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Pre Stack Seismic Imaging of deeper Subsurface: A Case Study from North Assam Shelf

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Summary

Accurate imaging of the deeper sub-surface remains a challenge when the subsurface is complex. Conventional processing based on NMO, DMO and post stack migration is inadequate to bring out the subsurface images. Pre-stack migration on the other hand, involves velocity analysis and stack in the common image point (CIP or CRP) domain and thereby accounting the dips and diffraction energies. The present study deals with the 3D pre stack time imaging using Kirchoff's approach aimed at enhancement of the strati-structural features within the pay units of Barail and Tura formations of Oligocene / Eocene reservoirs in Upper Assam.

Introduction

The study area is within the operational areas of Oil & Natural Gas Corporation Limited in Upper Assam basin. These areas of Upper Assam-Arakan basin has undergone a series of extensive tectonism from the time of rifting and drifting phase in Cretaceous period till the major tectonic event of evolution of basement ridge and Himalayas during Miocene period. These various phases have led to severe faulting and thrusting of the basin where major oil findings are located. Most of the identified oil traps are found to be horst graben related closures from the deep Eocene reservoirs of about 3500-4500 m depth.

The conventional 2D/3D processing involving Dip Move Out and Post Stack Time Migration may not image the subsurface when the dips are severe and the velocity gradients are high. On the other hand, Pre-Stack Time Migration (PSTM) resolves conflicts in velocities and dips by migrating reflections to their correct locations. Gathers after PSTM contain reflections from the horizons encountered by image rays, which are close to being vertical unless there are severe lateral velocity variations. Therefore velocity analysis, after PSTM is required and can be termed as residual velocity analysis, determining RMS velocities along image ray. Such velocities are more geologically consistent than NMO velocities. Since PSTM is typically carried out with first approximation using incorrect velocities, residual velocity analysis is imperative. It allows proper alignment of migrated events, thereby improving the continuity as well as sharpness of pre-stack time migrated images. Several approaches are available for the implementation of PSTM. The results of the present study showcases full 3D Kirchoff's PSTM implemented in common offset mode. Most of the times, the acquired pre-stack data is distributed irregularly. Since Kirchhoff migration is performed trace by trace, it can be implemented on irregularly sampled data.

Objectives

Processing objectives are to image the event continuity and strati-structural features within the pay units of Barail (TWT: 2400ms to 2800ms) and Tura formation (TWT: 3000ms to 3400ms).

Input data & Pre-processing

The 3D data was acquired with six receiver lines swath with End-On orthogonal geometry. The Bin Size was 25m*25m. Geometry merging was checked and was ascertained by plotting offset and first break mute function on the gather in figure-1 and followed by Linear Move-Out (LMO) checking in figure-2. The frequency content of input was checked to decide the final band pass filter for the data.

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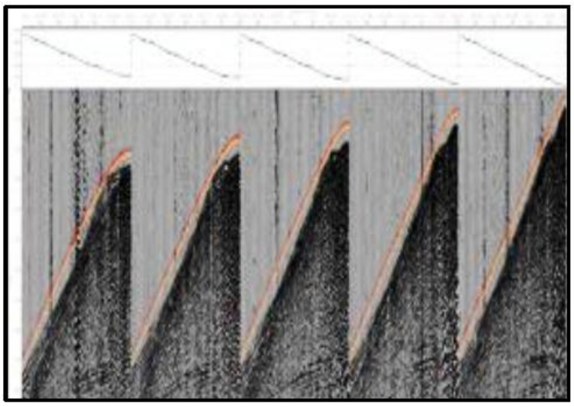

Figure-1: Geometry merging QC (FB Mute)

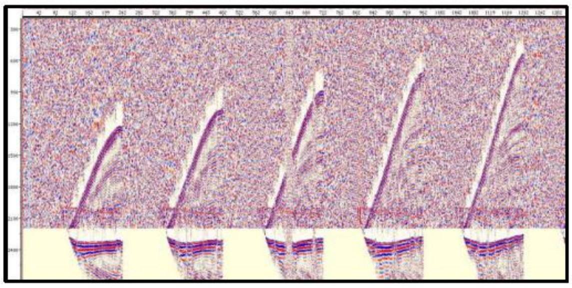

Figure-2: Geometry merging QC (LMO)

Processing Sequence

Editing and swath-wise de-noising with wavelet transform based filter and frequency decomposition approach was implemented for minimizing noise bursts and ground-roll followed-by spatial amplitude smoothing for de-spiking. All the swaths were merged to form a complete volume and surface consistent amplitude balancing was done to remove the effect of variation in shot-receiver ground coupling. A two window deconvolution before stack was chosen after testing. Velocity analysis was carried out in close interval on deconvolution applied gather to generate the stacking velocity volume and it was used to estimate the auto statics using 3D surface consistent approach and generated stack volumes in figure-3.

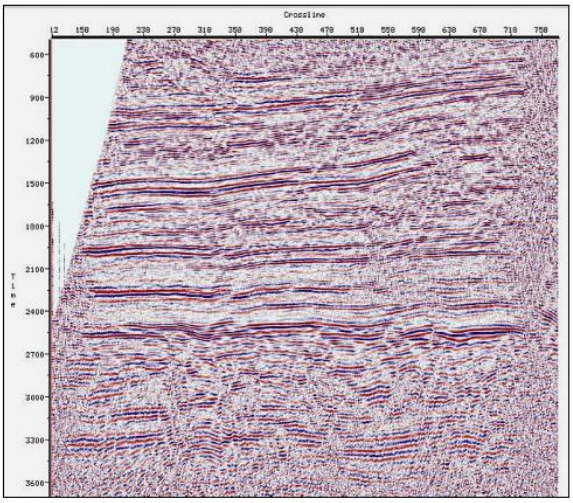

Figure-3: Auto-static applied NMO Stack

Pre-Stack Imaging

The PSTM work flow is given in the Figure 4.

Initial RMS velocity volume generation and target oriented Pre Stack Time Migration: The velocity functions picked on auto statics applied gather were subjected to smoothing over a base of 250m * 250m to arrive at a smoothed velocity field. This was taken as initial RMS velocity field for carrying out initial Pre Stack Time Migration for target oriented lines for RMS velocity analysis. Migration aperture (full) was kept as at 2000ms TWT.

Migration velocity analysis and final RMS velocity volume generation: RMS velocities were picked using the PSTM gathers with inverse NMO option. The initial RMS velocity filed was used for the implementation of inverse NMO on the PSTM gathers. The final RMS velocity volume was created for final Pre Stack Time Migration. Random noise attenuation was done on PSTM gather to minimize the smeared noise prior to stack. Space variant mutes were picked for stacking. Post stack noise attenuation and filter were applied on the PSTM stack volume in f-x-y domain.

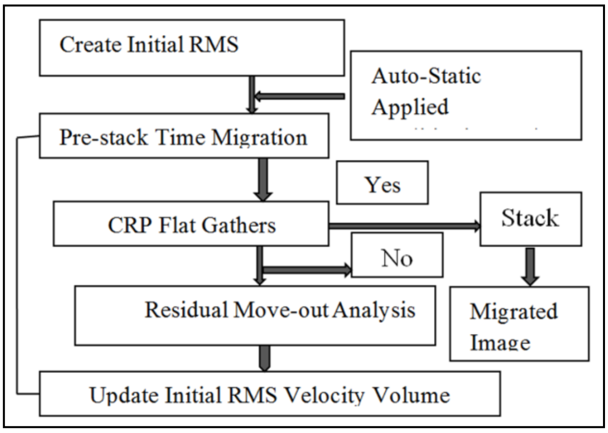

Figure-4: Pre-Stack Time Migration Work Flow

Results and Observations

Signal conditioning followed by PSTM with updated RMS velocity resulted in significant improvement mainly in

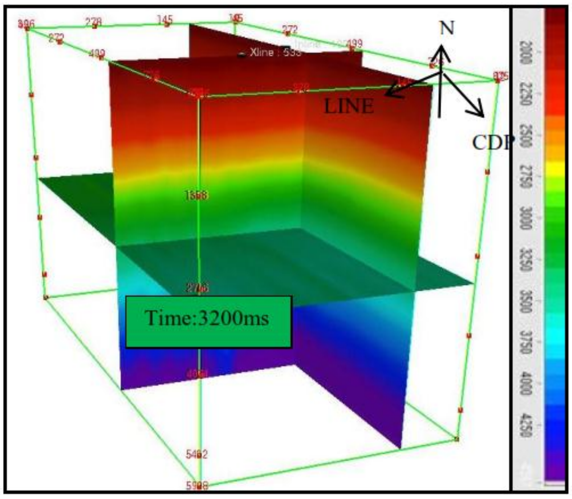

Figure-5: Cross Sectional View (IL: 250 & XL: 500) from the RMS velocity volume

the continuity of reflections, fault definition, spatial and temporal resolution at deeper subsurface compared to conventional post stack migrated sections. RMS velocity analysis was carried out on the PSTM gathers with close interval. Cross sectional view of final RMS velocity was displayed in figures-5. PSTM gather for In-line 250 was shown in figure-6 for checking the degree of flatness of CRP gather that also reflecting the degree of accuracy of RMS velocity. The pre stack time migrated section of Inline 250, corresponding nearby Inline of conventional post stack migrated processed section and Cross-line 500 were shown in figures-7, 8 & 9 respectively. A close examination of the PSTM data shows considerable improvement of images both laterally and vertically as compared with that of the conventional post stack time migrated data at deeper subsurface. RMS velocity and sections were overlaid in figure-10 to check conformity with major geological structures of the area.

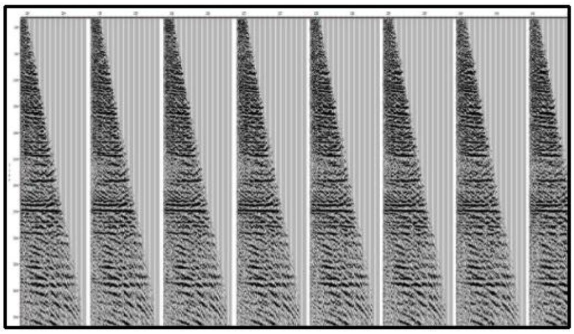

Figure-6: Sample PSTM Gather

The PSTM results indicate that Lower Barail and Tura formations are mapped in figures-11 & 12 on Inline-250 & 164 with a higher degree of confidence. The faults can also be seen more prominently and has extended from Miocene to Eocene. The horst and graben features which are very important from oil accumulation point of view have come up very prominently and were mapped with a higher degree of confidence at the above said formations.

Time slice map generated at different time level from final PSTM stack volume. Time slice at Tura formation (Time: 3300ms) was shown in figure-13 which is reflecting the prominent fault definition.

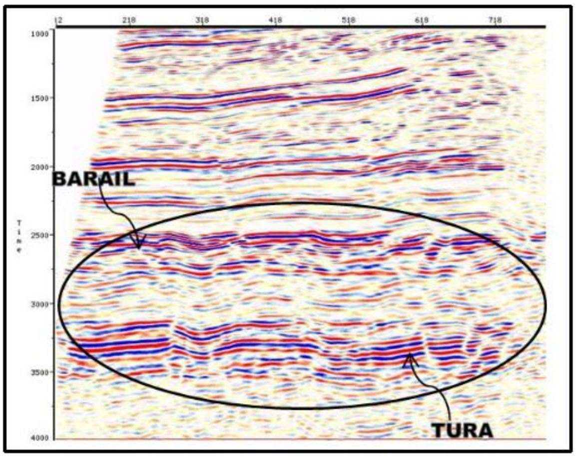

Figure-7: PSTM Section along In-line-250.

Time structure maps were generated and those are reflecting the different structural high and low of isochronal deposition in figures-14 & 15 respectively.

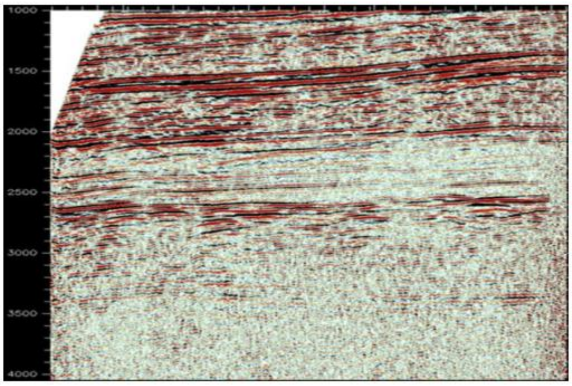

Figure-8: Conventionally (NMO+DMO+ Post stack migration) Processed Section

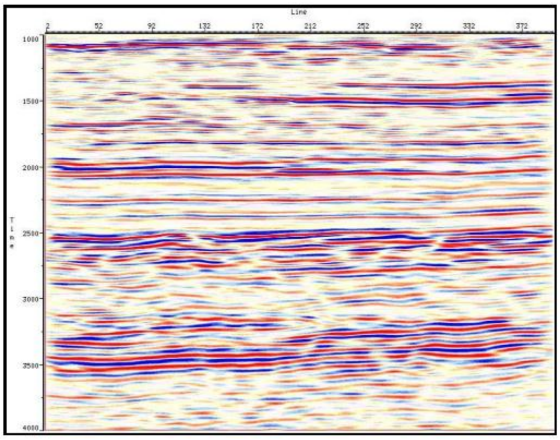

Figure-9: PSTM Section along Cross-line-500.

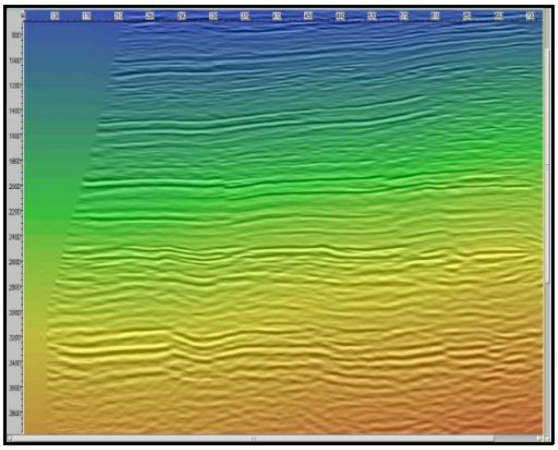

Figure-10: Composite display of RMS velocity and stack Section (TWT: 800-4000ms)

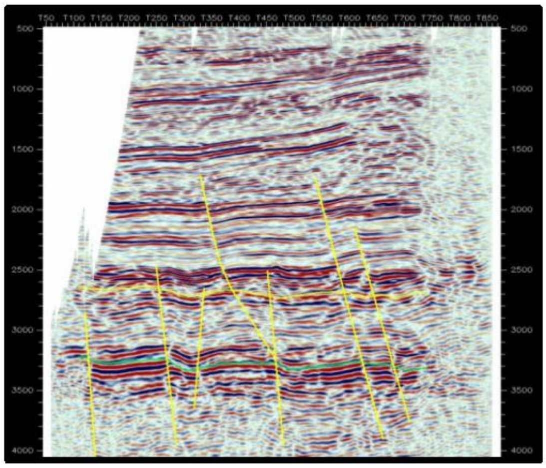

Figure-11: Horizon / fault interpreted PSTM section of IL-250

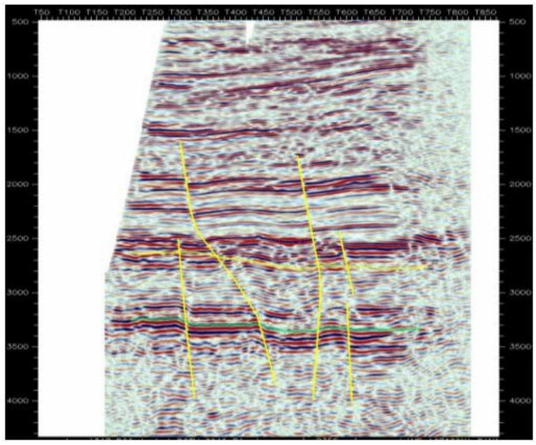

Figure-12: Horizon / fault interpreted PSTM section of IL-164

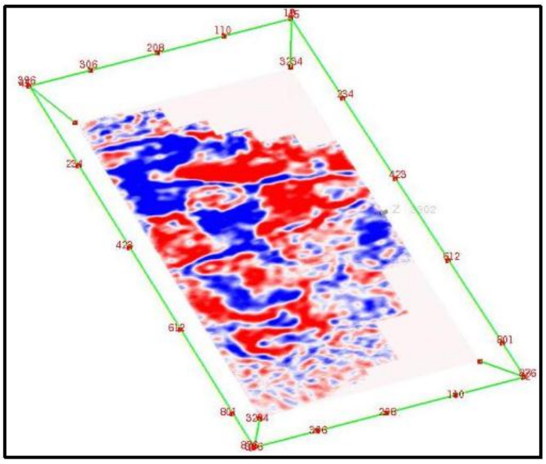

Figure-13: Time Slice at Tura formation (Time: 3300 ms.)

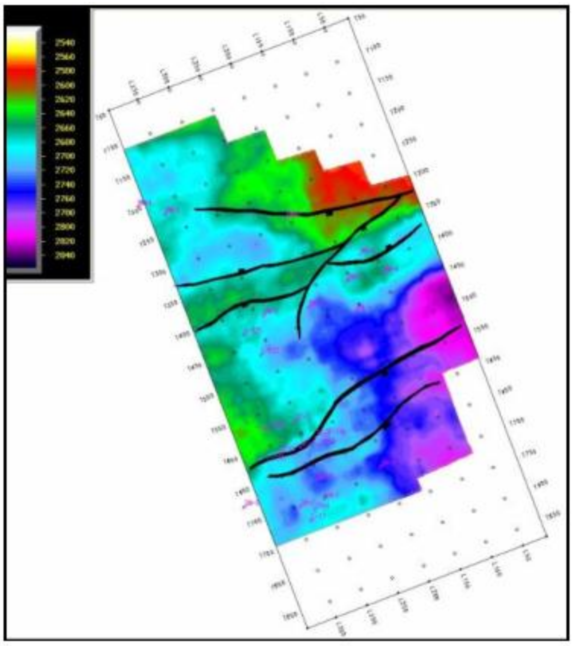

Figure-14: Time structure map of Lower Barail

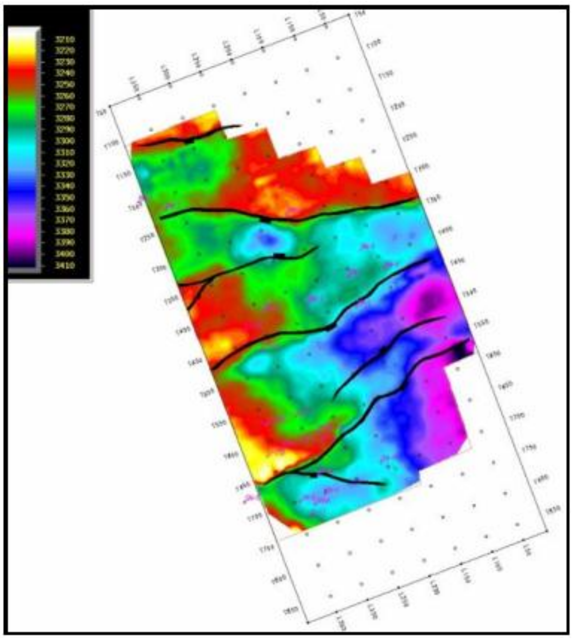

Figure-15: Time structure map of Tura

Conclusions

Signal conditioning and 3D Pre stack time migration has resulted in good quality imaging of the subsurface. This will enable the identification of the subtle features associated with the horst and graben features at Oligocene / Eocene levels and below. The improvements are observed mainly in the continuity of reflections close to entire Barail and Tura formations and fault definitions.

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NB: Views expressed here are those of the authors only and does not reflect those of ONGC.

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The tectonic framework of Assam, GSI.