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Non-linear slope tomography: A tool for global RMS velocity model building

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Abstract

Velocity modelling is one of the key process for time imaging and depth imaging which requires several loops of migration, velocity picking and velocity update. For larger offshore areas manual velocity estimation on semblance in a close grid is highly time consuming and error prone. An alternate technique was used to update the stacking velocity to RMS Velocity by method of non-linear slope tomography, which uses kinematic information i.e. dips and residual moveouts picked on Pre STM common image gather. Here we present the effectiveness of the nonlinear slope tomography for RMS velocity updation as compared to semblance based velocity estimation. This method has given promising results for ultra-deep water of Cauvery offshore seismic data.

Introduction

There are various methods for velocity estimation on seismic data i.e. semblance based velocity estimation, variable velocity scan, constant velocity scan (Seismic Data Analysis, Öz Yilmaz). These methods use offset and frequency of the seismic data and updates velocity in 1D local domain. It results in inferior quality of semblance formation as it has constraints of offset and presence of noise which smears the semblance, reduces the resolution. RMOs are also ignored, hence results in ambiguous velocity estimation. Whereas Non-linear slope tomography method (Gilles Lambaré, et all, Non-Linear tomography for time imaging) of RMS updation makes a global 3D velocity update of RMS taking into consideration of complex geology in every dip direction, RMOs are used to update velocity updation and full offset ray traced tomography is done. The velocity is also updated at its true location making it highly effective. Considering the effectiveness of this method, we are using this tool to update the RMS velocity from the existing stacking velocity of large volume of offshore data. The objective of this exercise is to obtain reliable RMS velocity field which can be further used for interval velocity conversion for Pre-SDM. Initial Kirchoff PSTM has been run in a sparse grid with initial velocity model and its output gathers and stack volume have been used for velocity modelling updation. Starting from initial prestack migration results, a demigration step is performed in order to convert kinematic information picked in migrated domain into kinematic information in the un-migrated domain. These are called as kinematic invariants because they do not depend on the velocity used for the initial migration. This method of tomography needs picks from locally coherent events and dips of the events which is further kinematically demigrated and further remigrated with updated velocity field. As only the picks are migrated, not the seismic data, it reduces the run time for velocity updation. This approach uses fully 3D slope tomography tool allowing for estimation of effective RMS velocity.

Method for Non-linear time tomography for effective velocity update

Kinematic information for slope tomography consists of locally coherent events in the Prestack un-migrated domain.The locally coherent events are characterized by their central position (*r,s,Tobs*) and by their local slopes in the un-migrated data cube (Fig.1)
($slope_m = dT_{obs}/dm$, $slope_h = dT_{obs}/dh$) (m denotes for mid-point position and h for offset).

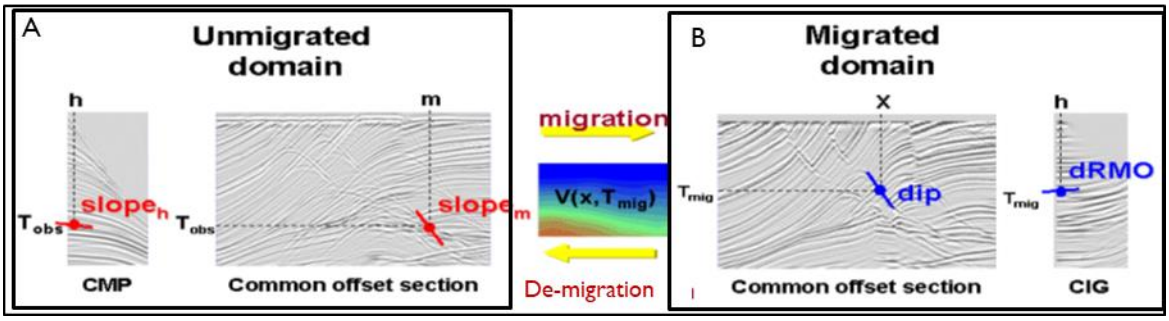

Fig. 1: Locally coherent events (A), in the un-migrated domain, where it is characterized by its central position and slopes (B), in the time migrated domain, where the migrated facet is characterized by its central position, dip and slope in the Common Image Gather (CIG), dRMO. (Courtesy: CGG)

These events are kinematically migrated in time for a given velocity model. The location and dip of the associated migrated facet are obtained and even the $dRMO = dT_{mig}/dh$ which is directly connected to the slope of the event in the CMP through by equation

$$dRMO=((dT_{sr}/dh)-(dTob/dh))/(dT_{sr}/dT_{mig})$$

where Tsr denotes the travel time used in the time migration (Chauris et al., 2002). A slope tomographic tool can be built to minimize the square of dRMOs or even the square of slope misfits

$$dslope_h = (dTsr/dh - dTobs/dh)$$

3D slope time tomographic tool is based on a fully non-linear iterative scheme converging to the velocity model best minimizing the *dslope* of the migrated facets. Its inputs are Kinematic invariants (locally coherent events in the unmigrated domain). Here in processing sequence they can be picked either in the PreSDM or PreSTM domain (Guillaume et al., 2008; Lambaré et al., 2007). The smooth effective velocity and anellipticity models are described in a sparse way by cardinal cubic B-splines functions, and compute numerically Fréchet derivatives of data, i.e. dTsr/dh, with respect to velocity and anellipticity parameters. A quasi-Newton scheme based on LSQR for the non-linear optimisation, with an appropriate regularization has been adopted.

Tomography work flow

In this work flow, (Fig. 2) we migrate the data with initial velocity model. CIG picking (residual moveout i.e. RMO and Dip) is performed on the migrated stack and gather. Kinematic demigration of CIG picks generates invariant (I) which is independent of migration velocity. Tomography updates the velocity using this invariant and initial migration velocity. A number of iterations are used for tomographic updates until the misfit between the slope and RMO is minimized.

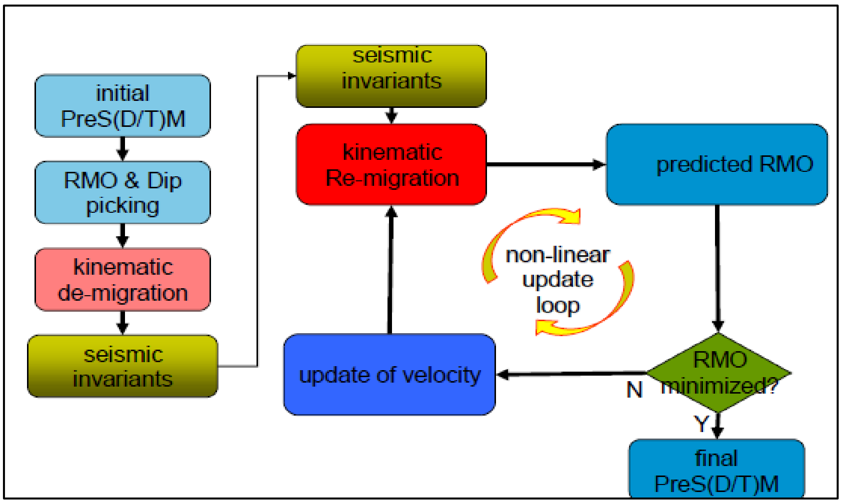

Fig 2: schematic diagram for nonlinear slope tomography (Courtesy: CGG)

Field data example

Inputs for the non-linear slope tomography are the Pre-STM gather and stack volume with the initial velocity model. The Pre-STM gathers were conditioned for residual multiples, linear and random noises for accurate picking of CIG. CIGs (RMO+DIP) have been picked on the conditioned Pre-STM gathers. Fig. 3 shows the RMO picks associated with the CIG gathers and Dips picked on the Pre-STM stack volume. The method used for RMO picking is plane wave diffractor method. We can see the RMO picks have been picked with very high quality factor (red in colour) as they have very good continuity and amplitude. The events which do not have good continuity and amplitude (green in colour), the quality factor is low and hence can be filtered out from the picks with constraints. Different method of QC like quality factor and Dip limits have been used to filter erroneous picks and ensure picking of reliable events. Angle mute of 45 degree has been used to avoid the stretch part at far offsets. This will ensure proper velocity updation through travel time tomography in time domain.

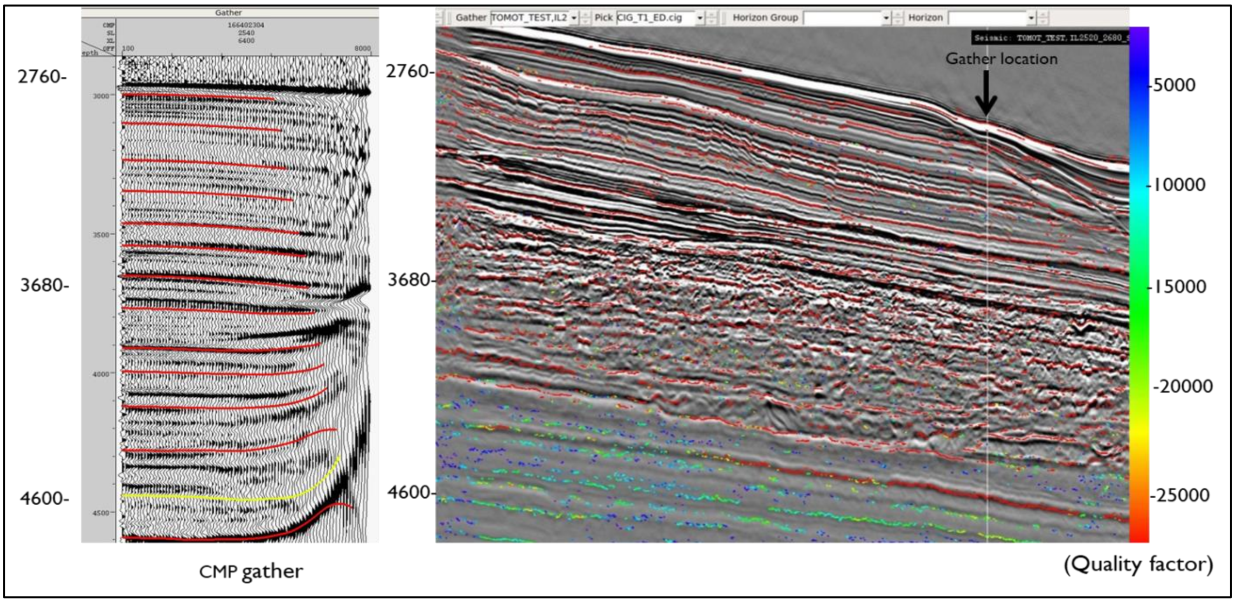

Fig. 3: CIG picking on Pre-STM volume (RMO+Dip)

Velocity model building and updation

Tomography update with 5 iterations has been done on the invariants. Input gather has been migrated with updated RMS velocity and compared with the initial velocity migrated gathers. Significant improvement in the gather flattening have been observed up to higher angles in both shallow and deeper section. Both the initial velocity (pink line Fig. 4) and the updated RMS velocity (black line Fig.4) has been overlaid on the semblance profile. The updated RMS velocity has been observed to follow lower velocity trend as compared with the initial model. Also it is following the semblance in closer proximity which validates the true updation of RMS velocity model.

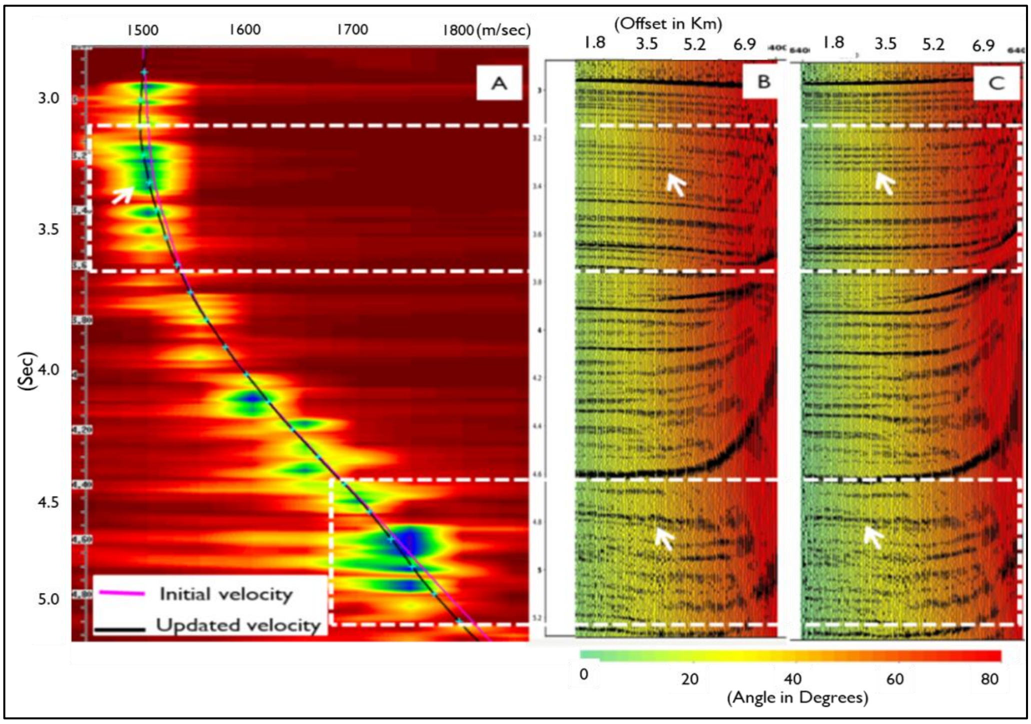

Fig .4: velocity profiles overlaid on semblance (A), gather flattening before (B) and after velocity updation(C) (incident angle plot in the background)

In Fig. 4 it is clearly marked with the dashed lines depicting the improvement in the flattening of gather after tomography updation. Stacking velocity function and the updated velocity function have been plotted against the semblance of the migrated gather. It's clearly evident that the updated velocity function is nearer to the semblance which validates the correct updation of RMS velocity.

Results and analysis

The updated RMS velocity has improved the stack section in many aspects. It has brought out very good resolution, continuity and amplitude enhancement is being observed in the data.

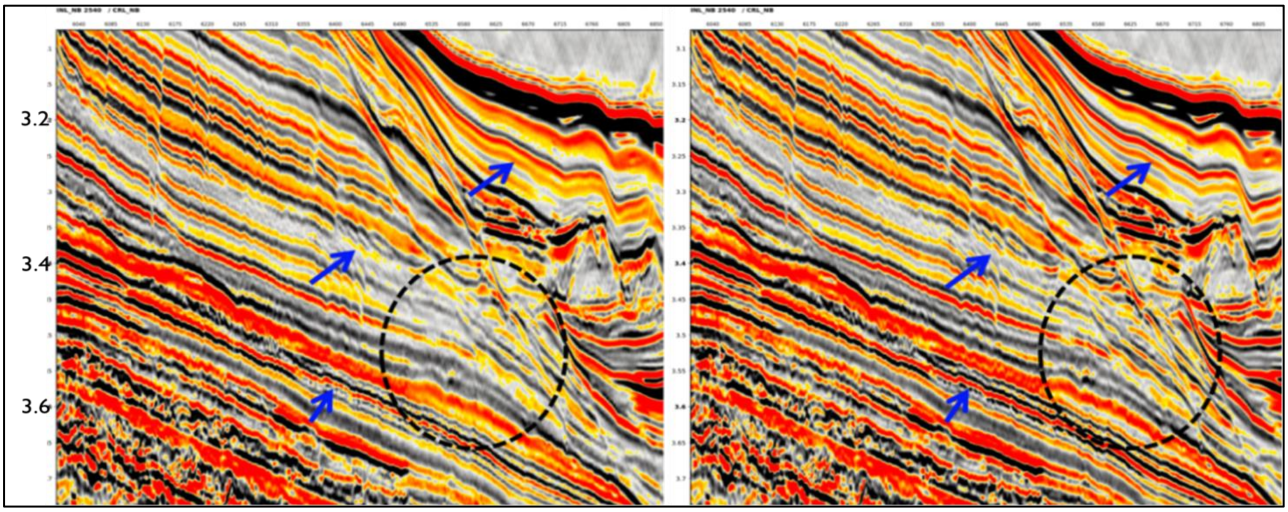

Fig.5: PSTM stack before and after velocity updation

The circled mark is showing high clarity, resolution and strength of amplitude which was lacking in the previous section with initial velocity model. It has also brought out events which were missing in the previous section and enhanced the resolution of the events (at blue arrow marked locations) (Fig. 5).

Conclusion:

In this case study we have presented a sophisticated and versatile tool for volumetric RMS velocity updation through non-linear slope tomography, a latest state of art invariant based tomography, which has given high fidelity results. The present case study has shown superior result over conventional velocity updation methods in Cauvery offshore seismic data. The velocity obtained from this technique has 3D global updation in very fine grid which has addressed the complex geology in wide range of dip direction, gather flattening up to higher incident angles and improvement in stack quality in terms of continuity and amplitude. The study supports that the semblance based manual RMS velocity picking can be avoided as it is highly time consuming. The proposed approach saves time, expedites the processing flow and also reduces cost of processing.

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