Improved imaging through full-azimuth depth migration in the local angle domain-A case study from Upper Assam Basin

Manoj kumar bhartee, Gayatri pandey, Kiran pal, AC mandal*
Oil & Natural Gas Corporation Limited, Jorhat

Email: bhartee_mk@ongc.co.in

Keywords

WAZ, Local Angle Domain (LAD), Well-tie tomography, VTI, Specular and Diffraction Imaging

Abstract

Seismic prestack depth imaging is widely applied to compensate for distortions caused by complex overburden. Comparing to the prestack time imaging it is capable to correct recorded wave fronts for non-hyperbolic deformations caused by local, mid to short wavelength size, anomalies in overburden. That is accomplished by tracing rays, usually bent at interfaces, for individual offsets with account for VTI anisotropy. However, the need for seismic imaging of complex fault pattern reservoirs forced the next step of advancing the imaging technology: account for azimuthal anisotropy.

The Barail coal seam in Assam poses significant imaging challenges due to its complex geological structure and the presence of faults and fractures. In this technical paper, we present the improvement in seismic imaging by ES-360 anisotropic PSDM of wide azimuth (WAZ) seismic data. The ES-360 technique utilizes a unique combination of anisotropic velocity model building and pre-stack depth migration to provide high-resolution images of subsurface structures, especially in areas with complex geology. Our study shows that the ES-360 method significantly improves fault imaging in the Barail coal seam area, helping to identify fault locations and orientations accurately. The results obtained from this study can help in developing better exploration and production strategies for coal seam gas in the region.

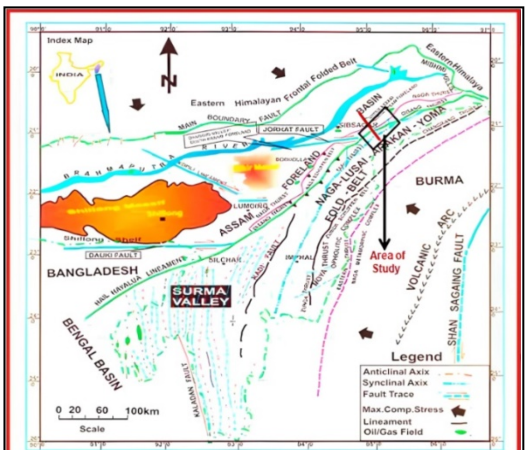
Introduction

Upper Assam Basin is a composite foreland basin which is located between the eastern Himalayan foot hills and the Assam - Arakan thrust belt. The basin is confined to northeast by Mishimi Hill block and to southwest it is partly disrupted by the Shillong plateau basement uplift. It is in the northeastern part of the Indian Plate. The compressional forces have generated a number of thrusts outcropping formations of Barail and Tipam groups in folded Schuppen belt to the east and southeast of study area.

Area of study

Lakwa area is located in the southern bank of the Brahmaputra River (Fig.1). The main formations of interest are Tipam, Barail, Kopili and Tura formations corresponding to Mio-Pliocene, Oligocene and Eocene formations respectively. The targets occur at a depth range of 2400 to 3150 m.

A base map showing acquisition fold and location of wells used during the present study is placed at Fig. 2 & 3 respectively. The objective for the survey was to map thin sands in the Kopili and Sylhet formations, as well as the fractures in the basement



Regional Map Showing Various Structural Elements of Assam & Assam-Arakann Basin

Fig.1: Area of study

between depths 2400 to 3150 m, which in turn correspond to two-way travel times between 2000 ms and 2800 ms.

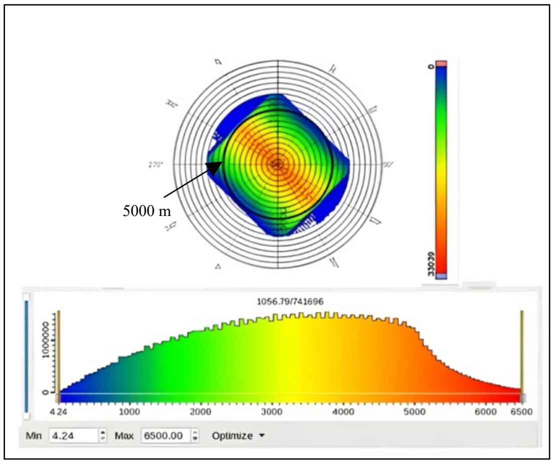


Fig.2: Azimuth and offset distribution of the input data.

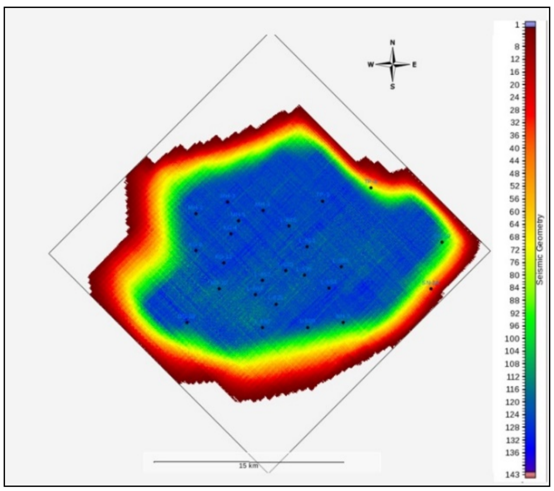


Fig.3: Location of wells used displayed on fold map.

The previous seismic prospect in this area was either based on conventional seismic imaging technology mainly obtained by iterative procedures using offset-domain pre-stack time and depth Kirchhoff migrations (PSTM and PSDM) or limited azimuth ES-360 PSDM.

Methodology

The residual statics-applied time gathers after multiple removals and RMS velocity volume from the earlier time processing were used as inputs for the depth processing under this project. The RMS velocity volume was converted to initial interval velocity volume using constrained velocity inversion method (Koren et al., 2006). A general processing flowchart is shown in Fig.4. Isotropic Kirchhoff PSDM was carried out on every 5 to 10 inlines and using the output stack, seismic attribute volumes such as dip, azimuth and continuity were derived. The dip and azimuth attributes calculate the structural dip and azimuth of the seismic reflectors in each reflection point. The continuity attribute calculates the continuity of the seismic data based on the dip and azimuth values (Software user documents, Paradigm). The depth gathers along with these computed attributes were input to the pre-stack auto picking algorithm. The picked residuals and input depth maps were used for running 3D grid tomography to update the input velocity.

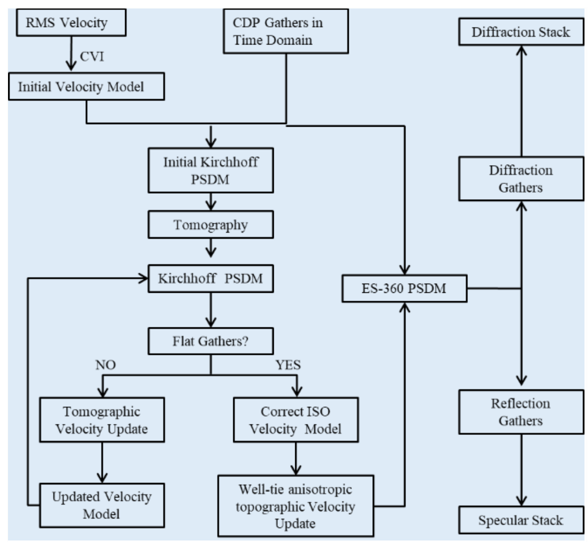


Fig.4: General processing flow diagram.

Multiple iterations of this procedure were done to derive a reliable isotropic velocity model, which flattened the depth gathers up to incident angle of 30 deg. (Fig.5) & corresponding stacks has been generated for quality control, improvements are clearly seen on subsequent updates (Fig.6). The data were then migrated with the updated velocity model (Fig.7). Well-tie tomography was done in isotropic to vertical transverse isotropic (VTI).
The purpose was to create a velocity model which when used for migration yields flat gathers and the reflectors in the image tie to the well markers.

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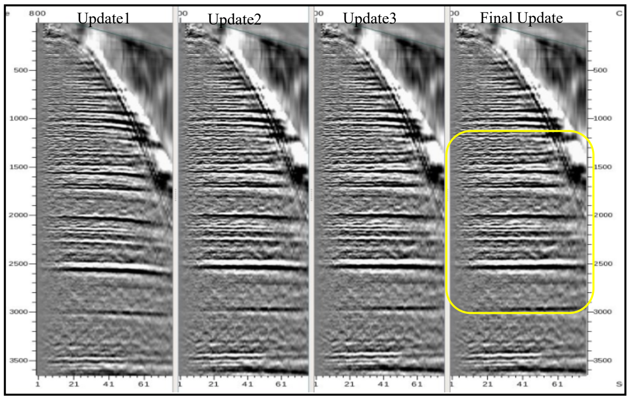

Fig.5: PSDM gathers QC at different velocity update.

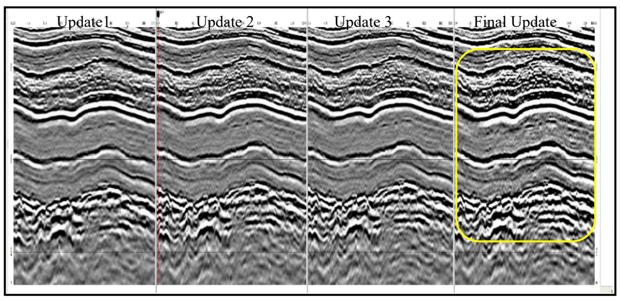

Fig.6: PSDM stack QC at different velocity update.

The mis-ties between well markers and the corresponding interpreted surfaces on the seismic volume at the well locations are computed and interpolated/extrapolated to generate mis-tie maps along interpreted horizons. These mis-ties were then used in tomography for updating velocity and anisotropic parameters.

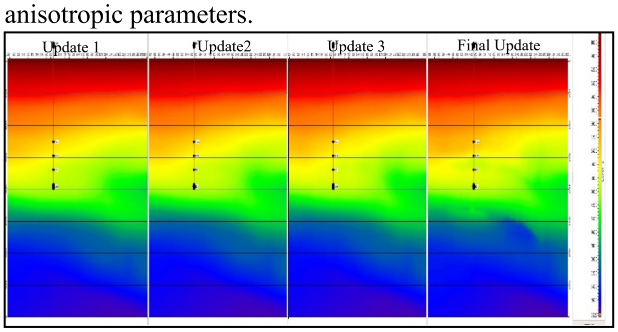

Fig.7: Interval velocity at a well location in different updates.

Final calibrated velocity, anisotropic parameters & residual gathers were used as input for ES-360 PSDM.

Results

The present technique of anisotropic PSDM offers several benefits over normal Kirchhoff PSDM likes improved imaging accuracy, enhanced resolutions; reduced imaging artifacts and more importantly it's improved the fault imaging. Comparisons of time processed Kirchhoff PSTM with ES360 PSDM scaled to time are shown in along an inline direction Fig. 8 & along a cross line direction in Fig. 9 respectively.

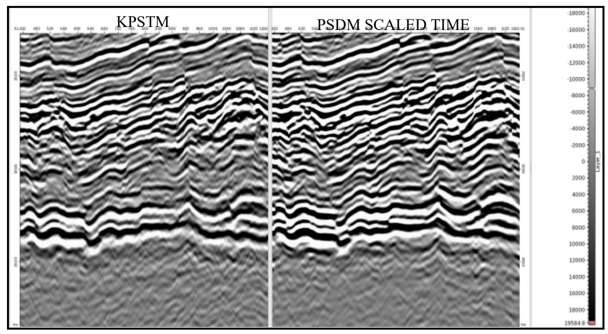

Fig.8: Comparison with Kirchhoff PSTM vs. ES360 PSDM scaled to time (along Inline).

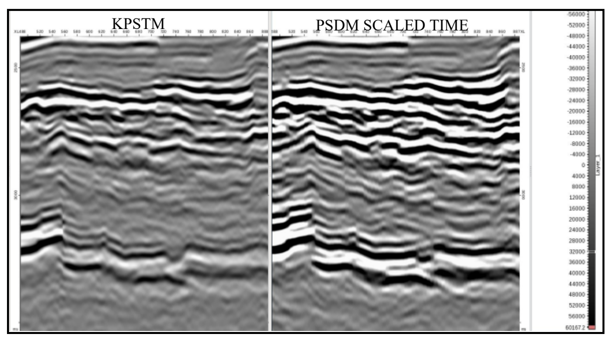

Fig.9: Comparison with Kirchhoff PSTM vs. ES360 PSDM scaled to time (along Cross line)

Reduced Imaging Artifacts: The ES-360 anisotropic PSDM method is less prone to imaging artifacts than normal Kirchhoff PSDM. This is because the algorithm is better able to handle complex geological structures and imaging conditions, resulting in more accurate and artifact-free images.

Improved Fault Imaging: Diffraction Stack of ES 360 PSDM is a high-resolution technique that can more accurately image faults in the subsurface.

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This is because it can identify small-scale features and details that may be missed by other imaging techniques. An example of enhancement in fault imaging at 3200m in depth are shown (Fig. 10, A & B) the fault pattern drastically improved after blending of specular stack with diffraction stack. Another example at 2500m depth is shown in Fig 11, A& B.

Diffraction Stack can provide a more detailed structural interpretation of the subsurface, allowing for a better understanding of the geological structures and their relationship with fault systems.

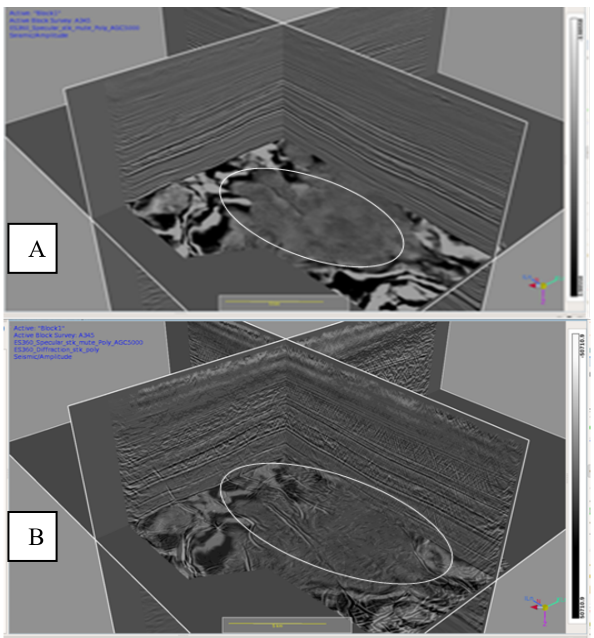

Fig.10: Specular stack A and blended with diffraction stack B at 3200m depth.

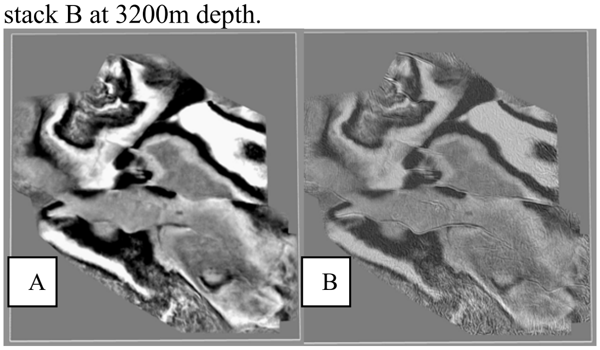

Fig.11: Depth slice of specular stack (A) and specular stack blended with diffraction stack (B) at 2500m

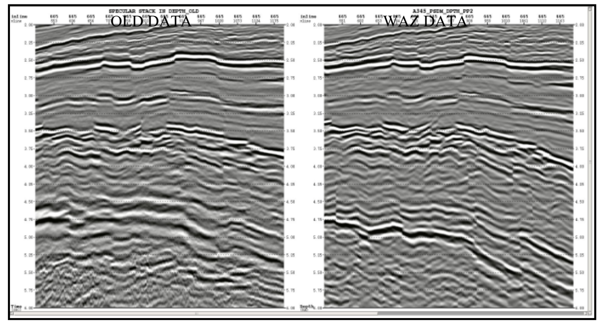

Fig.12: Comparison with ES360 old Vs. ES360 WAZ PSDM

Fig.12 shows the Comparison of ES360 old Vs. ES360 WAZ PSDM, the newly processed WAZ data shows the improvement at basement level as compared with limited azimuth old data.

Conclusions

From this case study, it can be inferred that ES360 processed data has the capability to resolve discontinuities like faults and fractures with higher precision which is achieved because of its advanced parameters like full-azimuth angle domain variation in amplitude, beam steering and anisotropic modeling. Imaging coal beds in seismic data processing can be challenging due to their low acoustic impedance contrast with surrounding rocks and their thin, discontinuous nature. This can lead to poor resolution and difficulty in distinguishing between coal and non-coal layers. Additionally, coal beds may contain natural fractures or faults, which can further complicate imaging. In the case of the Barail coal seam in Assam, the presence of complex geology and tectonic stress adds to the imaging challenges. However, utilizing wide-azimuth seismic data and anisotropic PSDM processing techniques like ES-360 can address these challenges and improve fault imaging in the region. The methodology and quality control measures adopted during the study, added value to seismic data by bringing significant improvements in imaging of the structural configuration in the target zone.

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