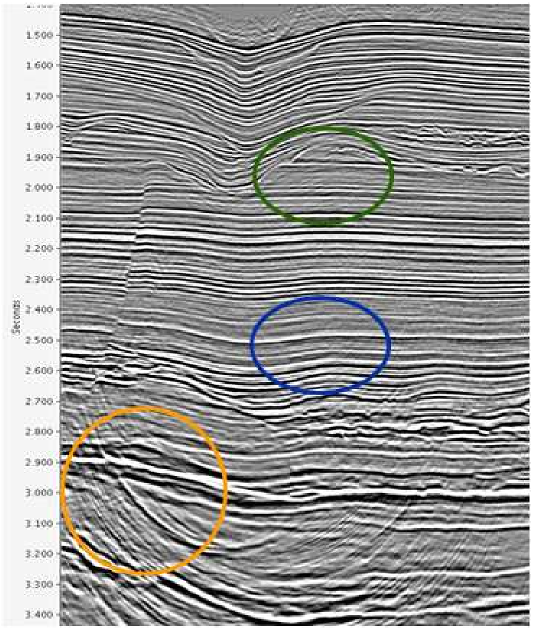
Improvements in signal-to-noise ratio, imaging and thin bed resolution can clearly be seen.

Conclusions

The acquisition and processing of the first purpose-designed MAZ survey offshore Brazil met the objectives to provide a significantly enhanced image of the reservoir, with improvements in resolution and signal-to-noise ratio.

Integrated acquisition and onboard processing, including state-of-the-art 3D multiple attenuation run onboard the vessel, allowed this high-quality early-out cube to be produced in time to influence well placement and horizontal drilling decisions.

The 2005 NAZ survey could have been used as a third survey for the MAZ processing, but that was not in the scope of this project.



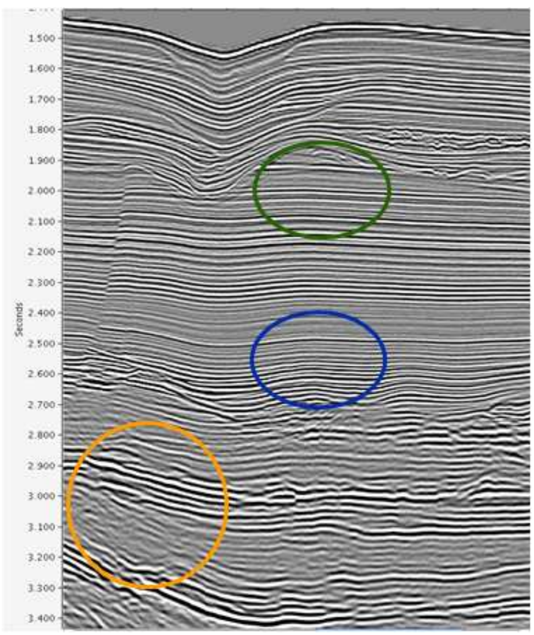


Figure 6 – Crossline stack from final MAZ volume (top) and existing 2005 data (bottom). Improvements can be seen in signal-to-noise from improved multiple attenuation (orange circle), improved resolution of thin beds (blue) and improved event continuity and signal-to-noise (green)

Acknowledgments

The authors thank Frade concession partners - Chevron Brasil Petróleo Limitada, Petrobras, Frade Japão Petróleo Limitada and WesternGeco for permission to publish this paper.

References

Aarre, V., 2008, On the presence, and possible causes, of lateral shifts below the Norne reservoir. *78th Annual International Meeting*, *SEG*, Expanded Abstracts, 3174-3178.

Dragoset, B., and Moore, I., 2008, General surface multiple prediction: a flexible 3D SRME algorithm. *First Break*, 26.

Keggin, J., Benson, M., Rietveld, W., Manning, T., Barley, B., Cook, P., Jones, E., Widmaier, M., Wolden, T., and Page. C., 2006, Multi-azimuth towed streamer 3D seismic in the Nile Delta, Egypt. *76th Annual International Meeting, SEG*, Expanded Abstracts, 25, 2891-2895

Manning, T., Keggin, J., Rietveld,W., Benson, M., and Page, C., 2006, Multi-azimuth (MAZ) towed streamer data processing flow from the Nile Delta. *76th Annual International Meeting, SEG*, Expanded Abstracts, 25, 2842-2846.