Pre-processing Improvements for Enhanced PSTM and TTI PSDM Images in the Santos Basin: A Case History

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Summary

The Santos Basin, offshore Brazil, is a geophysically challenging area to image due to the presence of evaporite sequence layers, carbonate layers and massive salts across the region. In addition, the rugose water bottom causes very strong multiples that are both in and out of the plane of the section. A case study undertaken to assess the impact of a fully-revised pre-processing and imaging flow demonstrates that newer pre-processing technology can deliver significantly improved imaging results, particularly in the pre-salt section. A Pre-stack Depth Migration (PSDM) using the newly pre-processed data as input and utilizing both Kirchhoff and Reverse Time Migration (RTM) algorithms, plus a correction for Tilted Transverse Isotropy (TTI), shows considerable uplift in comparison with the previous isotropic Kirchhoff depth migration.

Introduction

The recent discovery of a series of giant fields in the pre-salt section of the Santos Basin, offshore Brazil, has generated significant exploration interest in this area. This has created a need for higher quality seismic imaging of the pre-salt section.

In this paper we present a case history of an evaluation project to assess whether the latest advances in pre-migration processing can improve the removal of multiples and other types of noise that mask the sub-salt sediments.

The data selected for the test comes from the WesternGeco/TGS Brazil 2D Alliance survey (see **Figure 1**). This data set was acquired and processed in 1999/2000. Acquisition used a 5,000 cubic inch gun at a shotpoint interval of 37.5 m and a group interval of 25 m. There were 324 channels using an 8,100 m cable yielding 108 fold. The final survey outline consists of over 127,000 km of 2D data in the Santos, Campos and Espirito Santo Basins.

A subset of two lines from the Santos Basin portion of the survey was chosen for this evaluation. Both had substantial amounts of multiple and other noise remaining after the original time migration processing performed in 1999/2000. This left over noise resulted in numerous migration swings that masked deeper data in the final migration.

Figure 1: Location of the survey

Method

The data set was first processed in 1999/2000 and subsequently reprocessed in order to take full advantage of the latest developments in depth imaging. Starting in 2007, the original preprocessed data was used as the input to a reprocessing of the data through isotropic PSDM using Kirchhoff and one-way Wave-Equation Migration (WEM) algorithms. The introduction of depth imaging facilitated improved resolution of the salt geometry and subsalt sedimentary basins.

For the current test project the decision was taken to evaluate the impact of the numerous advances in preprocessing that have taken place in the decade since the original work was performed. These advances may be categorized into three main areas: amplitude/phase handling, multiple attenuation and time-imaging.

In the 1999/2000 processing the data was converted to minimum-phase in preparation for a spiking deconvolution. For the current processing this was replaced by a more deterministic processing methodology. A wavelet was extracted from the data and used to compute a de-bubble operator and a zero-phase conversion operator. The de-bubble operator significantly improves the interpretability

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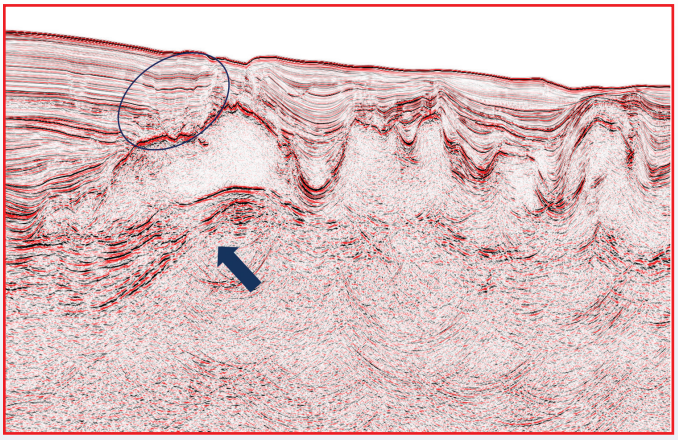

Figure 2: 1999/2000 Post-stack Kirchhoff time migration result.

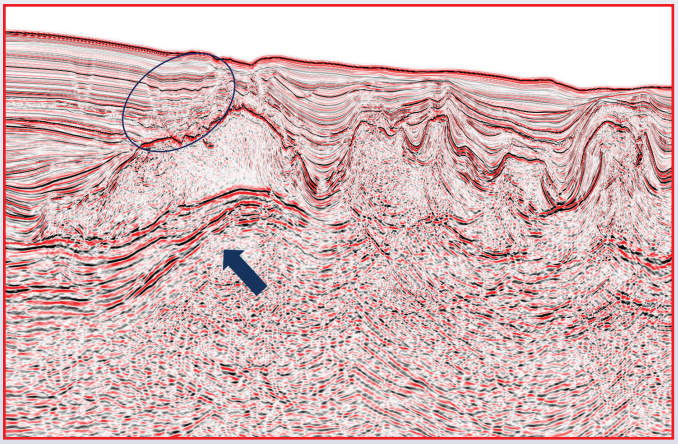

Figure 3: 2011 Pre-stack Kirchhoff time migration; compare with Figure 2. The blue circle illustrates the improved imaging of the shallow section. The blue arrow highlights the improvements to the subsalt section.

of the shallow section, while the zero-phase conversion step provides stable phase handling across the data set and a consistent phase at the water-bottom.

In 1999, in addition to the deconvolution step, multiple attenuation was performed using two passes of standard Radon transform multiple attenuation. For the revised processing flow 2D Surface Related Multiple Elimination (SRME) was used in conjunction with high-resolution Radon de-multiple. In addition the current processing included a rigorous multi-domain noise attenuation flow that utilized the receiver and offset domains. This significantly reduced any residual and out of plane multiple energy that remained in the data. The new processing also used a low frequency boost to enhance the imaging of the pre-salt section.

The original time processing in 1999/2000 used a Pre-stack Time Migration (PSTM) flow that included Dip-moveout (DMO) correction and FK-PSTM, followed by a final post-stack time migration. In the current processing this sequence was replaced with full Kirchhoff PSTM.

The 2007 depth imaging flow used isotropic Kirchhoff migration for the model building and the final migration. For the 2011 processing flow TTI Kirchhoff and TTI RTM were both used for the model building steps and the final migration.

The anisotropic parameters delta and epsilon were calculated using the Focusing Analysis (FAN) methodology developed by Cai et al. (2009) (see also He et al., 2009).

The TTI model building included determining TTI anisotropic parameters for the sediments above the salt, and tomographically updating the velocity in areas above and below the salt using gathers from Kirchhoff TTI PSDM. These parameters together with latest velocity model were used as input to the TTI RTM . After the TTI RTM, low frequency background noises are attenuated by Laplacian filter and amplitude scaling was applied.

Results

Considerable improvement was seen in the results of the 2011 processing when it was compared to the 1999/2000 results.

Figures 2 and 3 show the comparison results between the original 1999/2000 time processing and the 2011 processing. The sedimentary section above the salt shows improved continuity throughout the 2011 result, which is most likely due to the introduction of a deterministic processing flow and full pre-stack time imaging. The 2011 data has much improved low frequency continuity in the subsalt and contained fewer high frequency swings caused by leftover, out-of-plane multiples. This is due to the application of multiple iterations of noise attenuation

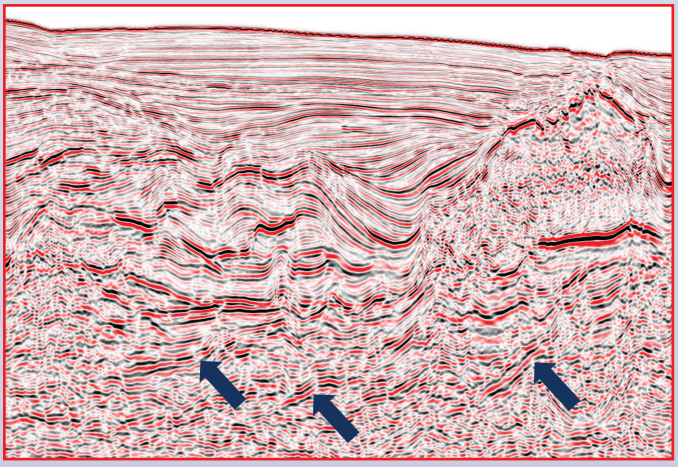

Figure 4: 2007 isotropic Kirchhoff PSDM

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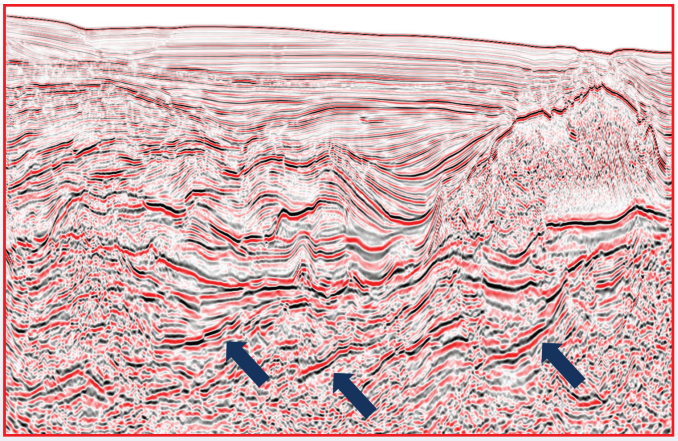

Figure 5: 2011 TTI Kirchhoff PSDM. Compared with Figure 2 the updated workflow has delivered significant improvement throughout the section, in particular the salt and pre-salt structures.

in the shot, receiver, CMP and offset domains, plus the introduction of a low frequency boost.

Figures 4 and 5 show a comparison of the Kirchhoff PSDM results. **Figure 4** shows the isotropic Kirchhoff and Figure 5 the TTI Kirchhoff. The anisotropic Kirchhoff shows considerable improvement throughout the section; in particular, there is a notable improvement in the subsalt rift and post-rift section as indicated by the blue arrows.

Accounting for TTI anisotropy significantly improved the imaging of the salt bodies and steeply dipping sediments. Delta values of around 7% and epsilon values of around 15% were estimated. Epsilon and delta were limited to the post-salt section.

Figures 6 and 7 show a comparison of images obtained using Kirchhoff PSDM and TTI RTM. The steep-dip imaging of the salt flanks, top and base of salt are greatly improved and the subsalt events are better imaged in the TTI RTM.

Conclusion

This Brazil 2D reprocessing study was considered a success. It showed that the implementation of a fully revised and up to date pre-processing flow can greatly improve the image quality below the salt on both time and depth migrations. In addition, the use of the TTI anisotropy correction and RTM significantly enhances the quality of the sediments below the salt, the salt base itself and the steeply dipping sediments.

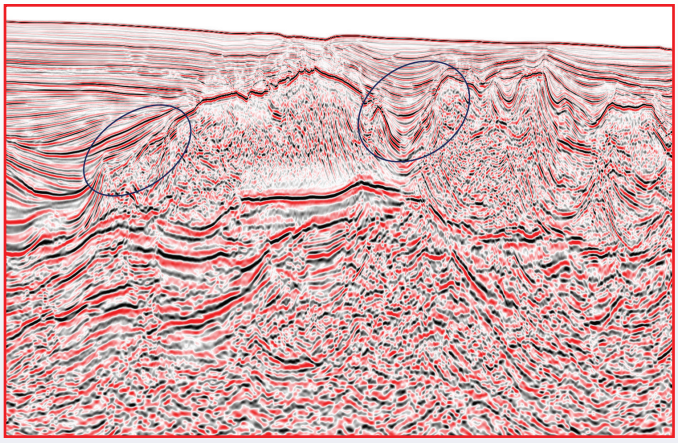

Figure 6: TTI Kirchhoff PSDM

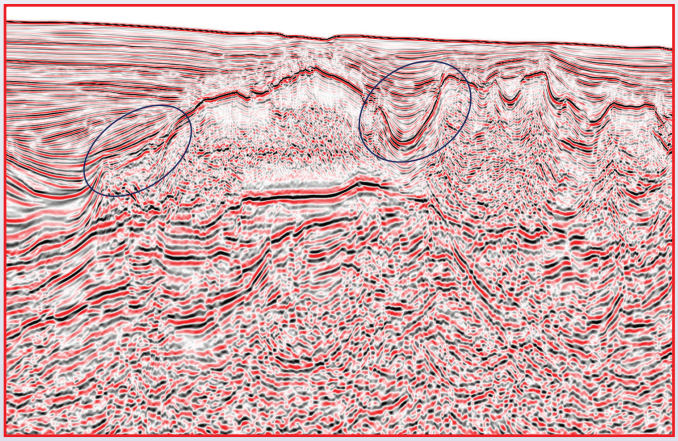

Figure 7: TTI RTM . Ellipses show areas of improvement as compared with the TTI Kirchhoff PSDM.

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