P 037

An Integrated Pre-Stack Depth Migration using Model based Velocity Estimation & Refinement - A Case Study in Andaman Offshore

*Subhendu Dutta *, Apurba Kumar Basak*

Summary

The problem of imaging the sub-surface accurately is always a challenge to the Geoscientists. This requires a proper understanding of the geology of the area/basin, objective of survey, adequate acquisition geometry to delineate the prospect and overall a smart processing of the data. The Time Migration algorithms result in events being spatially mispositioned and the results have the obvious drawback being represented by a two way travel time. The depth migration, not only provide an image in depth, but also avoid many assumptions and simplifications that causes mispositioning of events in the time domain. The reflections are positioned correctly and provide precise subsurface images with minute structural discontinuities, i.e. imaging of faults. The depth imaging techniques such as Pre stack depth migration is very much dependent on the interval velocity, which requires more accuracy in velocity model building. In this paper, a 2D deep offshore data pertaining to Andaman sub-basin has been taken as a case study. An integrated Pre-Stack Depth Migration using model based velocity estimation and iterative refinement, reveals better sub-surface configuration than earlier processed PSTM section.

***Keywords**: PSDM, Andaman Offshore*

Introduction

Imaging the subsurface in a geologically complex area is always a difficult task and the delivery of the output in a given time frame is most important in present day exploration business environment. Which type of migration algorithm has to be adopted on the data for processing, depends upon the complexity of geology and velocity in the area and governed by the diagram depicted in Fig-1. When the complexity of the structure is from moderate to complex & the velocity in the area is not very complex, then PSTM provides good result. But if there is a complexity in structure as well as velocity in the area, then Pre stack Depth Migration will provide a better result. The Time Migration algorithms result in events being spatially mispositioned and the results have the obvious drawback being represented by a two way travel time. The depth migrations not only provide an image in depth, but also avoid many assumptions and simplifications that cause mispositioning of events in time domain. The reflections are positioned correctly and provide precise subsurface images with minute structural discontinuities, i.e. imaging of faults. The depth imaging techniques such as Pre stack depth migration is very much dependent on the interval velocity, which requires more accuracy in velocity model building. Moreover, the uniformity in fold distribution in the whole dataset can help in focusing the exploration targets with confidence.

The conditioned decon gather & RMS velocity are the only two pre-requisites for running a PSTM job. For a Pre Stack Time Migration to produce good image, it is mandatory requirement that the input time gathers are noise free and the RMS velocity field is adequate to flatten the time migrated gather. For Pre Stack Depth migration the inputs are conditioned decon gather and interval velocity section in case of 2D. Therefore, an area comprising of complex velocities and structural complexities like Andaman deep offshore, is a case for depth migration where it will provide a section not only in depth but will provide true image as well, since the reflections are positioned correctly and provide precise subsurface images with minute details of faults.

Geology of the Area

The study area (Fig2) is located in the eastern side of the Central Andaman sub basin just at the north tip of Sewell

ONGC Ltd., Kolkata
Email: sduttaind@yahoo.com

rise and adjacent to the true backarc region. Central point of the block is about 275 Km from Port Blair. Andaman Basin is a North-South elongated depression narrowing to the south against the tip of Sumatra Plutonan elevated Paleozoic-Mesozoic arc massif. The Basin is surrounded by North Sumatra Basin (towards south), Mergui Basin in the east and Moattamma /IrrawaddyDelta (in the north) which are prolific hydrocarbon producing fields.

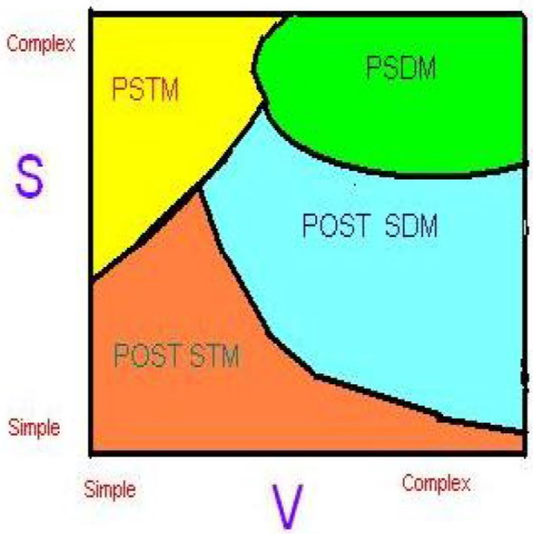

Fig-1: Processing algorithm to be chosen from above diagram

The Basin is segmented into many sub basins due to presence of several prominent morphotectonic elements. In a west to east transect, the main tectonic zones are the subduction zone i.e. trench, the Accretionary complex, forearc sub-basin, magmatic/volcanic arc, Central Andaman sub-basin (CAB) and the backarc basin. The Andaman Basin has two major depocentres. One is in the forearc ponded low part and another is in the main backarc part. Within the back-arc basin There are two volcanic Seamounts namely Alcock and Sewell which were probably together originally within the back-arc basin and that but were probably segmented later. Exploratory efforts started with surface Geological mapping in the Island area of the Andaman Basin from as early as 1959.

The study area is shown in rectangle. Out of few 2D lines shown below, one lead N-S line has been considered for the present study (Ref: Fig-3).

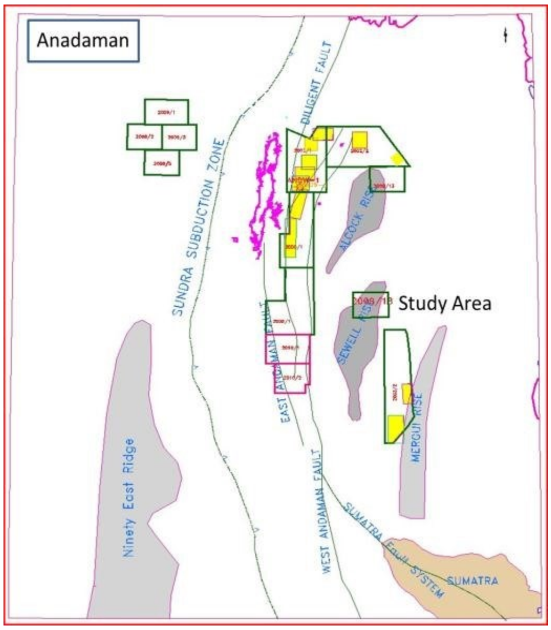

Fig-2: Location map of the area under investigation

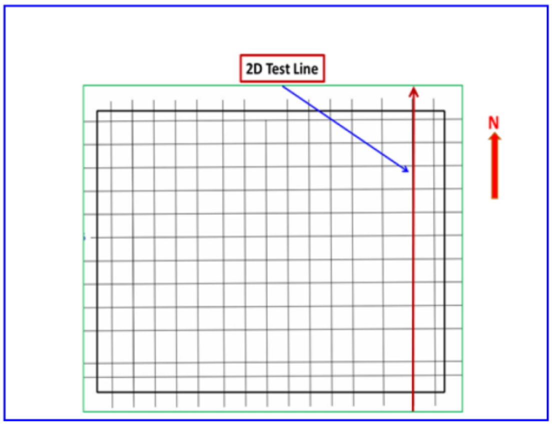

Fig-3: 2D line under study

Input Data & Conditioning

The input taken was conditioned decon gather and RMS velocity section that was used for PSTM. After through study of data it was observed that there is a further scope of multiple attenuation for water bottom multiple. Thus, multiple elimination programme was run on input gather. Fig-4 shows the multiple removal before and after respectively from the input gather. From Fig-4 of the difference plot, it is evident that sea bed multiple at a time approximately double that of seabed i.e. around 5.5 secs is removed from the input data and thus the output provides a multiple attenuated CMP gather which will be used as an input to pre stack depth migration, so that the imaging of the sub-surface at a level of seabed multiple will be imaged appropriately.

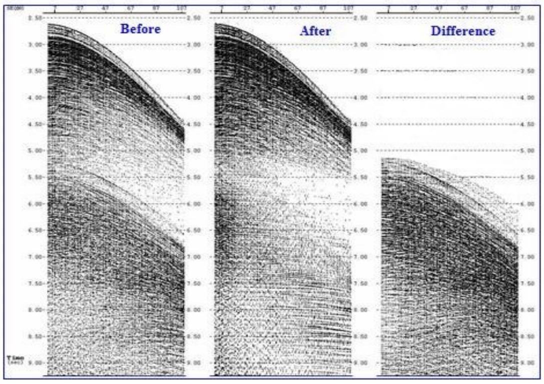

Fig-4: Multiple Removal

Depth Interval Velocity Model Building

Recent advances in computer-based interpretation systems have significantly reduced the cycle time for exploration projects while improving the accuracy of interpretations in the time migrated domain. However, as every interpreter knows, the final test for any interpretation lies in the ability to produce an accurate prognosis in the depth domain. It is inadequacies in this step of converting an interpretation from the time to the depth domain that are commonly the cause of poor predictions, leading to increased drilling costs or at worst, creating prospects that simply do not exist.

There are several approaches that can be taken to improve our predictions in the depth domain, from simply improving our initial velocity models using model-based techniques through to the ultimate in depth imaging, pre-stack depth migration (PSDM). Whether we interpret on time migrated data and scale our maps to depth or choose to interpret on depth migrated data, there are many tools available that can assist in building more accurate depth models. Whatever approach we take, our accuracy in depth is wholly dependent on our ability to produce an accurate interval velocity model i.e. the earth model and this can only be achieved by taking a modelbased approach using the interpreter's knowledge of the region to constrain that model.

Model refinement techniques that rely on tomographic approaches i.e. horizon based semblance creation and manual picking of depth residuals in a very close CRP interval as the sole method of model re-building or refinement.

As first step, interpreted time horizons on the earlier PSTM data from the interpreter was obtained. The time horizons were plotted on the PSTM stack section and any kink on the horizons , if any were removed by smoothing the horizons at all level (Ref. Fig-5). The first six horizons (H1 to H6) starting from seabed to deepest map able reflector i.e. H6 have been provided by the interpreters and the two horizons H7 and H8 have been defined by the processor for getting a good velocity model.

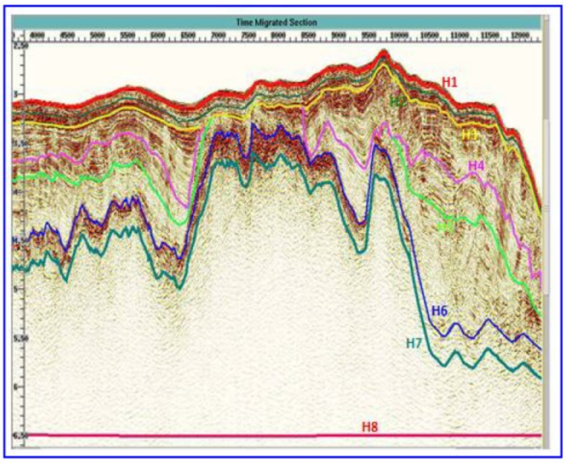

Fig-5: Interpreted horizons on PSTM section

After smoothing of the horizons, a model has been prepared in the time-migrated domain. Then RMS velocity extraction (Fig-6) was done along the interpreted horizons to build up a horizon based RMS velocity map/section. The velocity of the seabed only was kept as 1500 m/sec i.e. the velocity of water as fixed for the first layer.

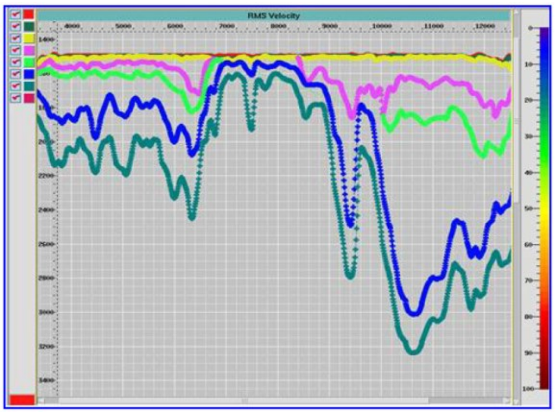

Fig-6: RMS velocity extracted picks

Velocities derived during the processing of seismic data provide substantial additional control away from wells but are seldom accurate representations of the earth velocity. The most common approach to convert this RMS velocity obtained from the data, i.e. inversing NMO from the time migrated gather (PSTM) and actually pick the RMS velocity from the velocity semblance, to interval velocity using the Dix equation (Dix, 1955), which relates root-mean-square (RMS) velocities to interval velocity through Equation (1). It shows that interval velocity, Vintn, can be calculated for the n^{th} interval where Vrmsn-1, tn-1, and Vrmsn, t_n are the root-mean-square velocity and travel times to the n-1th and nth layers respectively.

$$V_{intn} = \sqrt{V^2_{rmsn}t_n - V^2 rms_{n-1}t_{n-1} \;/\; t_n - t_{n-1}} \quad \textbf{(Eqn.-1)}$$

Several model-based techniques exists that can estimate the interval velocity of a layer from the travel time through it, but these techniques requires more time to complete a project as the travel time computation for layer stripping methods require more time. Therefore, when a data already undergone through PSTM, a fairly accurate RMS velocity information for each interpreted layers are available. Thus, interval velocity obtained from this transformation gives an initial interval velocity model to run initial PSDM.

Pre Stack Depth Migration

Kirchhoff's Pre Stack Depth Migration was done using the multiple attenuated decon gather and initial interval velocity model as the input. Fig-7 shows the flatness of the depth gathers vis-à-vis initial model and PSDM section shown in the background towards northern part of the 2D line under study.

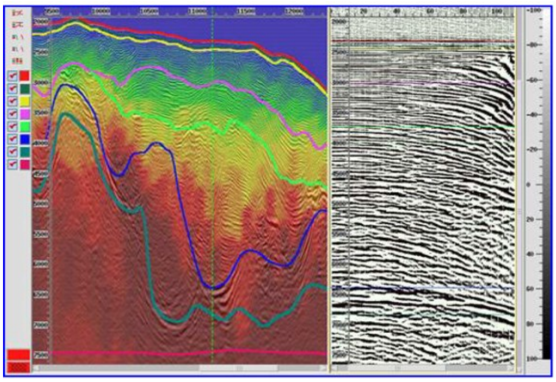

Fig-7: Depth Gathers vis-à-vis PSDM section superimposed with initial interval velocity field

From the above figure, it shows that the depth gathers are not flat with the initial interval velocity model, because of dip and lateral variation of velocity, which needs to be corrected through tomography. But the initial interval velocity field provides a fair estimate of good initial velocity model, a depth gather and a PSDM stack. Fig-8 shows the Schematic Geological Cross-section across Andaman Subduction Zone showing the position of the block (Rectangle).

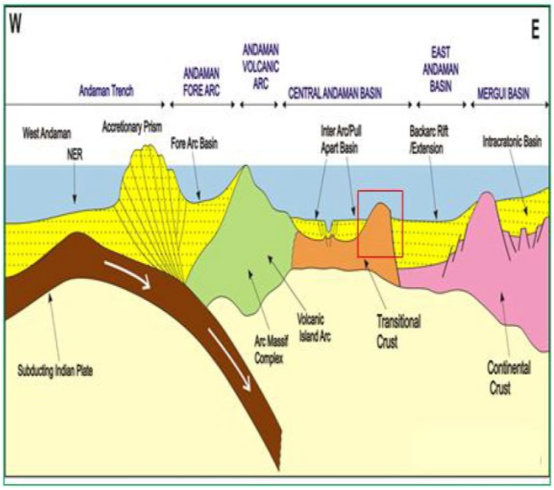

Fig-8: Schematic Geological Cross-section across Andaman Subduction Zone showing the position of the block (Rectangle)

Velocity Model Refinement Using Tomography

Tomography is a technique used to refine the velocity/depth model when PSDM has been performed with an incorrect velocity model. The depth migrated gathers from PSDM, get stacked applying a mute. The time migrated horizon interpretation are then converted to depth domain i.e. depth horizons using the initial interval velocity model. These depth horizons are then plotted on the initial depth section and the depth interpretations are redefined according to the depth section obtained from PSDM. The model was prepared for the re-defined depth interpretation and the tomographic semblance creation was performed for all the horizons one by one followed by actual picking of depth residuals from the depth migrated gather. Fig-9 shows tomographic semblance creation and interactive depth residual picking for H1and

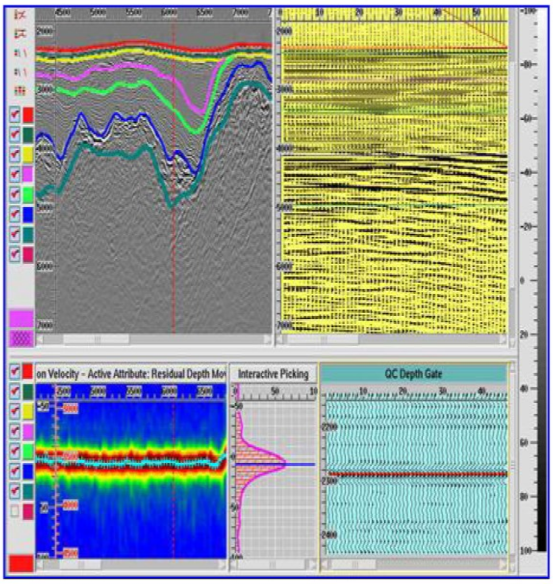

Fig-9: Tomographic Semblance creation & Picking

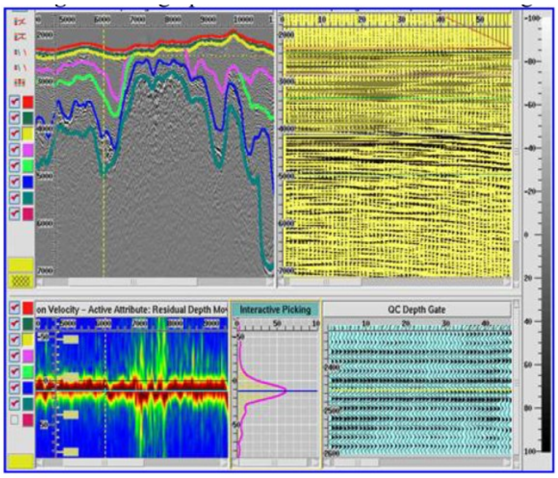

Fig-10: Tomographic Semblance Creation for H3

The quality of a velocity model used for PSDM can be assessed by analysing the output common reflection point (CRP) gathers. For a given CRP gather, all rays will have sampled the same point on the subsurface irrespective of their source-receiver geometry, and it would be flat if the correct velocity model was used for migration.

Any residual delay in the CRP gathers not only degrades the migrated image but also implies that the spatial position of the reflectors will be incorrect because of an incorrect model.

By analysing these residual delays, the model is refined through a number of techniques ranging from hyperbolic delay corrections to horizon-based and grid-based global tomography. In this paper we have used horizon based tomographic technique to correct the depth model. The new velocity model resulting from the updates is then used to re-run the PSDM, after which the process is repeated until the depth CRP gathers are flat. Fig-11 shows a typical tomography workflow to refine the velocity depth model.

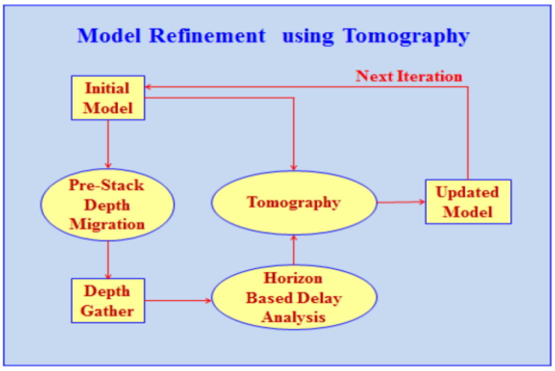

Fig-11: Tomographic Workflow

After tomographic picking of depth residuals, i.e. the residual moveout remains in the depth gathers because of velocity error, the initial interval velocity model is updated through tomographic process vide tomographic workflow described in Fig-11. Few iterations are required to correct the depth/interval velocity model so that the depth gathers obtained as an output of PSDM becomes flat. Fig-12 shows the Initial interval velocity model vis-à-vis Final Model, through tomography.

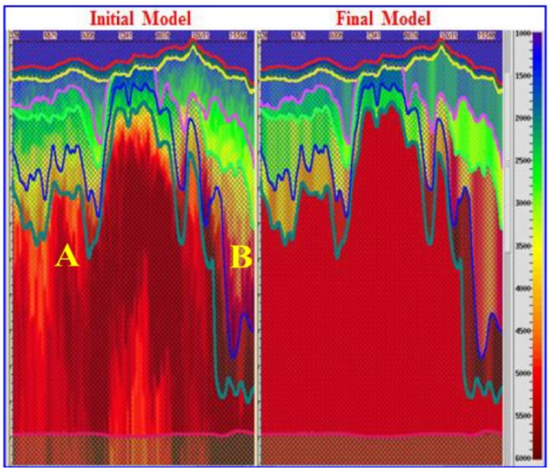

Fig-12: Velocity Model : Initial vs Final

Fig-13 shows the part of the whole section , area 'B' from Fig-12 above. The area 'B' is zoomed and shown that there is a lateral interval velocity variation from south to north bacause of structural dip and velocity complexity.

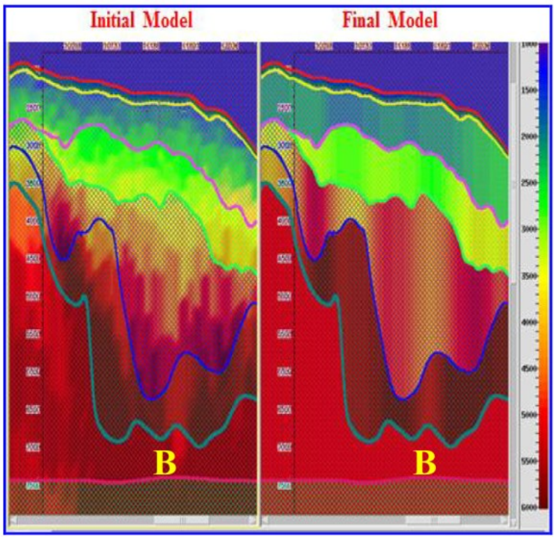

Fig-13: Initial vs Final Model in area 'B'(Zoomed)

Final Interval velocity model after tomographic update of two iterations is shown in Fig-14 below.

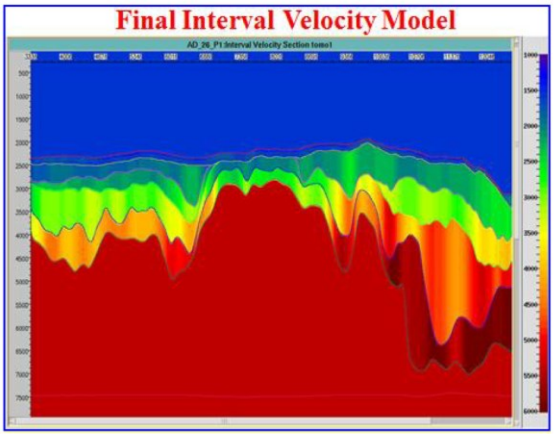

Fig-14: Final Model

Final PSDM & Time to Depth Conversion

The final PSDM was run with the velocity model updated through tomography. Aperture test was performed and the aperture was kept as 8 KM. The obtained PSDM gather is then scaled to time with the same velocity model in the background.

Quality Assessment

The quality essentially lies on the flatness of the migrated gathers in depth & time domain. Depth gathers already checked while performing tomographic iterations. The residual velocity analysis is performed on PSDM gather S2T to check for any velocity residuals & flatness of gathers in time domain as well. Fig-15 shows residual moveout analysis of a part of area, which shows almost zero residuals and flatness of the gather is seen in the right hand side panel.

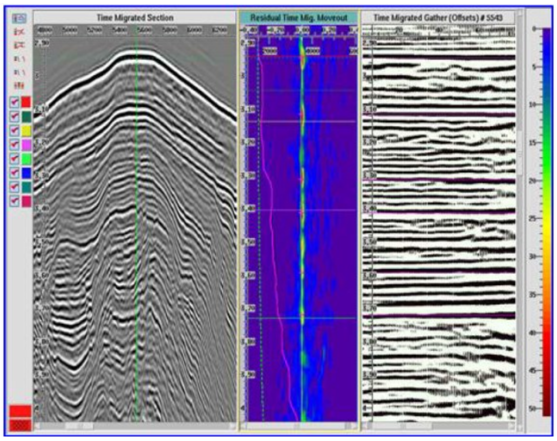

Fig-15: Residual Moveout Analysis in time domain

After residual moveout analysis, the gather has undergone for eta corrections, if any, which will flatten the gather in the longer offset (Ref. Fig-16).

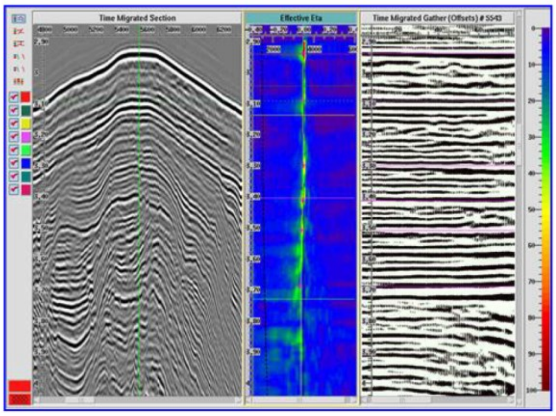

Fig-16: Eta correction

Fig-17 & 18 shows the comparison between earlier PSTM and PSDM scaled to time.

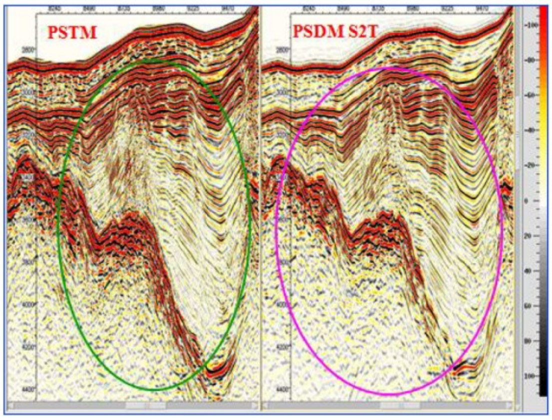

Fig-17: Comparison I

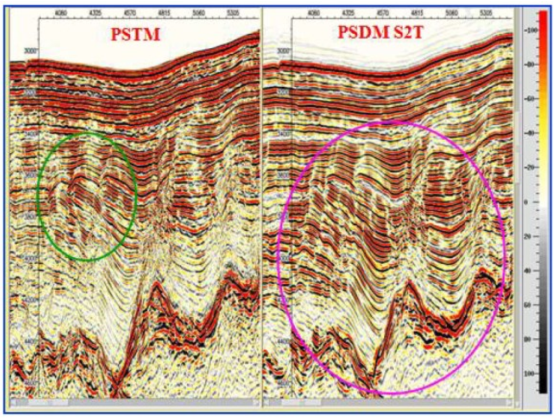

Fig-18: Comparison II

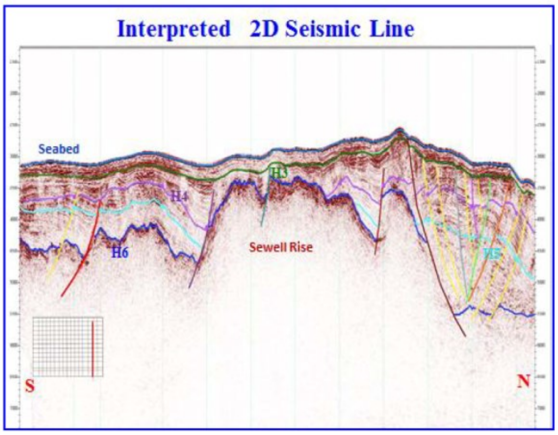

Fig-19: Interpreted Section in Time

Conclusion

Thus, the processed 2D seismic data has resulted in a noticeable improvement in output data quality enabling better interpretation. The diffractions which are seen in the PSTM section in Fig-18 (green circle) is not seen in the PSDM section scaled to time due to proper migration after collapsing the diffraction hyperbolas. The processed PSDM section reveals an improvement in terms of seismic resolution, noise attenuation and fault definitions than the earlier processed output.

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