Broadband processing enhances imaging of deep KG Basin targets in shallow water 3D seismic data

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Keywords

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Summary

Seismic data quality of the deep pre-rift and syn-rift section always suffer from lack of low frequency in conventional seismic acquisition and poor image focus due to velocity complexity. Low frequency has better penetration to deep targets but suffers from the ghost effect of conventional flat streamer acquisition. Broadband processing partly compensates for the ghost effect to recover the lower frequency that is very critical for interpretation of the deeper targets. PSDM with a more accurate velocity model honors the 3D velocity variations and gives better image focusing and positioning than PSTM.

Introduction

The NE-SW-trending Krishna-Godavari basin is a Pericratonic basin situated on the eastern continental margin of India. The detailed geophysical surveys indicate the basin to be divisible into three sub basins, viz. Krishna sub-basin, West Godavari sub-basin and East Godavari sub-basin. This block falls within the Krishna sub-basin in the vicinity of the Krishna River, east coast off India, with water bottom varying mostly from ten to one hundred meters over most of the area. The basin is divided into a number of rotated half grabens which are arranged in an en-echelon manner offset by major cross trends.

The Krishna-Godavari basin has originated during the Jurassic period due to extensional tectonics and evolved in two phases. The N-E trending horst and grabens wherein continental clastics were deposited during Late Jurassic-Early Cretaceous times from the rift phase. The extended ocean margin basin with 6000 to 8000 m of sediment fill during Late Cretaceous-Holocene from the drift phase. Seismic surveys indicate thick sedimentation in deep water, slopes and basin plains giving rise to extensive development of growth faults, associated with rollover anticlines, along with turbidite fans particularly during the Neogene.

The targets in this survey are Tertiary sediment, Cretaceous and deeper sediments with depth up to 6000 m. With such a thick overburden, the seismic resolution drops significantly. The objective for the acquisition and processing is detailed imaging of structural and stratigraphic features, especially the potential stratigraphic features in the Palaeocene, Eocene and Mesozoic sequences. The main syn-rift and pre-rift layers also need illumination deeper in the section, around 2 s to 4 s, for proper interpretation. High frequency has poor penetration to the deep due to intrinsic absorption and scattering from hard layers. Low frequency is very critical in this case.

Another challenge in this survey is the top basement reflector and structures which are complex and poorly imaged in legacy data. The basement map clearly indicates a NE-SW trending rift geometry. Basement depth varies from ~500 m to 6000 m and basement sharply deepens towards the SE. To properly image the top basement and deep buried Mesozoic tilted fault blocks requires a proper velocity model and advanced imaging technology.

The 3D seismic data were acquired in the first half of 2014 (Figure 1) with a conventional flat streamer configuration. The streamer length is 8 km which is longer than usual to record relatively large reflection angles of the deep target and improve the data sensitivity to velocity analysis. The longer offset data yields a conventional 81 CMP fold to improve the S/N in the stack. The seismic data were broadband processed and pre-stack time and depth migrated. It intrinsically results in higher resolution in comparison to legacy data.

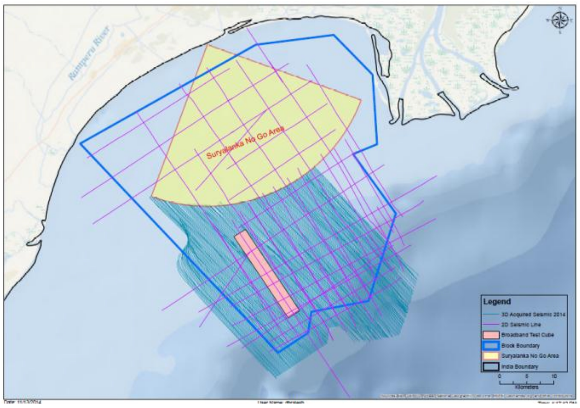

Figure 1. Outline of KG Offshore Block displaying the 2D and 3D seismic lines.

Broadband increased the lower and higher frequency amplitude spectra providing for high precision seismic resolution to several of the deep seated features of pre-rift and syn-rift that were essentially invisible (or not properly imaged) with vintage seismic.

Broadband pre-migration de-ghosting

Data processing initially involved the re-processing of the 2D legacy data and a 3D fast-track, poststack migrated, short offset volume to address several of the interpretation priorities. Based on the 2D reprocessing a test broadband cube was delineated approximately along the sail in-lines of the 3D data so as to compare results of broadband with conventional processing (Figure 2). Upon data comparison it was decided to broadband process the full-offset volume in PSTM/PSDM domains.

The employed processing flow of broadband processing was very much similar to the conventional processing flow except for one extra de-ghosting step added after the major de-multiple steps. The Ghost Wavefield Elimination (GWE) with Frequency-P (Slowness) domain bootstrap pre-migration de-ghosting method was employed for these data (Wang and Peng, 2013).

The extra low frequency from de-ghosting successfully imaged the deeper targets, such as steep flanks around 2 s to 4 s (Figure 2). The de-ghosting attenuates the ghost successfully and increases low and high frequency S/N ratio compared with a normal whitening filter. Figure 3 compares the water bottom wavelet and spectrum of conventional and broadband processing. The water bottom is much sharper in the broadband result with a side lobe free wavelet, which is much easier for interpretation. The amplitude spectrum shows broader bandwidth up to 150 Hz.

Pre-stack depth migration

With the clearer images benefiting from deghosting, the velocity analysis and modeling were much more reliable. A better velocity further improved the image. The enhanced low frequency spectra are paramount for the improved depth migration.

TTI anisotropic PSDM was used to represent the thick shale layers with high dip angle across the whole survey. Figure 4 shows the comparison of PSTM and PSDM results. PSDM improves the image focus, reduces migration swings and gives more accurate positioning especially in the highlighted areas.

Conclusions

Broadband seismic processing brings up the low frequency in deep target by pre-migration de-ghosting. Velocity update and PSDM then benefit from it which leads to a better velocity above and at the target level. The final broadband PSDM result has better deep penetration, more accurate dipping event positions and a sharper and more focused target image.

The final result reveals sequences in the deeper syn-rift sediment deposits which are distributed into several mini-basins troughs bound by fault scarps basement ridges. In the overburden, broadband 3D seismic resolution reveals accurate stratigraphic detail. Seismic interpretation mapping has un-covered structural dip closures and stratigraphic traps. Mapping through the syn-rift reflections, these were enhanced significantly by the added low frequencies from broadband.

Acknowledgements

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References

Wang, P. and Peng, C., 2013, Premigration deghosting for marine streamer data using a bootstrap approach in Tau-P domain: 83rd Annual International Meeting, SEG, Expanded Abstracts, 4221-4225.

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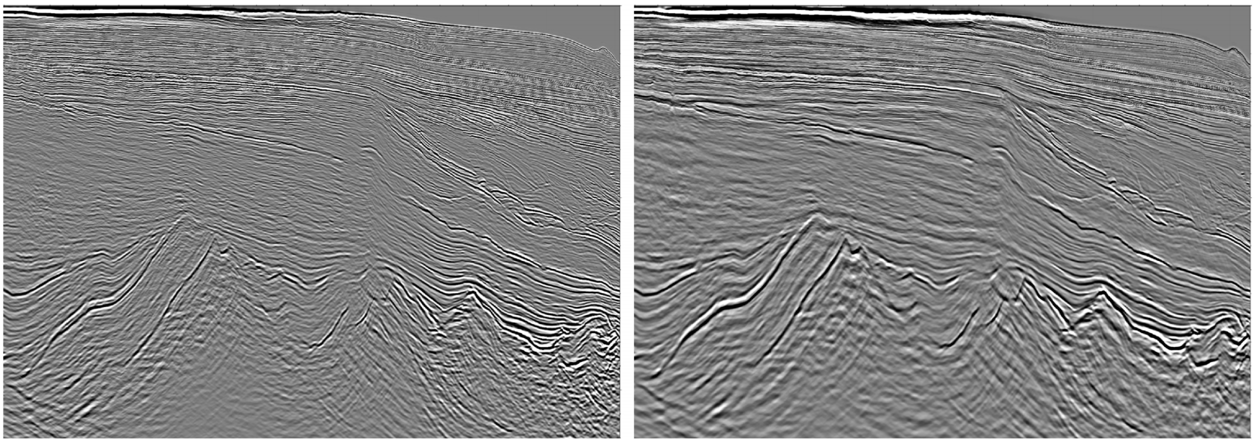

Fig 2. Conventionally processed PSTM and Broadband PSTM.

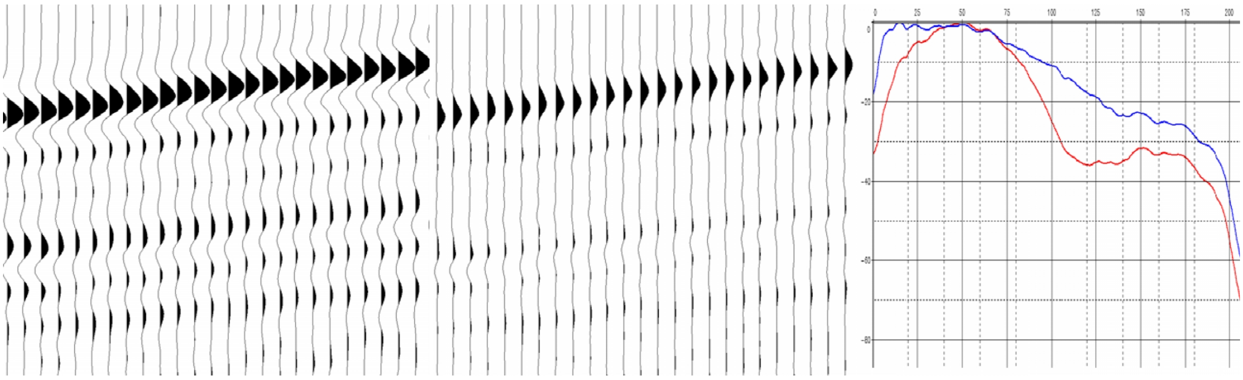

Fig 3. Water bottom wavelet comparison. Left is conventional PSTM and middle is broadband PSTM. In the right figure, red is conventional PSTM and blue is broadband PSTM spectrum.

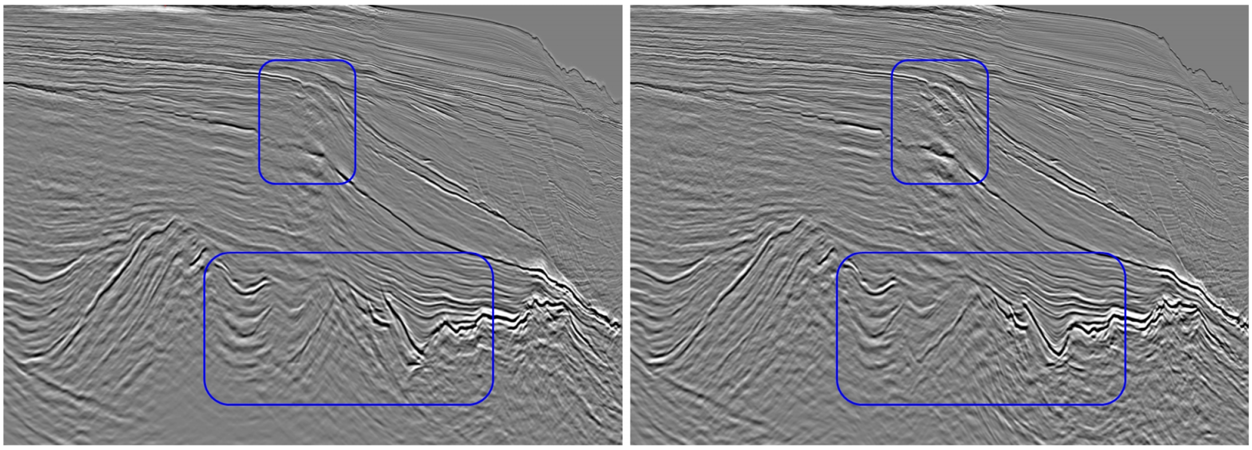

Fig 4. Left is PSTM and right is PSDM stack converted to time domain.