Pre Stack Depth Imaging using Model Based Velocity Estimation and Refinement – A case history from the East Coast of India


Summary

Depth Imaging has brought a new dimension of clarity and quality of subsurface images by minimizing structural uncertainties. But determination of the precise interval velocity field for the subsurface imaging is a major challenge in Pre stack depth migration. The present study deals with the deep water data from the east coast of India, around the 85 degree East Ridge. This work describes the methodology for interval velocity model building using coherency inversion, picking of residual move out to get updated velocity model and finally the Pre stack Depth images after refining the velocity depth model using Model based Tomography. The work also compares the results of the PSDM and PSTM images of the same area.

Introduction

Pre Stack Depth Imaging is a popular high resolution imaging tool especially in areas of complex geological settings and lateral velocity variations. In time migration no lateral velocity variations are accounted. This is valid as long as the lateral velocity variation and the structural complexity are gentle. Areas with strong lateral velocity variations cause severe ray bending at layer boundaries. Depth migration takes into account the geological structuring thereby taking care of the lateral velocity variations. Time migration accumulates energies along the diffraction surface and places the summed energy at the apex of the diffraction surface. On the other hand, depth migration, accurately accumulates the energies along the anhyperbolic surface as defined by the ray tracing using interval velocities, and positions the summed energy at the proper location. Therefore it is of utmost importance to estimate the interval velocity model in depth, which governs the ray tracing exercise, with enough accuracy. Lack of confidence in the estimation of interval velocities may often lead to poor imaging.

Methodology

The acquired seismic data are preprocessed using standard processing techniques like data conditioning, deignature, swell noise removal, band pass filter, spherical divergence correction, deconvolution, ensemble equalization, radon demultiple etc. The data is then subjected to coherency inversion for the estimation of Depth- interval velocity model.
Interval velocity analysis through coherency inversion is a model-based approach to velocity analysis designed to estimate interval velocities directly using ray tracing. Model-based interval velocity analysis is a layer-stripping process. This means that the velocity for the first layer should be defined and then the depth model before proceeding to the next layer. Interval velocity analyses for all the layers cannot be performed at one go because the velocity and depth of an upper layer affect the velocity and depth of the lower layer.

**Coherency Inversion**

This approach involves pre-stack CMP gathers as the guiding data. Unmigrated time model is required as input. Starting with the shallowest layer, for a range of trial velocities, the T0 from the time model is locally converted to depth using normal incidence ray migration. Travel times are computed through normal incidence ray tracing for the depth model for a range of offsets. The computed travel times are overlain on the CMP gather and the semblance is estimated. The procedure is repeated for a range of interval velocities with certain increment.
The trial velocity yielding peak coherence is identified as the interval velocity of the cmp under analysis (Fig. 3). 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 the next layer and so on till the last layer. The end product of this is the depth-interval velocity section for all the layers, which can be used as initial interval velocity model for Pre Stack Depth migration.

Model Building

For proper estimation of interval velocities through coherency inversion, a model in a thick layer sense is required. The boundaries are to be picked in such a way that they are coincident with major acoustic impedance contrast boundaries i.e. velocity boundaries need to be picked. 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. Adhering to this the horizons were picked on the Time migrated section. Total of 10 horizons were picked as shown in fig 4. Using the RMS velocities picked on time migrated gathers in a horizon consistent manner an RMS velocity section was created (fig 5). This RMS velocity section was used to demigrate the horizons to unmigrated Time domain.
Pre Stack Depth Imaging using Model Based Velocity Estimation and Refinement – A case history from the East Coast of India

The interval velocity section in depth obtained as a result of coherency inversion is shown in fig-7. Using this interval velocity section initial PSDM was performed (fig-8). It was observed that the gathers were not totally flat at certain locations. So, picking of depth residuals and horizon based tomography were adopted for the refinement of both interval velocity and depth model.

Depth- Interval velocity Refinement and Tomography

Global approaches based on tomography overcome the limitations in the layer stripping methods. When pre-stack depth migration is performed with an initial, incorrect, velocity model derived from inversion methods based on non-global (local) approaches, the depth gathers will exhibit non-flatness. The degree of non-flatness is a measurement of the error in the model. Tomography uses this measurement of non-flatness (residual move out) as input and attempts to find an alternative model, which will minimize the errors. Layer stripping approach may result in the accumulation of errors in the deeper parts of the section when there are errors in the shallower parts. Tomography updates the shallower and deeper portions simultaneously.

The horizon based approach has grid nodes at discrete points along the horizons. The error in depth at a given location is solved by analyzing the time delays along the ray path from source to receiver traversing several grid nodes. Horizon based approaches update both the reflector geometry and the velocity simultaneously. After refinement through tomography an updated interval velocity and depth model were generated and consequently final PSDM was performed.

Discussions & Conclusions

The Depth sections are scaled to time for comparison with the PSTM section. Figs. 10, 11 and 12 show a significant improvement in the continuity and definition of the events. They also indicate greater coherency and higher image quality. On the other hand PSTM section lacks continuity. It is observed from figs. 13 and 14 that the definition of the fault plane and the resolution of events across the fault have increased considerably in the PSDM section.

From the above discussion it is evident that PSDM based on iterative model building and tomographic update can produce reliable results in the form of improved fault definition, higher coherency and continuity of events in tectonically complex setup.
Pre Stack Depth Imaging using Model Based Velocity Estimation and Refinement – A case history from the East Coast of India

Fig. 10: Scaled to time PSDM (L) and PSTM Section(R)

Fig. 11: Scaled to time PSDM (L) and PSTM Section(R)

Fig. 12: Scaled to time PSDM (R) and PSTM Section (L)

Fig. 13: Scaled to time PSDM (L) and PSTM Section(R)

Fig. 14: Scaled to time PSDM (L) and PSTM Section(R)

References:

Furniss, A., 2000, An Integrated Pre-Stack Depth Migration Workflow using Model Based Velocity Estimation And Refinement, GEOHORIZONS (6).


Online help of Geodepth software, M/s Paradigm Geophysical.


Acknowledgements

The authors place their sincere thanks to Director (Exploration), ONGC, for his kind permission to publish this work. The authors are thankful to Miss. Parul Pandit, Mrs. Mamta Jain, Mr. V. S. Bhatnagar, Mr. Surendra Kumar, Mr. A.V.S. Sarma, Mr. R. S. Rana for their kind cooperation and support.

The views expressed in this work are solely of authors and do not necessarily reflect the views of ONGC.