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Advanced reprocessing of the Air Field South 3D seismic survey, Rajasthan

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Introduction

The Air Field South (AFS) area is in Development Area 3 (DA-3) of the Barmer Basin, a northern segment of the Cambay Tertiary rift system. The location and general stratigraphy of this block are shown in Figure 1 and Figure 2 respectively. This is an area of great significance to Cairn India with several discoveries having been made in the region and several undrilled leads are yet to be tested.

For the AFS area, 3D seismic data was acquired in 2006. The available processed seismic data is of good quality and resolution and enables the shallower geology down to the Dharvi Dungar (DD) Formation to be well imaged but beyond that the image quality degrades with depth. There is an exploration need to understand deeper structure more precisely and to enhance the seismic resolution to examine the possibility of amplitude anomalies being associated with potential reservoir reflectors.

The present case study discusses an application of advanced processing techniques to achieve the goal of enhanced imaging. In this new processing approach different spatial noise attenuation techniques (3D RNA & 3D FK in cross spread domain with combination of Time Frequency Denoising technique in several domains) been adopted to improve the signal to noise ratio, time varying dip filter angle has been used to migrate different horizons with their corresponding dip. Spatially consistent dense velocity analysis has also been performed to optimize the stack response by improving the coherency and continuity in the data. The application of these techniques has been found to improve the imaging over the entire stratigraphic section and also enable the interpreter to map subtle markers more confidently as well as identify several amplitude anomalies in the Dharvi Dungar Formation.

Seismic Acquisition & Processing History

Three 2D vibroseis surveys were recorded over the study area (by Shell in 1996, by CEIL in 2003 and in 2004). Approximately 525 km^2 of 3D were then acquired between May and August 2006 and processed fast track in 2006-07. Subsequently, PSTM re-processing has been carried out between September 2008 and February 2009.

Data quality of the fast track volume is fair to reveal horizons at shallow levels but poor in resolution at deeper levels. Hence to improve the image an enhanced processing project was carried out.

Enhanced processing of AFS 3D

To achieve the goal, the processing strategy was divided into three major steps.

- Denoising: To increase the signal to noise ratio, spatial de-noising techniques been adopted.
- Varying Dip introduction: To improve the imaging of highly dipping fault at deeper level and flat events at the shallow level, a time varying dip has been considered for migration.
- Dense velocity analysis: To enhance the details of the complex geological features, a dense velocity analysis had been performed.

The major factors considered in the whole processing was to broaden the frequency bandwidth for better fault definition and preserve the low frequency to improve the continuity of the deeper events.

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Figure 1: Location map of Air Field South

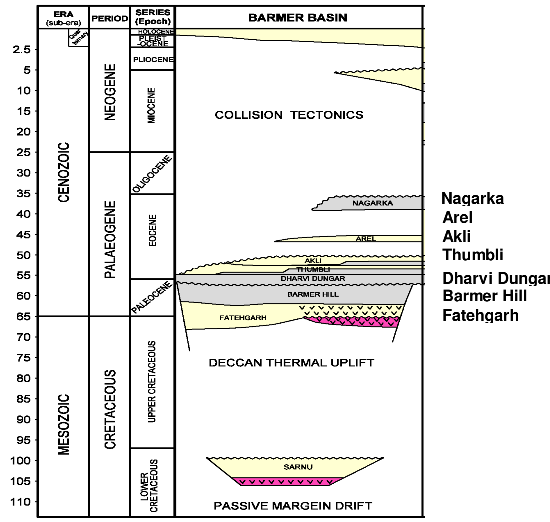


Figure 2: General Stratigraphy of Barmer Basin

De-noising

The fast track processed data was found to be contaminated by vibroseis source-generated noise as well as random noise. The noise cone in the shot was masking the primary event and also reducing the relative amplitude of the events at the far offset, hence significantly affecting stack response. To reduce the random noise, 3D Random Noise Attenuation (RNA) followed by 3D FK has been applied in the cross spread domain. The de-noising in the cross spread domain did not fully attenuate all the source generated noise visible in the inner noise cone. To attenuate this residual noise a spatial time frequency de-noising been applied in the Receiver and CMP domains (Figures 3 and 4). This produced an acceptable result.

Time Varying Dip Filter Angle for PSTM

The dips of the geological horizons in the AFS area vary from low angled to steep. At shallower levels the dip of the layers are generally low, however deeper horizons have very steep dips due to complex faulting. In this geological scenario, if a low Dip Filter Angle has been provided for migration to image the shallow event, the highly dipping events are imaged poorly. Conversely, if high Dip Filter Angle values have been used in migration to image the deeper events, the shallow events become nosier. Hence, for proper imaging of the full stratigraphic section a time varying Dip Filter Angle has been used (lower dip at the shallower level and higher dip at the deeper level) for migration. At the same time the migration aperture was tested and a value of 3km was selected.

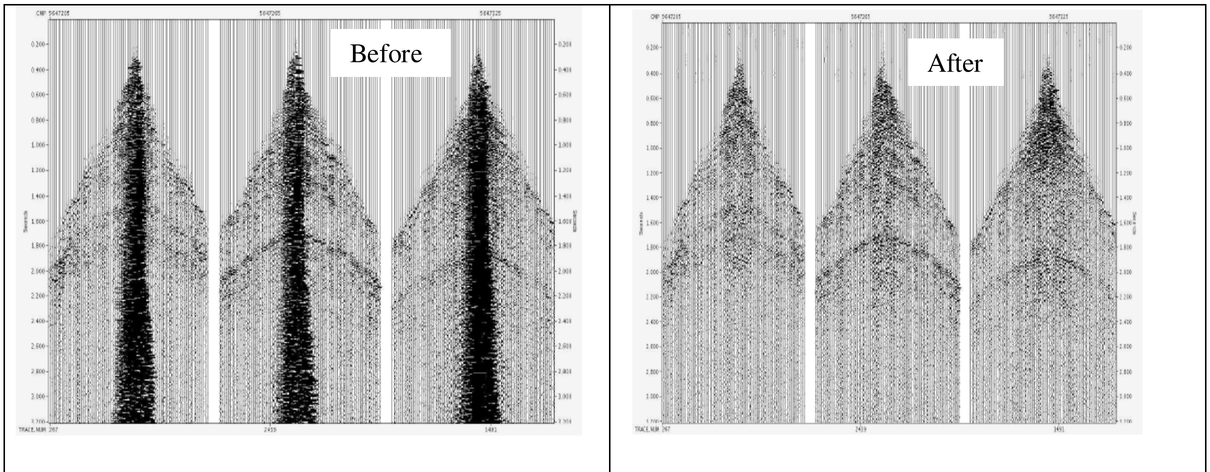


Figure 3: Improvement on gathers after random noise attenuation

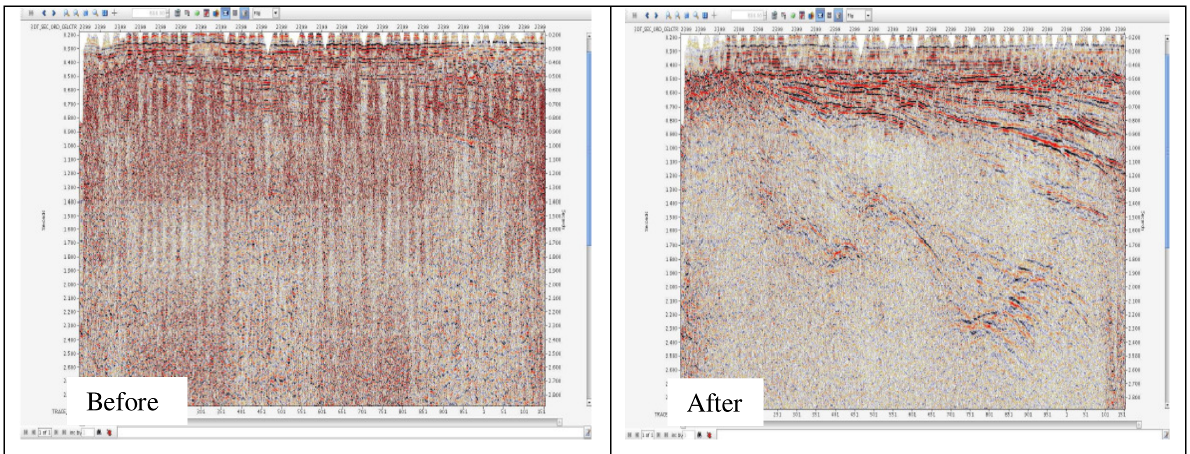
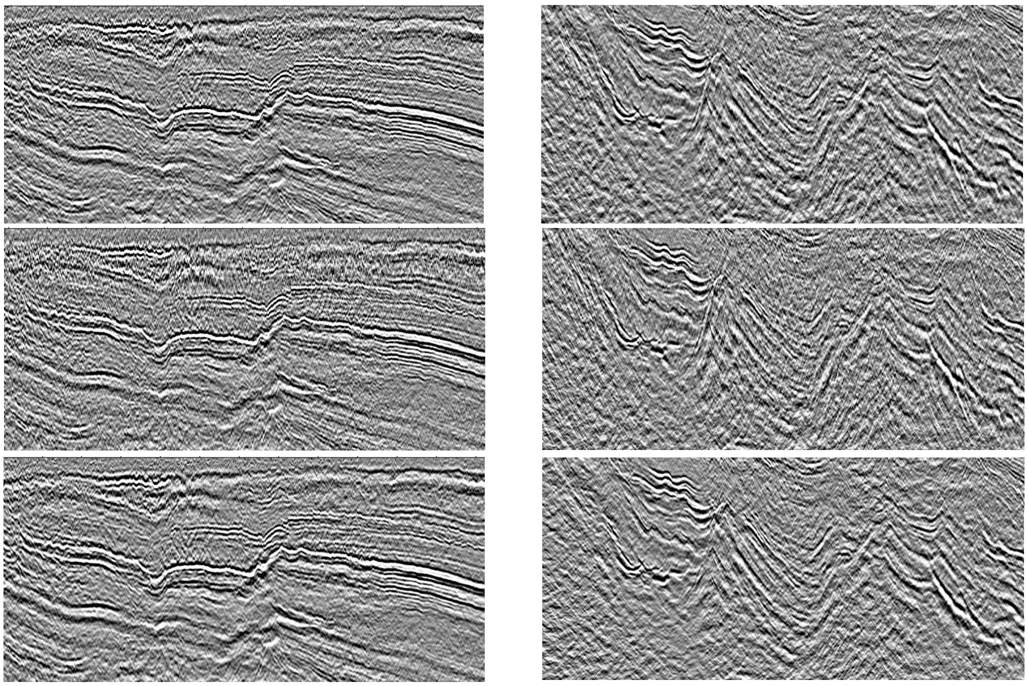


Figure 4: Improvement on stack after random noise attenuation



Dip-40 deg

Dip-60 deg

**Dip-
30 (at shallow)
55 deg (at deep)**

Figure 5: Improvements after Pre Stack Time Migration (PSTM) using time varying Dip Filter Angle

Dense Velocity Analysis

In detail, the geology of the AFS area is complex with rapidly varying depositional geometries and topography. In this kind of geological setting, velocity analysis at discrete locations does not guarantee optimum stack response along the whole seismic section and is unable to resolve geological details. For better imaging of geological horizons a Spatially Consistent Dense Velocity Analysis been performed which provided a superior result to that of a discrete velocity analysis (Figures 6 & 7). This is an automated picking routine, which outputs time, velocity and correlation statistics for every time sample at each CMP location. These picks were first refined along the inlines and further processed through a 3-D cascaded median filter to produce a stable robust model, which can optimise the stack response.

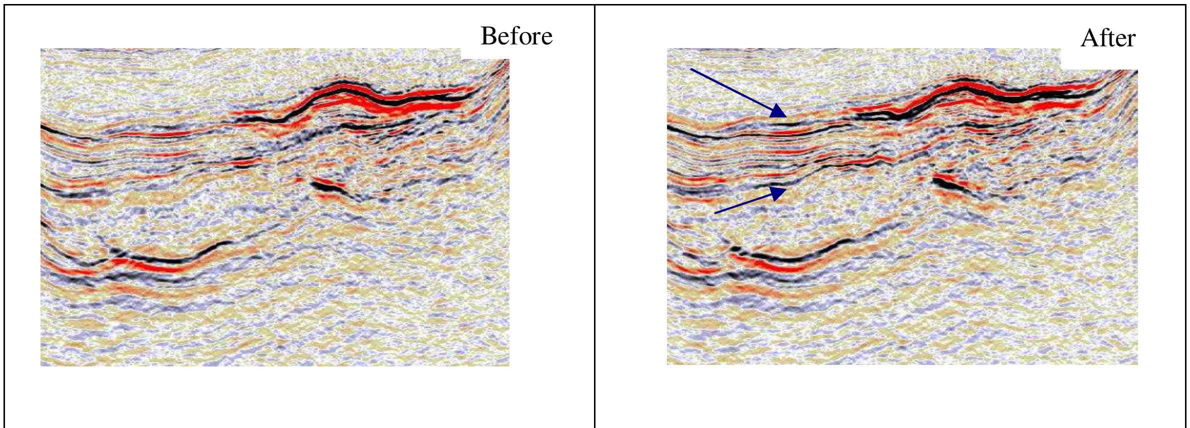


Figure 6: Improvement after Dense Velocity Analysis for Shallow Events

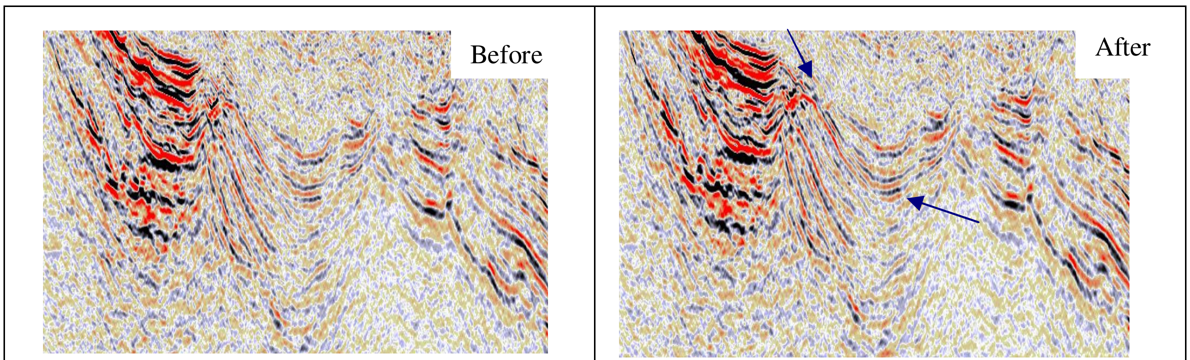


Figure 7: Improvement after Dense Velocity Analysis for Deep Events

Discussion

The processing workflow has been set to broaden the frequency spectrum by preserving the low frequencies. This allowed better imaging of the low frequency reflections of the deeper horizons by improving the continuity of the events. This also helped to image the faults better, which was one of the major aims of the reprocessing project (Figure 8). In all stages of this advanced processing, effort has been made to preserve amplitude fidelity by not applying any kind of AGC or any other processing which could hamper the true amplitude of the data. This has considerably reduced the uncertainties in amplitude delineated prospects and leads (Figure 9).

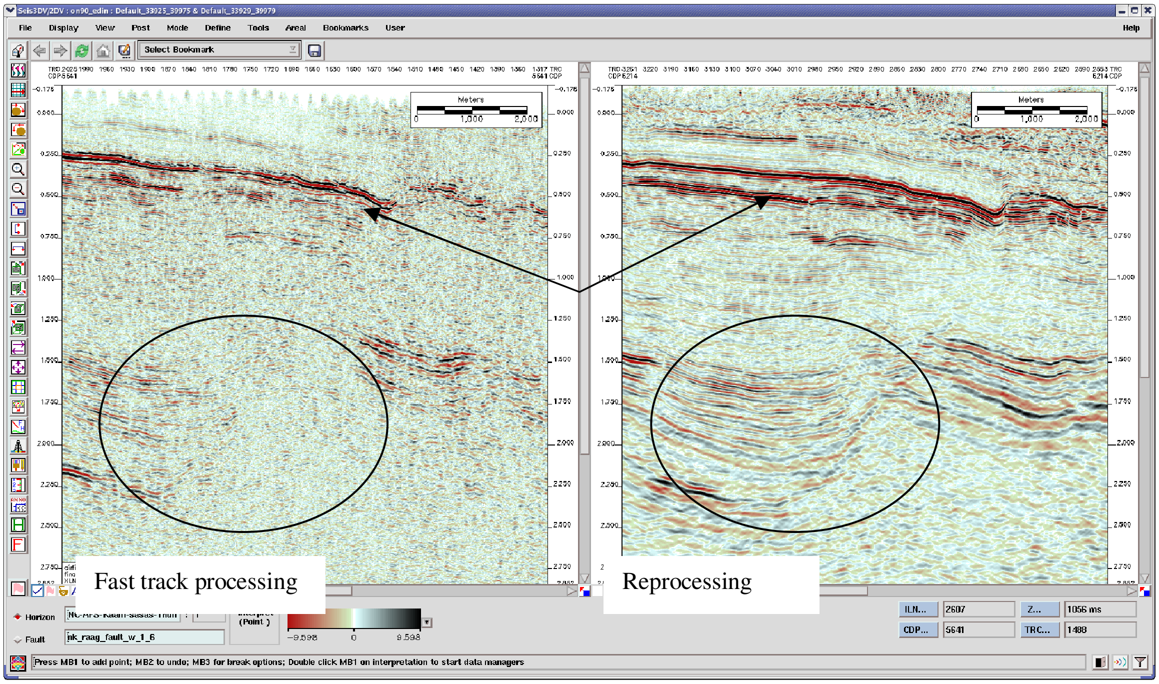
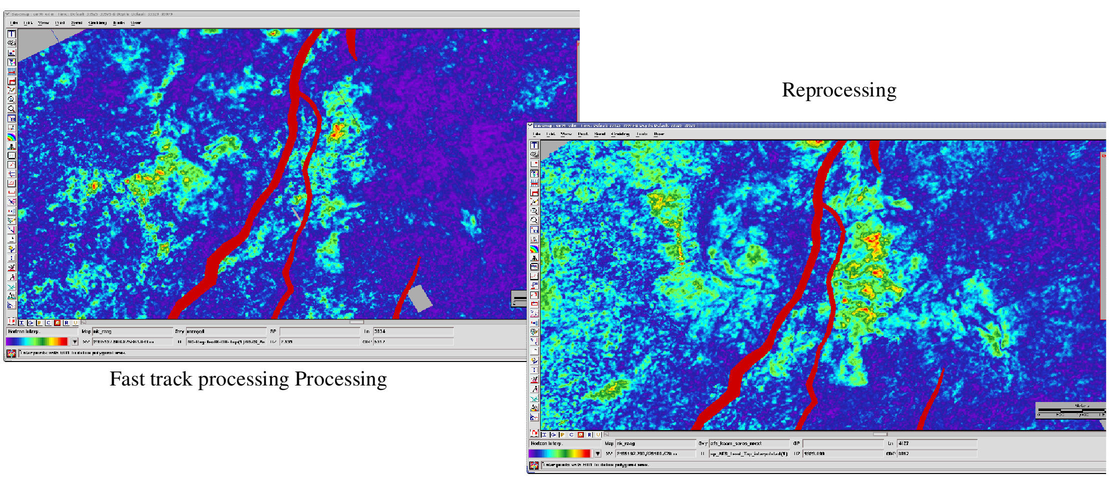


Figure 8: Comparison of old processed data with re-processed data



Reprocessing

Fast track processing Processing

Figure 9: Comparison amplitude extraction at Dharvi Dungar Formation

Conclusion

The advanced processing techniques demonstrated here have considerably improved the imaging of entire stratigraphic section in the AFS area of the Barmer Basin in Rajasthan. By improving the signal to noise ratio and migrating the horizons more accurately with the corresponding dip with a dense velocity grid, the resolution, coherency and continuity of the older parts of the section (Dharvi Dungar and older formations) has been greatly enhanced, thereby increasing the prospectivity of this part of the basin.

Broadening of the frequency spectrum provided better fault definition & improved imaging of deeper geological events. True Amplitude preservation helped in AVO, Inversion and seismic attribute studies. The reprocessed dataset enables the interpreter to identify several new leads and prospects in this area that were previously misinterpreted on basis of the original 'fast-track' processed data.

The value of the 'fast-track' processing approach in general is called into question when such considerable improvement is possible with a more appropriate schedule; particularly where time invested in a 'fast-track' deliverable competes for resources and distracts those concerned from a comprehensive processing project.

Acknowledgement

The authors would like to thank Cairn India management for the encouragement and permission to publish this article. We would also like to thank Mr. Howard Roberts for his valuable advice during the processing work. We are also thankful to all our colleagues at Cairn India for their valuable suggestions. We would also like to thank WesternGeco for their effort to process the dataset and deliver on schedule.