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Improved Seismic Imaging through Prestack Depth Migration using Synthetic Seismic Data

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***Abstract* —A necessary requirement for a reliable seismic depth imaging is to have an accurate estimation of the earth velocity model. Seismic depth imaging fundamentally consists of computation of two way travel time and downward extrapolation of the observed wave field through a suitable algorithm. The Prestack velocity analysis and model building tools need to be combined to obtain an accurate velocity model. The methodology involves interval velocity building using coherency inversion and picking of residual moveout to get the updated velocity model. The Prestack depth migration (PSDM) is then performed with this refined velocity model. The results from the Prestack time migration (PSTM) and PSDM using 3D synthetic seismic data are discussed.**

Keywords — Interval velocity model, coherency inversion, PSDM, PSTM, velocity analysis

I. INTRODUCTION

Seismic depth Imaging is a vital and well-used technique in the analysis of sediments and rock layers. It therefore has important applications in the exploration and mining industries. Seismic depth imaging through Prestack depth migration has significantly improved the imaging of subsurface structures by minimizing the structural uncertainties[1][5]. Prestack depth migration is one of the most accurate seismic imaging tools developed to model the areas of complex geological situations. The method has the ability to focus and position reflectors in geological regions with strong lateral velocity variations. Therefore, the estimation of an accurate velocity model is the key to a successful subsurface imaging, since only a reliable velocity model can allow migration algorithms to account properly for the seismic wave propagation and ray path bending in the depth domain. Time migration accumulates energies along the diffraction surface and positions the summed energy at the apex of the diffraction surface [6][8]. Depth migration, on the contrary accurately accumulates the energies along the hyperbolic surface as described by ray tracing using interval velocities, and positions the summed energy at the proper location. Therefore it is very important to estimate the interval velocity model in depth, which governs the ray tracing exercise, with enough accuracy. The improved images of the subsurface have implications for better reservoir characterization [2].

II. THE DATA SET

The synthetic seismic data set used here has been made available by Society of Exploration Geophysicists (SEG) [11]. The synthetic seismic data (seismic response of some simple geological structures) have been produced using a modeling technique [12].

The study data consists of a Prestack line (Inline 401) from a 3D synthetic seismic data set. The data contain 2392 shot points with 544 traces per shot recorded over 8ms; an offset range from 40m to 2695m; and 25m shot with 12.5m receiver spacing.

III. THE METHODOLOGY

The synthetic seismic data is processed by applying standard processing procedures like geometry merging, data conditioning, noise attenuation, low-cut filtering, muting, spherical divergence correction, deconvolution, offset regulation and velocity analysis. The processed

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data is then prepared for coherency inversion to estimate the Depth-Interval velocity model which serves as an essential ingredient to depth migration. The detailed steps involved in the Prestack depth migration methodology are given in Fig.1.

The interval velocity analysis through coherency inversion is a model-based approach designed to estimate interval velocities directly using ray tracing [6][7]. The model-based interval velocity method is a layer stripping approach [10], where the interval velocity is estimated layer-by-layer starting from the shallowest to deepest.

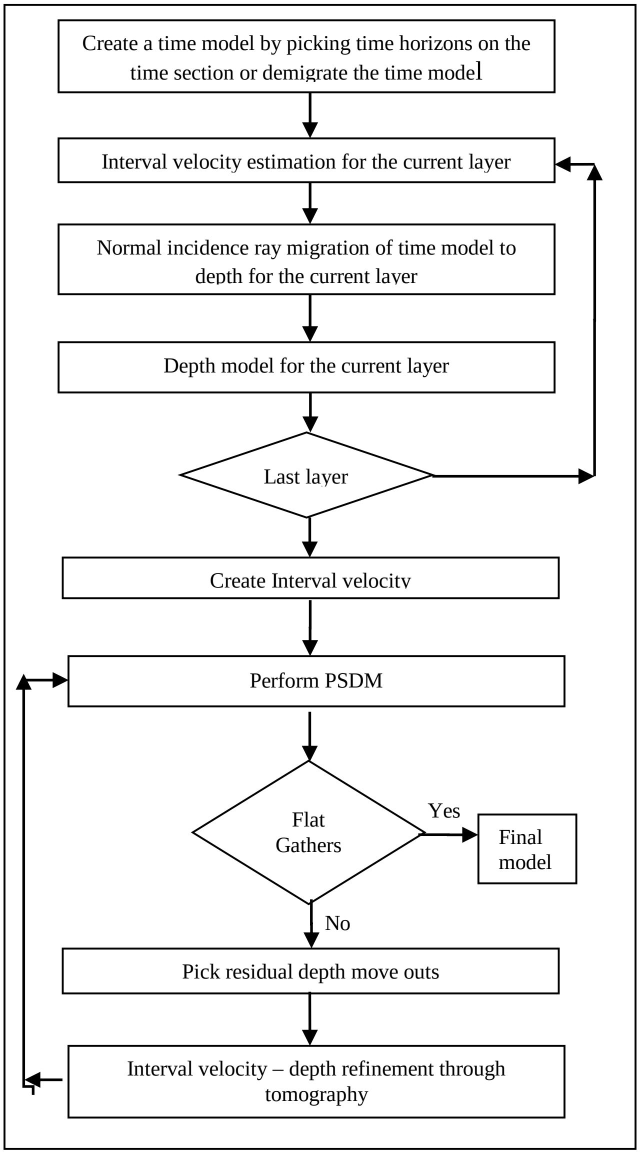


Fig.1. The flow chart of the Prestack depth migration methodology [6].

A. Coherency Inversion

This is one of the horizon based interval velocity estimation method, in which the laterally varying interval velocities can be obtained in a data driven manner. This approach involves Prestack Common-Mid-Point (CMP) gathers as the guiding data [1]. The un-migrated time model is required as input. Starting with the uppermost layer, for a range of trial velocities, the initial time from the time model is locally converted to depth using normal incidence ray migration [6][8].

Travel times are computed through normal incidence ray tracing for the depth model for a range of offsets [6][7][8]. The computed travel times are overlain on the CMP gather and the semblance is estimated. The process is repeated for a certain range of interval velocities with appropriate increment.

The trial velocity yielding peak coherence is identified as the interval velocity of the CMP under analysis (Fig. 2) [6][8]. Such analysis for several CMP gathers along the current layer yields interval velocity profile. The time model of the active layer is then converted to depth through normal incidence ray migration using the estimated interval velocity. The method is repeated for all subsequent layers until all layers in the model is exhausted. The end product is the depth interval velocity section for all the layers, which is now used as the initial interval velocity model for the Prestack depth migration [6][7].

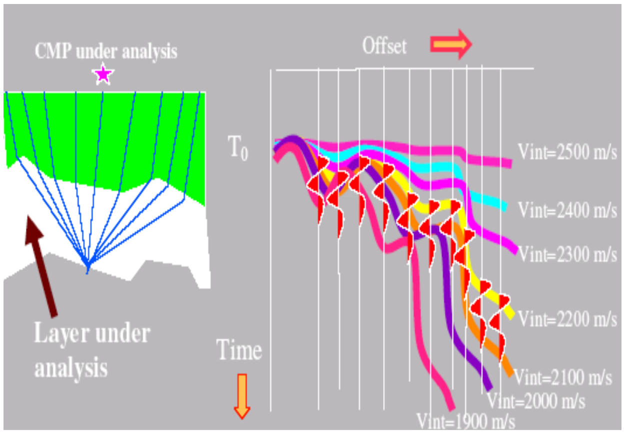


Fig.2. The principle of Coherency Inversion [1][6][8].

IV. RESULTS

A. Velocity Model Building

To estimate interval velocities through coherency inversion, a model in a thick layer sense is required [4][6]. The boundaries are to be picked up in such a way that they are coincident with major acoustic impedance contrast boundaries i.e. velocity boundaries need to be picked [6]. This is due to the fact that the kick in the seismic trace results from the wave propagation through the layer. The signal to noise ratio plays major role in the estimation of interval velocity with confidence. Initial RMS velocities were calculated from the stacking velocities using Dix conversion (Fig.3).

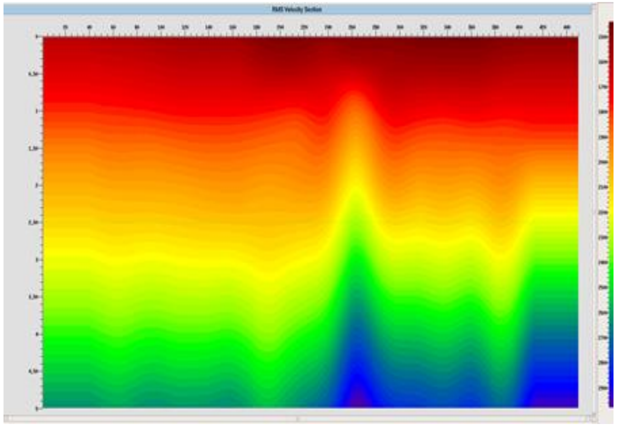


Fig.3. Initial RMS Velocity section

A total of 4 horizons were picked as shown in Fig.4.Using the RMS velocities picked on time migrated gathers in horizon consistent manner an RMS velocity section was created (Fig.5). This RMS velocity section was used to de-migrate the horizons to un-migrated time domain.

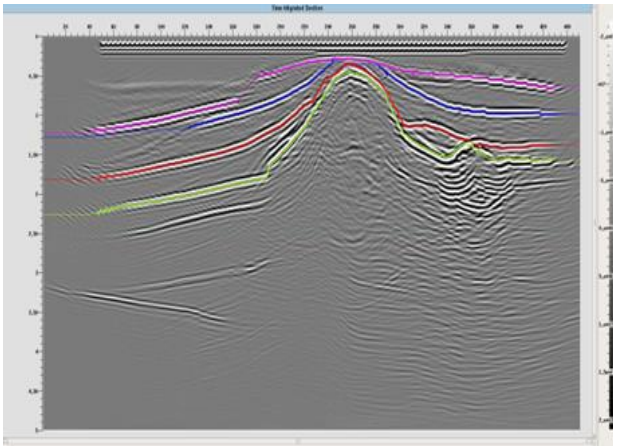


Fig.4. The horizon picks on the time migrated section.

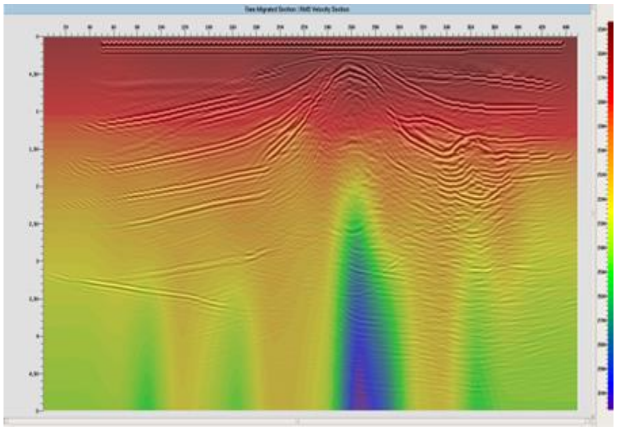
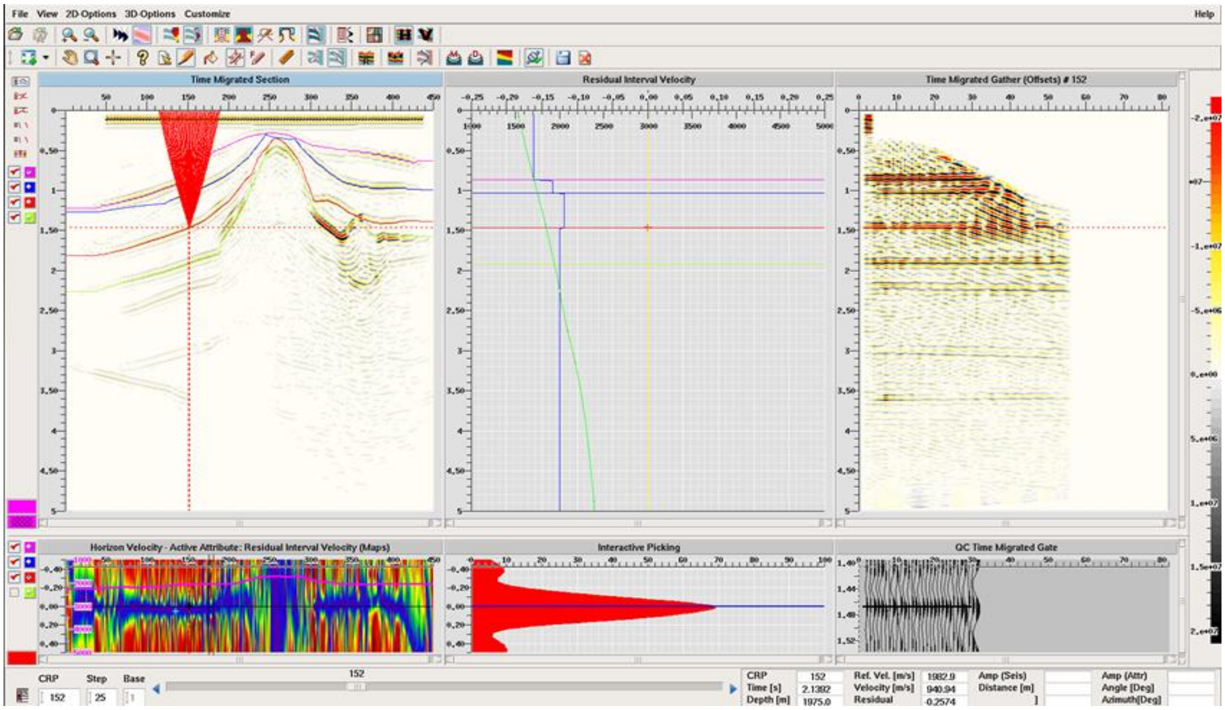


Fig.5. Horizon consistent RMS velocity section with PSTM stack.

The interval velocity analysis through coherency inversion is estimated from interval velocities following the ray tracing as shown in Fig. 6. It was observed that the gathers were almost flat at all locations (Fig. 6). The interval velocity section in depth obtained through coherency inversion is shown in Fig.7.



CRP 152
Step 25
Base 1

CRP 152
Time [s] 2.1382
Depth [m] 1975.0
Ref. Vel. [m/s] 1982.9
Velocity [m/s] 940.94
Residual -0.2574
Amp (Seis)
Distance [m]
Amp (Attr)
Angle [Deg]
Azimuth[Deg]

Fig.6. Estimation of Interval velocities through coherency inversion.

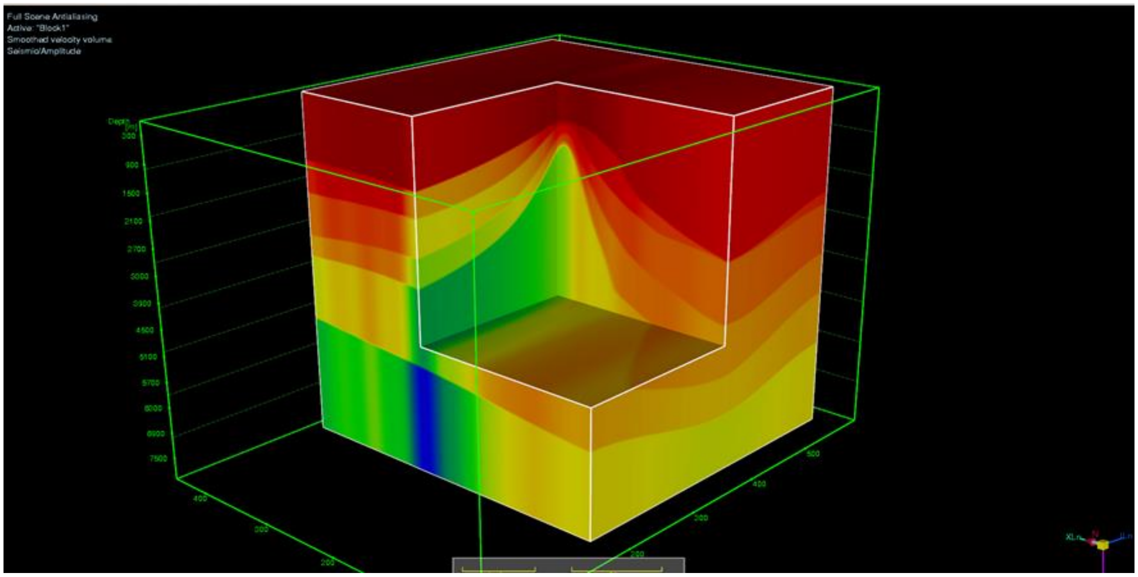


Fig.7. Interval Velocity model obtained from the Coherency Inversion

B. Prestack Depth Migration

Migration is a process which removes the effects of wave propagation from seismic data. Seismic data is generated by waves propagating through a subsurface. The image that is obtained in this process is a distorted image that does not correctly reflect the true geometry of the subsurface structure. While a horizontal reflector in depth will appear as a horizontal reflector on the time section, a dipping reflector is always incorrectly positioned on the seismic section. It is the task of migration to correct this mis-positioning by collapsing diffractions. These are illustrated in Figs.8 and 9. Normal Move out (NMO) stack section has been prepared using stacking velocity by applying non- zero offset correction between sources and receivers (Fig.8).

Prestack and Poststack : Migration operating on the prestack data (gathers) is prestack migration and migration on the stacked section is poststack migration.

Poststack migration fails for complex subsurface sections, where prestack migration proves its worth.

Time and depth migration: The difference between these two types of migration is in their ability to handle complex subsurface structure. Depth migration can detect and process the lateral velocity variation more easily and accurately then time migration.

Kirchhoff Prestack Migration is applied on prestack data to correct mis-positioning of the reflected events. It is defined as summation of all energy distributed along the diffraction curve and collapsing the energy at one point located on the apex of the diffraction hyperbola.It also improves the temporal resolution.

The interval velocity section in depth obtained from coherency inversion (Fig.7) is used for performing Prestack depth migration. Prestack time migration (PSTM) is performed using horizon consistent R.M.S velocity. As per the comparison between PSTM stack and PSDM stack (Fig.9), we can see improved subsurface reflectors in PSDM stack, which are important for structural and stratigraphic interpretation. Depth Slice (at 1600m) comparison between PSTM and PSDM illustrated in Fig.10.

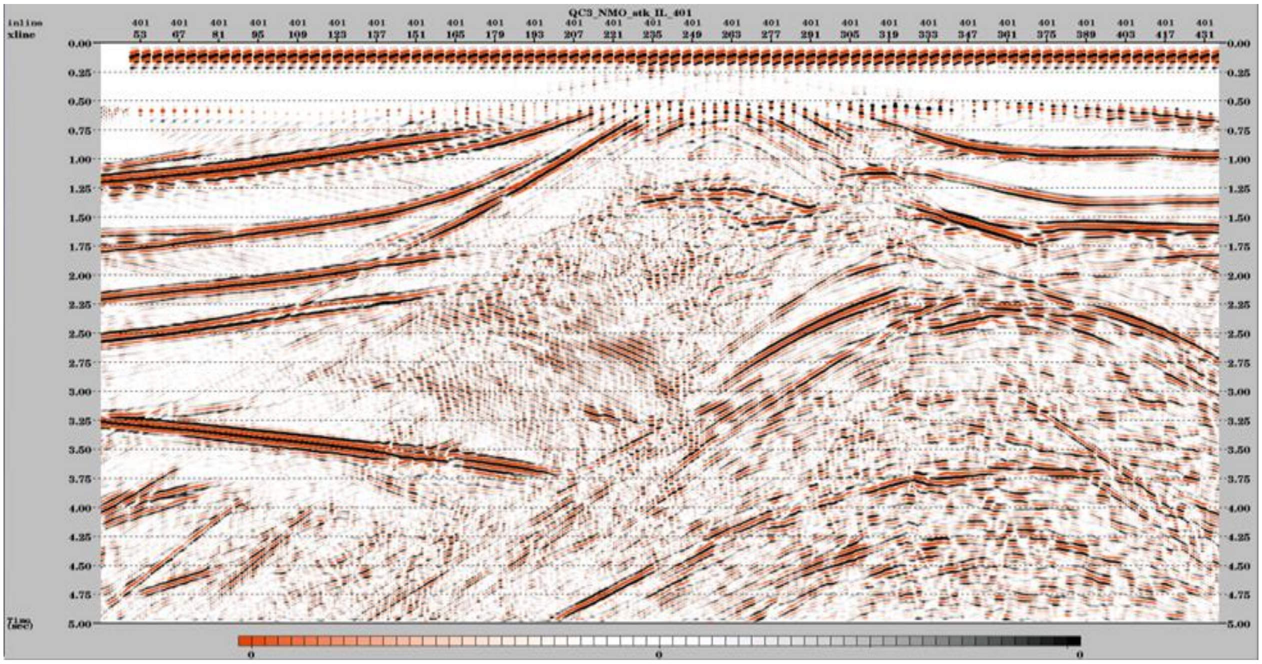


Fig.8.The Normal Move Out Stack (Un-migrated Stack)

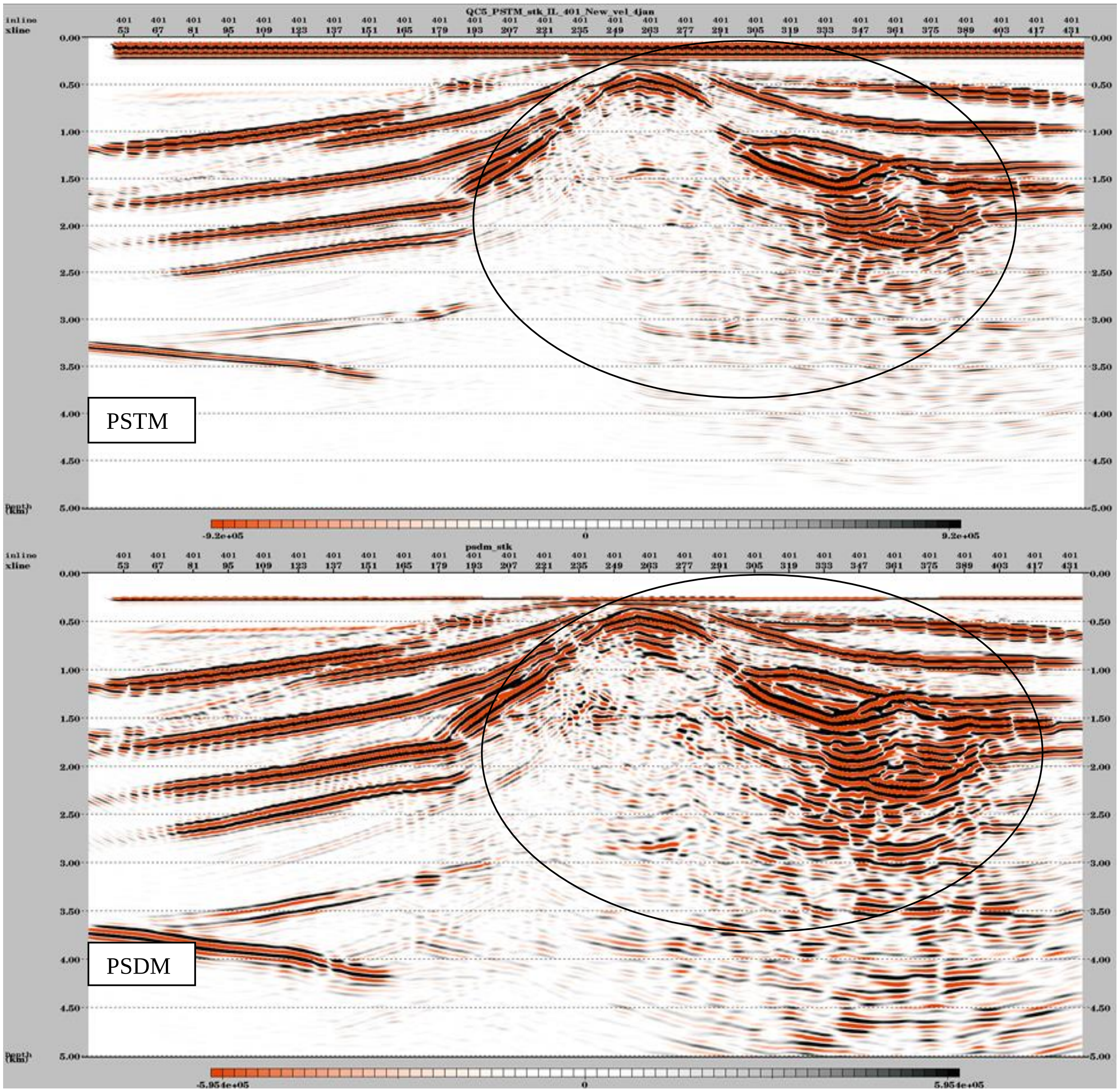


Fig.9. Stack Comparison between Prestack Time Migration (PSTM) and Prestack Depth Migration (PSDM). The oval (solid black) shows the improved reflectors.

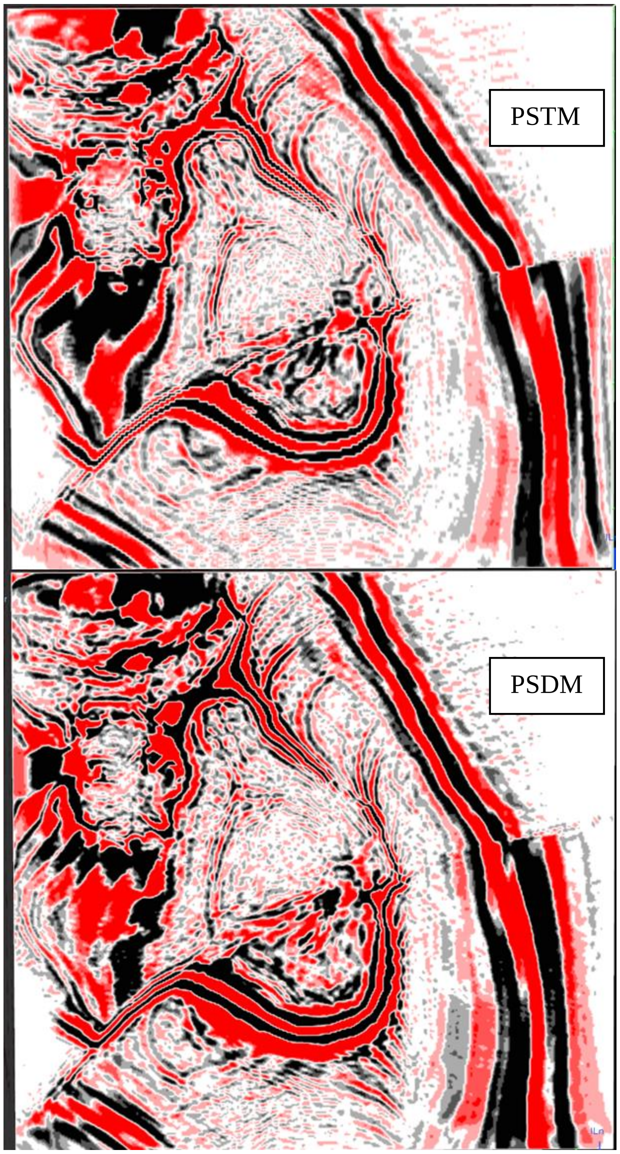


Fig.10. Depth Slice (at 1600m) Comparison between Prestack Time Migration (PSTM) and Prestack Depth Migration (PSDM).

V.CONCLUSIONS

The study demonstrates that the Prestack depth migration based on iterative velocity model building can produce improved subsurface image and continuity of events in tectonically complex structures like salt domes. The improved and enhanced images produced from PSDM compared to those obtained from PSTM indicate that PSDM should be preferred over the conventional PSTM methodology employed [3] to process and interpret the 3D seismic volume. The depth migrated images of the subsurface have implications for better understanding and interpretation of structures particularly benefitting the oil and gas industry.

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