An imaging case study of Ragay SC43, Philippines: From 2D to 3D PSDM Processing

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SUMMARY

Ragay SC43 Block is located off the southern tip of Bondoc Peninsula, between the Ragay Gulf and the Sibuyan Sea. Huge carbonate reef was developed and complex faulting system dominated in the shallow sediment in this area. This results in a very complex subsurface geology with strong lateral velocity contrast, which made high resolution PSDM processing essential for the successful structure imaging in this area. With dense model representation and optimized inversion regularization, a more detailed velocity model is derived by high resolution tomography update technology. High resolution velocity model is achieved in shallow sediments as well as between huge reef and surrounding sediments. Together with high fidelity controlled beam migration technology, the carbonate reef reservoir was much better imaged which gives valuable information for the future E&P activities in this area.

Key words: fault, carbonate reef, high resolution model building, controlled beam migration.

INTRODUCTION

Ragay Gulf, off the southern tip of Bondoc Peninsula in Philippines, is believed to offer potential for more than 100 million boe and has the proximity to consumer markets in Manila (Sternback and Connolly, 2000), but the hydrocarbon exploration was impeded by generally poor quality of the legacy seismic data. The Philippine Far East region is experiencing renewed wildcat exploration as a result of improved marine seismic data and a better understanding of the prospective play types for oil and gas. The age and geologic column of this area is similar to N.W. Palawan, because the islands share a related depositional and tectonic history. N.W. Palawan commercial discoveries are productive in carbonate reservoirs, and include Malampaya field and Nido Field (Grotsch et. al, 2000).

In this area, the initial 2D marine seismic shows a number of structures that could represent large-scale subsurface oil traps. They are mainly carbonate pinnacle reefs and carbonate banks, which is a proven reservoir type in the Philippines area. But the Ragay Gulf exploration has been hampered poor seismic data due to its complex geology. A new 3D acquisition survey was shot in 2009 as shown in Figure 1. PreSTM processing was done at 2010 and the seismic data quality is improved over previous 2D data but still in lack of resolution especially down to the target level at carbonate reef. New PreSDM processing was done recently and a step change of seismic data quality is achieved thanks to the improved velocity model building technology and advanced depth migration algorithm.

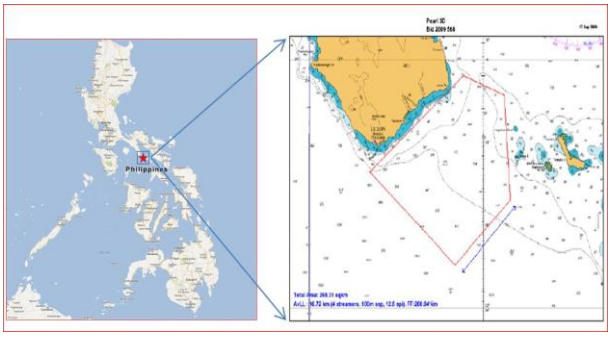

Figure 1: Ragay field location

SEISMIC DATA COMPARISON AND ANALYSIS

The initial attempt to explore this area was a 2D seismic survey acquired in 2007. The 2D seismic data revealed a number of structures that represent subsurface oil trap in the carbonate pinnacle reefs. Due to the complexity of subsurface geology, the 2D seismic data was not giving satisfactory imaging at both the shallow sediments and deep carbonate reef. The section is quite noisy and energy is not focused. The 2D seismic section is shown in Figure 2.

It is quite clear that 3D imaging is necessary in this complex area. A 3D survey covering a total area of approximately 260 km^2 was shot in 2009. The 3D data was initially processed with 3D PreSTM technology. 3D PreSTM has achieved much better shallow imaging and better signal-noise-ratio in the data comparing to the previous 2D section. However, it failed to

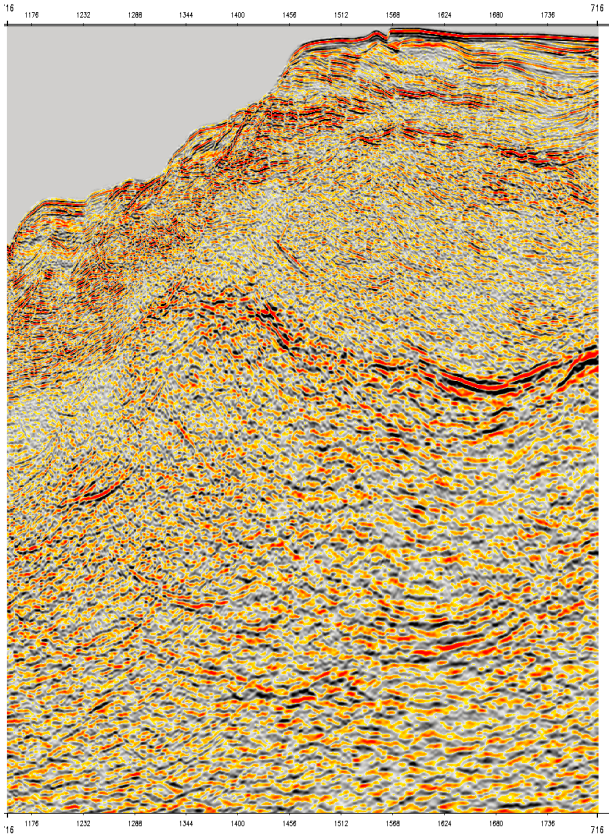

Figure 2: 2D PSTM seismic section

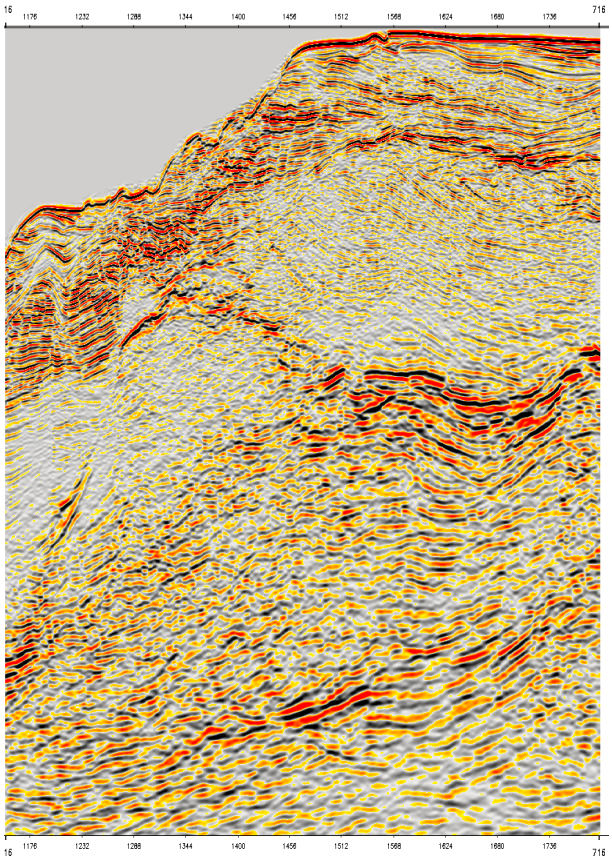

Figure 3: 3D PSTM seismic section

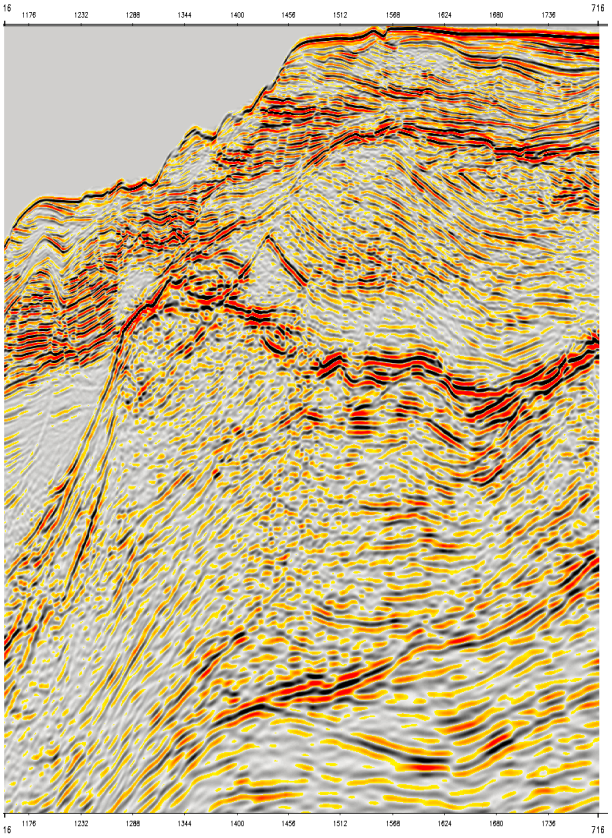

Figure 4: 3D PSDM seismic section

provide good imaging of carbonate reef level due to the complex structure. It was realized that it was out of PSTM's capability to image sharp reef boundary given the strong lateral velocity variation in the data. The 3D PSTM section is shown in Figure 3.

This data was re-processed with PreSDM with the objective of achieving a better carbonate reefs and pre-reef sediments imaging. It is apparently that the objective is achieved by applying the latest model building technique and advanced seismic imaging technology:

1) High-resolution model building is realized by using dense velocity and gather grid (50x50x20m). It is working quite well in the shallow part as the signal-noise-ratio is relatively high. Due to high quality common imaging gather (CIG) picking, harsh pre-conditioning before inversion can be avoided so that sharper velocity contrast is obtained. The updated model is much sharper and more geology-consistent. The migrated gathers are more flat.

2) High fidelity controlled-beam migration (CBM) was used to account for the strong velocity contrast and also greatly enhance data signal noise ratio. As a specialized version of beam migration, Controlled Beam Migration (CBM) enhances signal-to-noise of image and steep dips, it has been a powerful imaging tool which can deliver clear, easy-to-interpret structural images in complex areas (Gray et al., 2009). CBM has been widely used for velocity model building, structural imaging and imaging of sparse and noisy data (Ting and Wang, 2009). However, earlier version of CBM falls short for AVO analysis and the inversion process. The new development of High Fidelity Controlled Beam Migration (HFCBM) further reduces the migration artefacts, enhances

the signal-to-noise ratio and preserves the relative amplitudes (Zhou et al., 2009). It has been very successfully in the reprocessing of the Ragay field.

A 3D PreSDM section is shown in Figure 4. The reef boundary is much better delineated and faults are better imaged compared to PSTM data. Timeslices at 800ms and 1800ms are also shown in Figure 5 and Figure 6 for PreSTM and PreSDM result, respectively. Obvious imaging improvement at the shallow faults and carbonate reef is seen in the PSDM result.

HIGH RESOLUTION MODEL BUILDING

In seismic data processing, the accuracy of velocity model is crucial for imaging the geological structures beneath complex overburden. In the model building part of seismic prestack depth migration projects, tomography based on the analysis of the curvature of migrated common image gathers (CIG) (Stork,1992) broadly used. With the increasing challenge of imaging the structures under extremely complex geological bodies (e.g. gas cloud, hydrates, faults etc.), the requirement of velocity resolution is becoming higher and higher. The high resolution velocity model building methods become a key component in seismic processing. In addition to a good tomographic inversion algorithm, the selection of CIGs, the reliable automatic CIG picking tools and the model representation techniques are also critical for a high resolution velocity update.

Shallow Velocity Model Update

The accuracy of tomography is mainly limited by the model representation (e.g. model grid size) and the regularization of the inversion solver. For this 3D data at shallow part, even though the structure is quite complex but the data quality is still good and signal-noise-ratio is high. In practice, a dense model grid with the grid size of 50mx50mx20m was used and a mild pre-conditioning was applied for velocity inversion to achieve high resolution velocity update in the shallow areas.

The high resolution tomography update was implemented and a detailed velocity model is obtained as shown in Figure 7. Without high resolution update, the velocity trend is smoothed and velocity leakage across faults. From the migrated gather it is also shown that there is still quite some curvature. And the conflicting event curvature also indicates that there is big velocity contrast in a very small vertical dimension of 100-200m. The velocity is much more geology-consistent with the fault structures after high resolution update. The conflicting gather curvatures are also minimized.

Deep Carbonate Reef Velocity Update

In the deep target zone, due to the poor data quality and limited reflection angle, the high resolution tomography that is successfully applied in the shallow update is no longer valid. At the deep part, the tomographic inversion is more ill-conditioned and requires a stronger regularization (big smoothing) to stabilize the inversion, which reduces the resolution. It is mandatory to have some geology interpretation which can restrain the smoothing over the boundary. In this data, the carbonate reef top was interpreted and used to restrain the velocity update. By doing this, the velocity contrast across reef boundary is still preserved. The velocity is much more geology-consistent after reef update. The reef boundary is much better imaged and some internal structures show up in the reef.

CONCLUSIONS

It is demonstrated that 3D PSDM processing with high resolution model building and advanced migration algorithm has brought a step change of seismic data quality in the survey of Ragay Gulf. It greatly improves the imaging of shallow faulting system and deep carbonate reef, with the potential to unlock its huge carbonate reservoir. This work flow provides a promising solution for the imaging issues in the complex area with poor signal-noise-ratio that is typical in Philippines.

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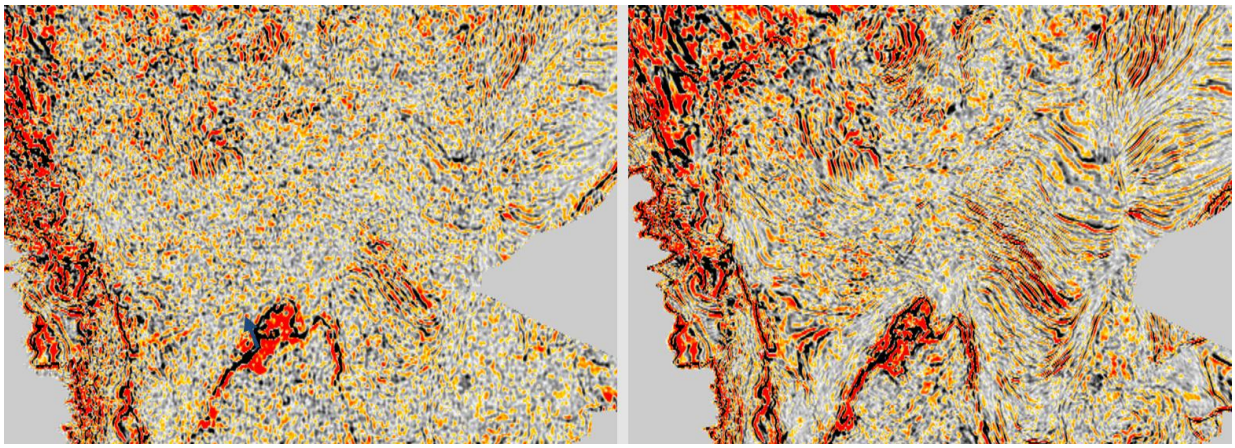

Figure 5: 3D PSTM v.s. 3D PSDM timeslice comparison (800ms, shallow fault planes / dipping strucutre are much better imaged with depth migration)

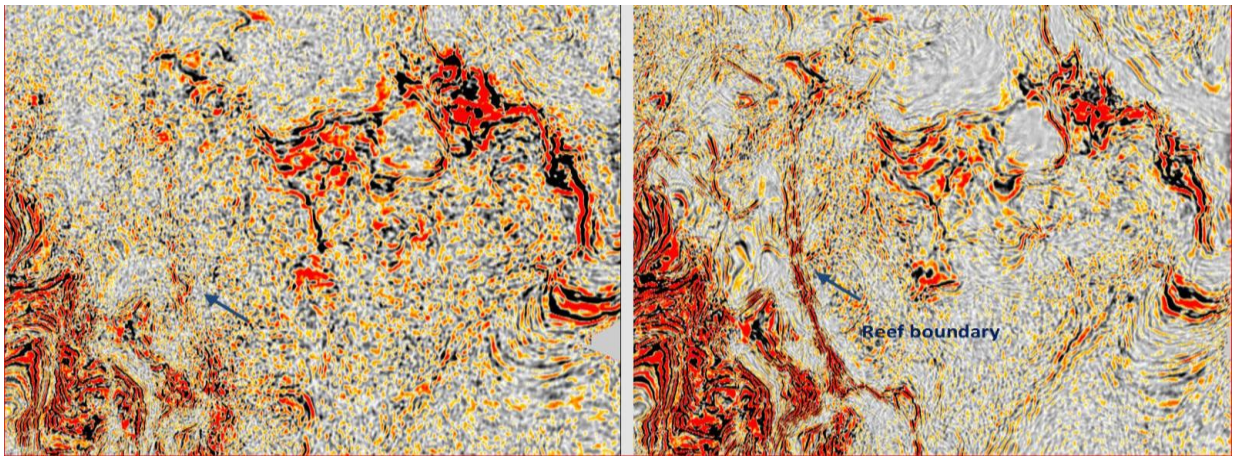

Figure 6: 3D PSTM v.s. 3D PSDM timeslice comparison (1800ms, reef dipping boundary is much better imaged in dpeth migration)

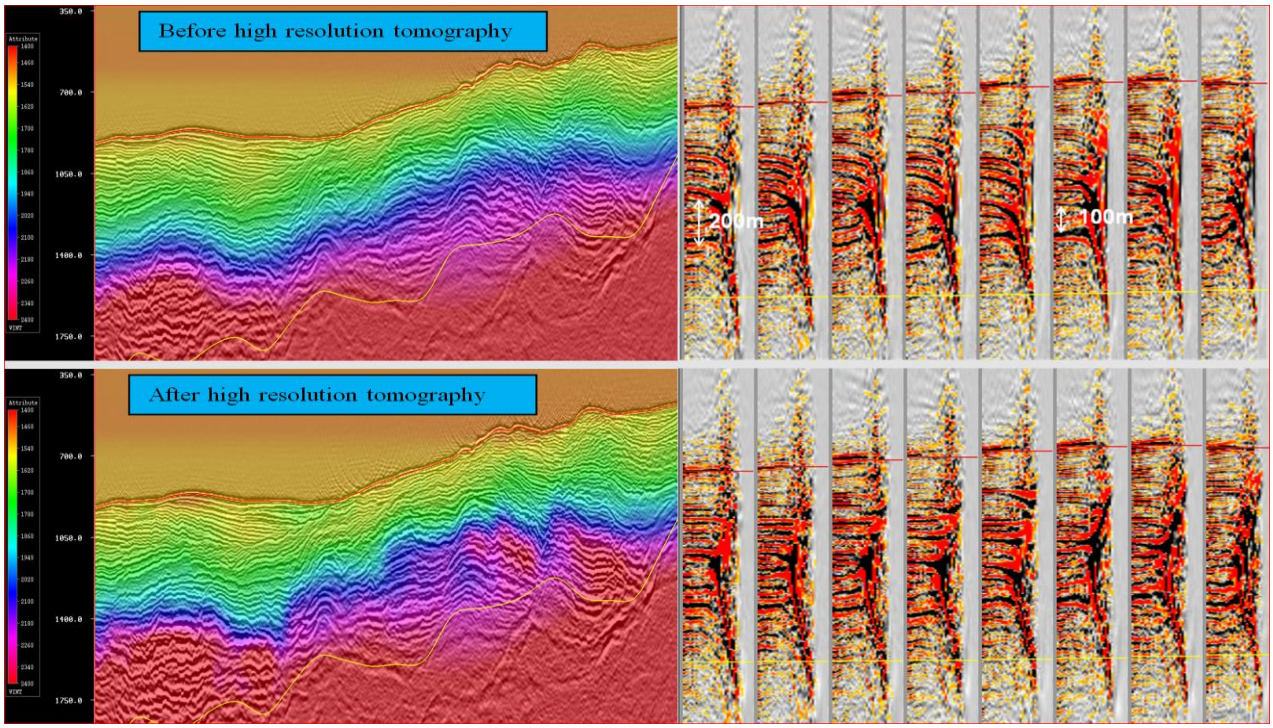

Figure 7: High resolution tomography for velocity update (Details were put into the velocity model with geology conformation, hence gather curvatures are pretty much elliminated.)