Reducing Exploration Cycle Time in the Campos Basin: Integrating Seismic Data Acquisition and Processing.

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Abstract

This paper presents the integrated approach to seismic data acquisition and processing currently being used in the Campos basin. An advanced onboard data processing workflow is described that was designed to provide high-quality data directly from the seismic vessel, enabling earlier reservoir and exploration decisions.

Introduction

Since 2009 WesternGeco has been acquiring Q-Marine surface-seismic data in the Campos basin for Petrobras (Figure 1). To maximize the value of this data an integrated approach to acquisition and processing was implemented to provide near-final-quality products directly from the vessel in a fraction of the usual delivery time.

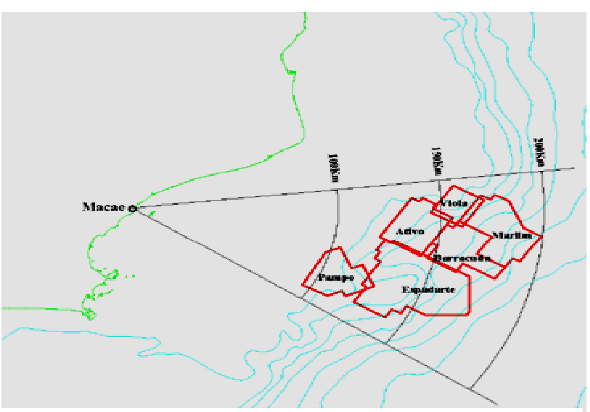


Figure 1. Location of the survey acquired by M/V Western Neptune 2009-2011.

Key data challenges in this area include variable water-depths (from 60 to 3400 m), complex water-layer multiple wavefields, strongly faulted and complex reservoir geology and high cable feather due to strong and variable currents in the area. In addition some of the data were acquired in areas that were highly obstructed (for example, with platforms and FPSOs), giving irregular data acquired with several different source and receiver geometries (Figure 2).

These surveys form one of the largest time-lapse projects in the world, which meant that the data also needed to be optimized for 4D processing.

An onboard data processing sequence was designed that met these challenges and requirements, using technologies more usually reserved for in-house data processing. This provided data of superior quality compared to a conventional 'fast-track' onboard product.

The enhanced data processing workflow was enabled by a dedicated processing center onboard the vessel staffed around the clock and connected by a high-bandwidth satellite connection to Rio de Janeiro data processing center, where data could be reviewed by WesternGeco and Petrobras.

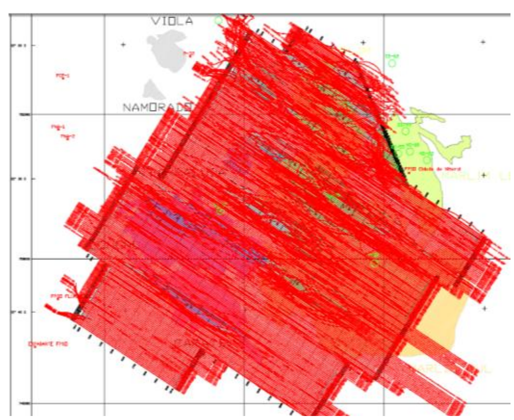


Figure 2. Post-plot map showing irregular coverage in the northern part of this 1650 km2 survey.

Data processing workflow

Highlights of the data processing sequence included;

- Calibrated marine source (CMS) processing
- A 3D surface related multiple elimination (3D SRME) workflow
- Compact Fourier interpolation (COMFI)
- High-density prestack time migration

The Q-Marine acquisition system brings several benefits for surveys that are designed to be optimized for time-lapse analysis. Some of these, such as dynamic spread control (where source and receiver positions are optimized for repeatability) were described by Le Diagon et al. (2010). In addition to highly repeatable positioning, the CMS technique allows the synthesis of far-field signatures from near-field hydrophone measurements for every shotpoint. During data processing a shot-by-shot operator is designed that matches each of these individual signatures to a common target signature, reducing non-repeatability due to variation in pressure, gun timing and array geometry (Figure 3).

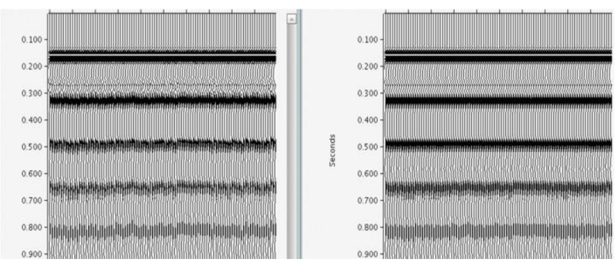


Figure 3. Left: Input signature for CMS. Right: Output signature after CMS.

Effective multiple attenuation is critical in this region where multiple energy often interferes with primary reflection data at the reservoir level introducing noise and uncertainty in interpretation and amplitude analysis. The main challenges in this area are surface multiples generated from sea-floor and near-surface reflectors and diffractors. Peg-leg multiples from deeper reflectors were also frequently observed.

A combination of multiple attenuation techniques were used, including Radon-domain multiple attenuation (which discriminates multiples and primaries based on velocity), *tau-p* deconvolution (which discriminates based on periodicity) and SRME, a technique that produces an estimate of the multiples directly from the data using an auto-convolution technique (Verschuur et al. 1992).

SRME is commonly implemented in 2D in onboard processing workflows, as it is efficient and can easily be run in near real time. There are, however, two main assumptions in 2D that lead to inaccuracies in the multiple model. Firstly it is assumed in 2D SRME that the receivers lie inline directly behind the source, and secondly that there is no crossline dip. In the Campos basin acquisition, wide-tow acquisition arrays, strong feathering due to currents and multi-vessel undershooting geometries compromise the first assumption, and it is this aspect that was addressed with a 3D SRME workflow. This workflow uses a 3D swath of input data to allow the multiples to be predicted at true azimuth, rather than the zero-azimuth assumption of 2D SRME (Figure 4).

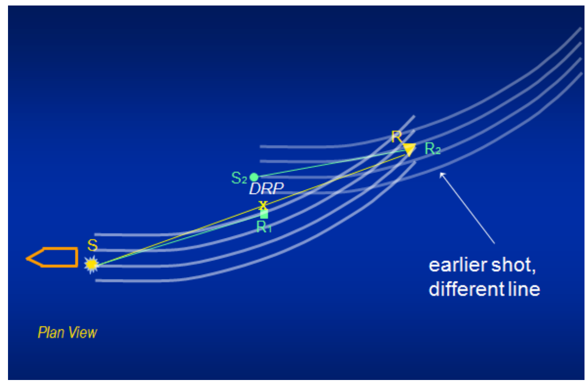


Figure 4 In true-azimuth SRME, the multiple traveltime S-X-R can be better predicted by the convolution of sub-events S-R1 and S2-R2 than can be predicted in 2D SRME where only a single cable from a single inline is input.

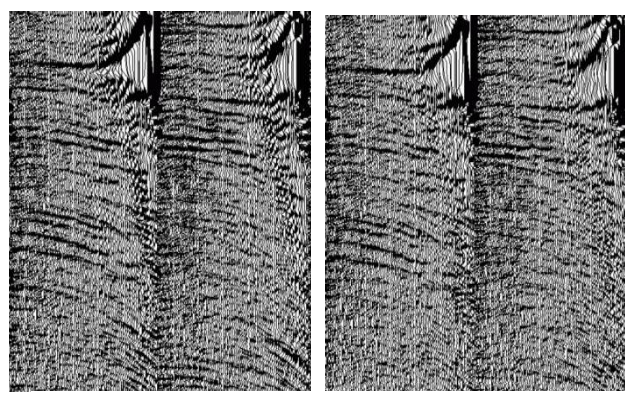


Figure 5. Left: Gather after Radon. Right: Gather after Radon and SRME. The display show how was attenuated the far-offset aliased and the near-surface multiples.

The true-azimuth SRME workflow is efficient and while it does require data from multiple input sail lines, it does not have to wait for a large swath of data to be acquired before it can be run. Figure 5 show how the true-azimuth SRME attenuates the far-offset aliased and near-surface multiples.

One of the assumptions of Kirchhoff prestack time migration is that the input data are in regularly sampled within common-offset groups. Due to The high levels of infill and undershooting in this acquisition campaign, the data were highly irregular, so an explicit regularization technique was used to condition the data prior to migration. Compact Fourier interpolation (Moore and Ferber, 2008) was used to output the data in 80 common-offset groups with data at bin centers on a 12.5 mx12.5 m grid. Full Kirchhoff prestack timeqmigration was then run using a migration velocity picked from migrated data onboard the vessel (Figure 6).

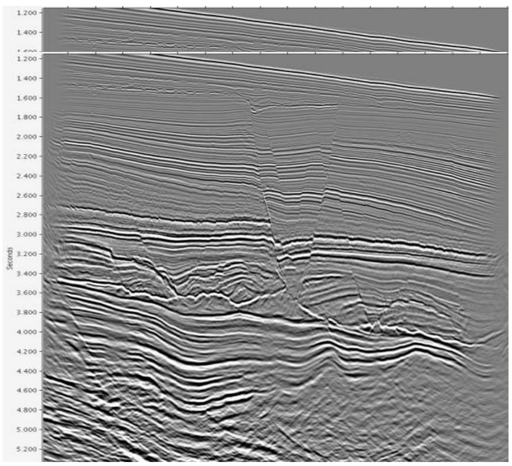
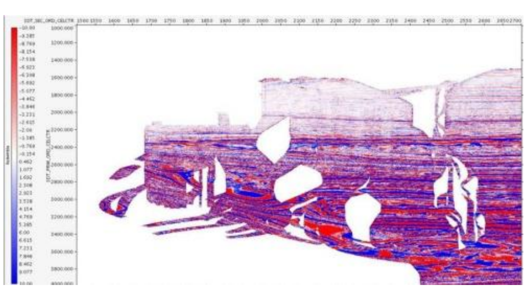


Figure 6. Stack after prestack time migration.

Acquisition Quality assurance

In addition to the rapid delivery of high-quality seismic data volumes, the additional flexibility allowed by integrating acquisition and processing onboard the vessel also allowed improved acquisition quality assurance. For example, it was possible to judge the effect of noise (such as seismic interference) on the final product, and to compare the effect of additional campaigns of undershoot in the area, giving confidence that the reservoirs were sufficiently illuminated for interpretation and 4D analysis.



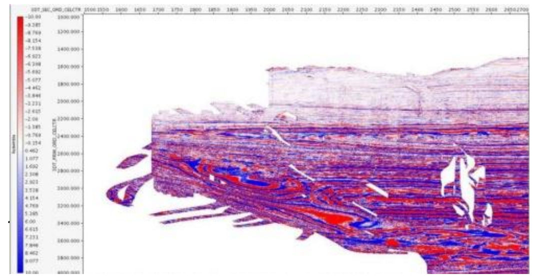


Figure 7. Time slices through prestack time-migrated volumes produced before and after acquisition and processing of undershoot data.

Conclusion

Integrated acquisition and processing during the Campos basin 4D seismic campaign significantly reduced the turnaround time for the delivery of high-quality seismic data, enabling earlier reservoir and exploration decisions. Because high quality data was delivered 6 weeks after the last shot.

The data processing workflow developed for this area, was customized for the different geophysical situations encountered in each prospect, and provided high-quality products that included high-resolution prestack time-migrated interpretation volumes, angle stacks for AVO analysis and enhanced prestack gathers ready to be used for depth imaging or further 4D processing.

In addition, dedicated and flexible data processing resources provided enhanced acquisition quality assurance.

Acknowledgments

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References

Le Diagon, F, P. Waterson, J. Paulsen, R. Tovar, I. Macedo and A. Ortolan. et al. 2010 Results seen from the first application of a System for Dynamic Control of Vessel, Source and Streamers in 4D acquisition off shore Brazil. *Proceedings of the Rio Oil and Gas Expo & Conference.*

Moore, I. and R.Ferber, 2008 “Bandwidth Optimization for Compact Fourier Interpolation”, *70^{th} EAGE conference & exhibition, Extended abstract.*

Verschuur, D. A.J. Berkhout, and C.P.A. Wapenaar, 1992, Adaptive, surface-related multiple elimination, *Geophysics,* 57*, 1166-1177.*