Integrating legacy data with new towed-streamer acquisition tuned for imaging objectives: a Campos Basin case study

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Summary

Results are presented from the processing of new acquisition in combination with complementary reprocessing of legacy data over 8200 square kilometers in the deep waters of the Campos Basin, offshore Brazil. The acquisition configuration was a result of extensive survey design and modelling studies, designed to meet both the technical needs of the area and the regulatory requirements of Brazil. Survey planning considered characteristics of the existing legacy data, specific geological targets, imaging challenges in resolving the pre-salt syn-rift section, and sampling requirements of high-end imaging methods. We show that the combination of a legacy survey with an appropriately designed new survey provides the basis for robust velocity building and notable improvements in image quality, which will bring greater confidence in interpretation and reservoir characterization work.

Introduction

Exploration and reservoir development in Brazil's Campos Basin continues to add new seismic data to areas that have been previously covered with 3-D surveys. Combining multi-sensor, broadband fidelity with richer azimuth illumination is a proven concept for providing upgraded seismic data in a practical and efficient manner (e.g., Oukili *et al*., 2020; Reiser and Mueller, 2021). This technology was deployed in the Campos Basin as part of a pragmatic strategy to upgrade existing data. The new narrow-azimuth survey was acquired with a north-south orientation, complementing the east-west legacy survey acquired more than twenty years earlier. The combination of these two datasets with their different azimuths and the harmonizing of the pre-processing, velocity model building and imaging brings important uplift to subsurface illumination.

Survey Design

Planning for this survey focused on ensuring the new data would benefit the velocity model building and imaging challenges in the Campos basin. Multi-azimuth streamer acquisition is not a new development in Brazil; surveys over several blocks/fields have shown good uplift in imaging with the inclusion of additional azimuthal information (e.g., Cooke *et al*., 2011; Burren *et al*., 2013; Comeaux *et al*., 2013, Vieira de Luca *et al*., 2017). Contemporary towed streamer acquisition allows unobstructed areas to be surveyed quickly and efficiently, applying the multi-azimuth concept effectively over large areas, covering many proven and prospective fields.

The legacy data was acquired east-west using a Continuous Long Offset (CLO) configuration, providing offset coverage up to 8 km. CLO is an acquisition configuration that uses two vessels, one source-only vessel along with a second vessel equipped with both sources and streamers, allowing offsets longer than the streamer length to be acquired (van Mastrigt *et al*., 2002). The configuration for the legacy CLO data was 8 streamers towed 100m apart, with a length of 4050m. The second source vessel sailed 4000m ahead of the streamer vessel, providing a dataset with an 8 km maximum offset, and equivalent to around 2 x 32km of active streamers in the water. The original CLO data was reprocessed through depth model building and imaging showing good improvement with modern techniques, but it still exhibited some imaging and illumination challenges.

The new, second azimuth covering the area used a configuration with a spread of 14 multi-sensor streamers, 10 km long, towed 100m apart, acquired with a north-south orientation. This was an industry record at the time; the largest seismic spread ever towed in Brazil, with around 140 km of active streamers in the water. Figure 1 shows a schematic of the two acquisition designs.

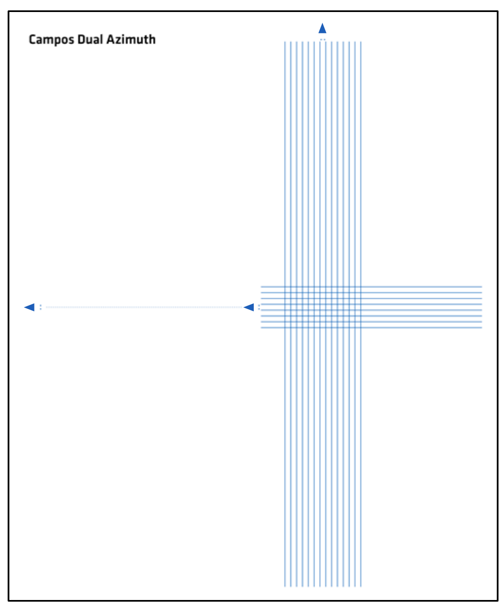

Figure 1: Schematic layout of Campos GSX dual azimuth acquisition configuration: legacy CLO data shot east/west, using two vessels achieving a maximum offset of 8 km, and new Campos Deep Water data shot north/south with 10 km cables

The new survey design was developed to bring additional azimuthal information and to increase the maximum offset to aid both imaging and velocity model building in this complex basin. The survey design included a forward modeling study, based on information from the legacy reprocessing, to help understand the potential for diving wave penetration.

Operational Efficiency

The Campos Basin is well known for rough weather and extensive barnacle growth. Keeping the barnacle growth to a minimum is essential for reducing drag on the cable and provides cleaner seismic data. Despite this challenge, the new acquisition was completed ahead of schedule, with minimal down-time, thanks to the use of two technical innovations: 1) a proprietary streamer coating designed to hinder barnacle growth, and; 2) the combination of Remotely Operated Streamer Tool deployment (ROST) of Streamer Cleaning Units (SCU). Applying the streamer coating to the first kilometer of each streamer successfully mitigated barnacle growth of the coated sections. The reduced barnacle growth meant that the fronts of the cables did not have to be scraped during the survey. The SCUs removed the barnacles that grew on the uncoated sections of streamer. The SCUs are usually deployed from a work boat, but for this survey the use of ROST to deploy and retrieve the SCUs reduced small boat operations and therefore the overall HSE risk (Skadberg *et al*., 2021).

Velocity Model Building

Aspects of the velocity model building work in this area have been discussed previously, taking advantage of automated tomography methods to provide a quick look Fast Track image (e.g., Martin and Bell, 2019). The Full Integrity model building picked up from this robust starting point, taking advantage of the new data's offset and low frequency characteristics by employing Full Waveform Inversion to

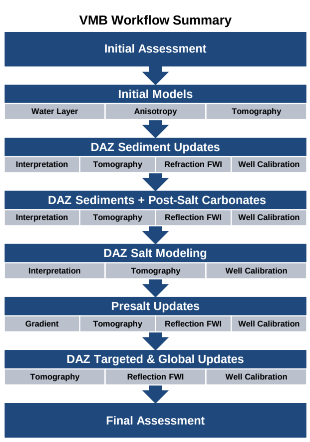

Figure 2: Basic TTI VMB workflow used for the CDW processing.

develop a more detailed velocity model (Alcantara et al., 2021). The basic TTI VMB workflow is shown in Figure 2.

Data-driven methods were used through-out with appropriate QC, interpreter validation and well calibration at key stages. Information from both azimuths was used in velocity model building, providing additional information for constraining the updates. As expected from the pre-survey modeling exercise, the FWI using the diving waves penetrated through much of the sedimentary over burden and salt allowing stable updates to be achieved (Figure 3), while reflection information was used to drive the deeper updates (Figure 4).

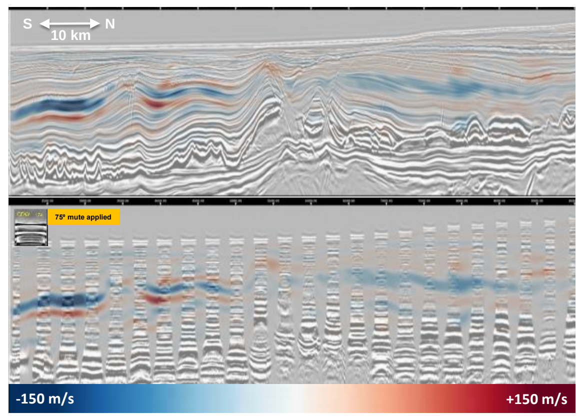

Figure 3: Example stack (top) and butterfly image gathers (bottom) with FWI perturbation overlay used in the quality control of early stages in the VMB.

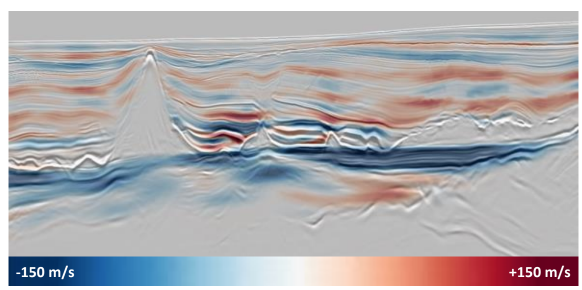

Figure 4: Example quality control stack with perturbation overlay from reflection driven updates to the velocity model.

Imaging

The dataset was imaged using a TTI Kirchhoff Pre-Stack Depth Migration (KPSDM) for high resolution imaging of the post-salt sequence and simpler salt structures, and with a TTI Reverse Time Migration (RTM) for resolving more complex structures. Both migrations provided image gathers for parallel post-processing and imaging enhancements on the separate surveys. The combined dual-azimuth image provided the anticipated illumination benefits as well as improvement in the signal-to-noise ratio. Figure 5 illustrates the improvements achieved by the reprocessing and addition of an extra azimuth, while Figure 6 shows examples of the final RTM and KPSDM dual azimuth images

Conclusions

New acquisition combined with reprocessed legacy data delivered improved imaging over 8200 square kilometers in the deep waters of the Campos Basin, offshore Brazil. This was achieved using an acquisition configuration based on extensive survey design and modelling studies, designed to meet both the technical needs of the area and local regulatory requirements. Several key factors were considered: characteristics of the legacy data, specific geological targets, imaging challenges in resolving the pre-salt syn-rift section, and sampling requirements of the high-end imaging methods. The combination of the legacy survey with an appropriately designed new survey provided the basis for robust velocity building and notable improvements in image quality, bringing greater confidence in interpretation and reservoir characterization work.

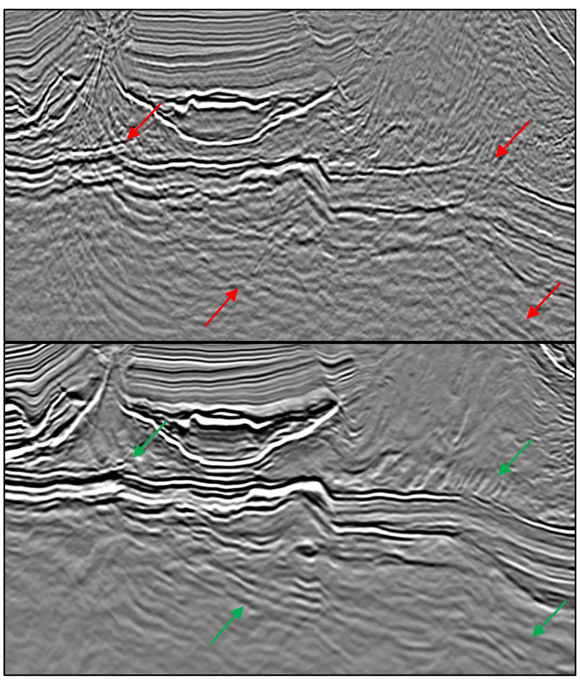

Figure 5: Example stack images from the original processing of the legacy east-west survey (top) and the new dual-azimuth stack (bottom).

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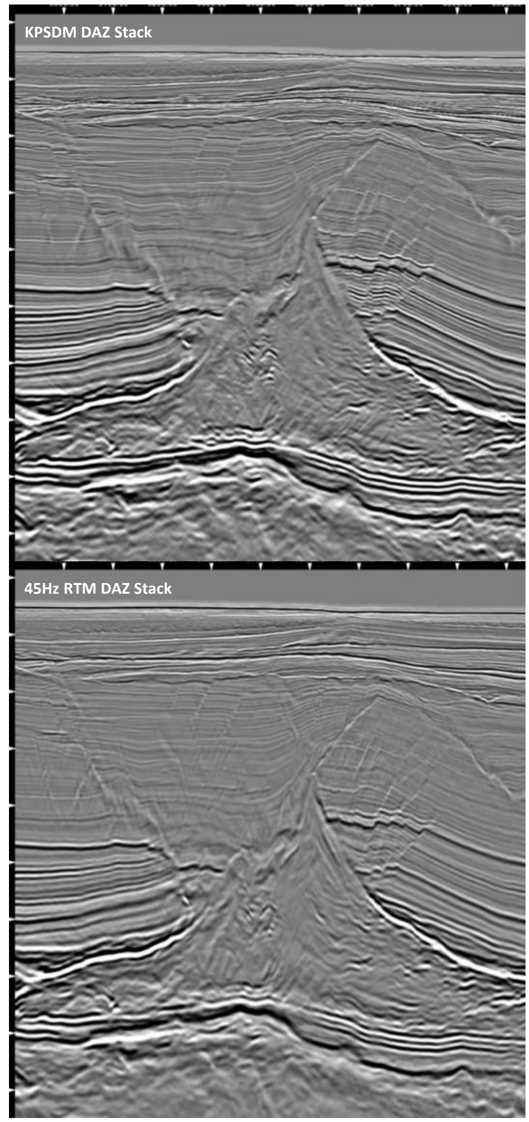

Figure 6: Example images of the KPSDM (top) and RTM (bottom) dual-azimuth final stacks.

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