Can we correct for azimuth dependant variations of residual move-out in land WAZ context, using depth non-linear slope tomography? An imaging case history.

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Abstract

High-density wide azimuth (WAZ) land surface acquisitions have demonstrated superior imaging capabilities. Apart from the traditional poor signal-to-noise ratio of land data we face a new challenge: the necessity of reconciling the kinematics of the various azimuths. In this paper, we present an imaging case history involving WAZ non-linear slope tomography. Using surface information (kinematic invariants), velocity model updates are performed both in depth and time. We chose to start from an initial pre-stack time migrated (PreSTM) dataset. After applying a structurally consistent filtering to improve the S/N ratio on stacked data, we used a dense automated tool for dip picking. In parallel residual move-out (RMO) was computed on all azimuths simultaneously. Our case study demonstrates that WAZ non-linear slope tomography in the depth domain greatly improves the imaging of the structures when compared to the initial PreSTM result. We observe that even if tomography in the time domain significantly enhances imaging, it cannot successfully honor the kinematics of the various azimuths within the constraints of time imaging assumptions. On the contrary, WAZ non-linear slope tomography in the depth domain offers an efficient way to reconcile these kinematics, thus promoting the use of depth imaging when processing high-density WAZ data, even in the context of mild geological complexity.

Introduction

The seismic industry is currently faced with the increasing development of dense wide azimuth (WAZ) surface seismic onshore acquisitions. To efficiently process these datasets for an optimal imaging characterized by an azimuth-dependent illumination of the sub-surface, new techniques such as offset vector binning have been developed. Offset vector binning avoids the use of excessive regularization and interpolation schemes (Vermeer, 2002). The resulting common offset vector volumes (COV) can be migrated individually with preserved offset and azimuth information on output. The migrated common image point (CIP) gathers are finely sampled along the surface dimensions. Azimuthal residual move-out (RMO) can be extracted from these CIP gathers (Lecerf et al., 2009) to perform in turn migration velocity analysis. The mandatory structural information is computed using a robust 3D automatic picking of coherent events in the COVs after structurally consistent filtering (Traonmilin et al., 2008; Siliqi et al., 2009). WAZ non-linear slope tomography can then invert azimuthally varying WAZ RMO for updating either interval depth V_{int} and ε fields (Guillaume et al., 2008) or effective time V_{eff} and η_{eff} fields (Lambaré et al., 2009).

In this paper, we present the application to a land dataset from a high density WAZ surface survey, and migration results for both time and depth velocity model building routes with emphasis on azimuth related focusing issues (Zimine et al.,2010).

Non-linear slope tomography applied to land WAZ data

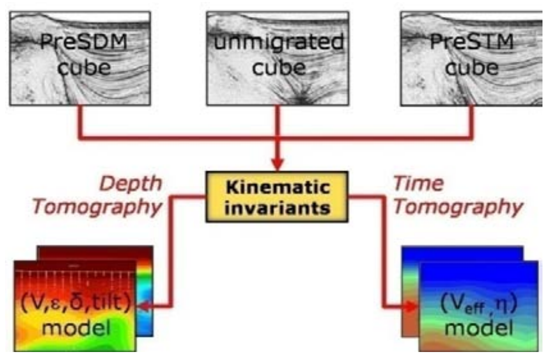

Figure 1: Kinematic invariants and their links with depth and time tomography processes.

Non-linear slope tomography (Guillaume et al., 2008) is an accurate tool for velocity model building that minimizes the local slope of migrated events in the common image point(CIP) gathers. The use of locally coherent events makes it particularly adapted to dense volumetric picking. Resolution of non-linear aspects provides the best possible update of the velocity model from a given picking. We use here the extension of the method to WAZ data (Montel et al., 2010) coupled with a dense WAZ RMO picking (Lecerf et al., 2009). Note that picking of locally coherent events can be done indifferently in the depth or time-migrated domains or even in the un-migrated domain (*Figure 1*). When picked in the migrated domain, a kinematic de-migration (Guillaume et al., 2001; Chauris et al., 2002) insures the conversion of the local event to the un-migrated domain with no compromise on the geometry, providing so-called kinematic invariants.

Project description, data pre-processing and picking

Seismic main characteristics: For velocity model building purposes, a subset of 160 km^2 was selected from a high density WAZ land orthogonal surface acquisition, over a faulty elongated anticline. All the figures presented in this paper are extracted from a central 7.5 km line, with a dip direction with respect to the main structure. This dataset was processed through offset vector binning to deliver 225 single-fold COVs with homogeneous offset and azimuth within each COV. These ‘pseudo minimum datasets’ (Vermeer, 2002) represent cubes with minimum holes or over fold. The $offset_X$ and $offset_Y$ increment (400m) and range (-3000m to +3000m) used by the tiling process are directly related to the acquisition scheme (200m between shot lines and between receiver lines). Offset and azimuth information is homogeneous within a COV and preserved throughout the processing sequence.

Processing from COVs: The main steps carried out before the attributes picking phase were 1) de-noising in cross-spread mode, 2) offset vector binning, and 3) initial PreSTM of 225 COVs independently. Migrated output was reordered in CIP gathers using the 3D ‘snail gathering’ sorting technique in increasing azimuth within increasing offset classes. Examples of such CIP gathers are displayed in *Figure 3*.

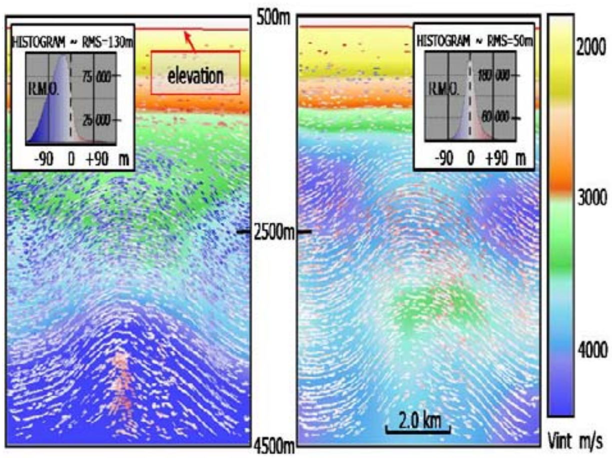

Figure 2: Depth tomography results, before (L) and after(R) inversion. Overlay of velocity models & ‘facets’. Colour code of facets: blue = negative, upwards RMO; red = positive, downwards RMO; white = no RMO.

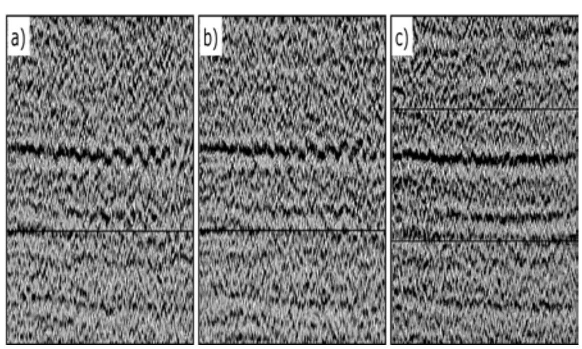

Figure 3: ‘Snail gather’. Azimuthal kinematic variations are better addressed in the depth domain. Oscillations observed on initial PSTM (a) remain after WAZ time tomography (b). After WAZ depth tomography (c), we have definitely eliminated the wobbling effect. The gather is located on the left flank of the anticline seen on figure 4.

Picking: This kind of data sorting is suitable for WAZ parabolic elliptical RMO picking. This approximation is reasonable as incidence angles are limited. Furthermore, Lecerf et al. (2009) have shown that this approximation is adequate to compensate for azimuthal velocity variations as the algorithm takes into account all azimuths simultaneously and is less sensitive to the noise than independent azimuthal sectoring analysis.

To update time and depth velocity models through slope tomography, we need to compute the kinematic invariants in the un-migrated domain via a de-migration process. Here we perform a kinematic de-migration in time(Lambaré et al., 2007). The following attributes are mandatory input to the de-migration:

- Dense volumetric WAZ RMO from ‘snail gathers’.
- Skeleton, in-line & cross-line dips and quality factor. All of these attributes are picked from a near-offset stack of migrated COVs to avoid RMO effects at far offsets.

To pick relevant locally coherent events, a structurally consistent filtering (Traonmilin et al., 2008) was applied prior to picking on the near-offset stack. For picking on the stacked data, we used a recently developed technique for automatic structural mapping of coherent horizons under the form of a skeleton (Siliqi et al., 2009).

Time and depth tomography and imaging results

Our non-linear slope tomography handles structural dips and elevation, as well as multi-azimuth and WAZ acquisition geometries, and is applicable in both time and depth domains. Effective parameters V_{eff} and η_{eff} will be updated in the time-migrated domain (Lambaré et al., 2009) and the interval parameter V_{int} will be updated in the depth-migrated domain from the same set of kinematic invariants (*Figure 1*). An example of the depth tomography result is given in *Figure 2*; the RMO histogram before inversion denotes too low velocities with a large amount of negative RMO values (predicted RMO at maximum offset). The ‘facets’ correspond to the re-migrated invariants in the initial and final models; each facet is defined by its X, Y and Z position, its structural dip and RMO derivatives to $offset_X$ and $offset_Y$ (dip_{Hx} and dip_{Hy}, in Montel et al. (2010)). In the final model, the RMO histogram is centred and narrowed, and the migrated facets, now focused, nicely follow the anticline structure. The same kind of observations can be done after time tomography.

Figure 3 shows that this dataset exhibits azimuth dependant kinematics variations characterized by a wobbling effect on time-migrated ‘snail’ CIP gathers. This effect remains after time tomography but disappears after depth tomography. In this case depth velocity model building solves azimuth dependant variations in the context of land WAZ acquisition, resulting in enhanced focusing as illustrated by flatter CIP gathers. *Figure 4* allows us to compare the migrated results from time and depth tomography. Depth domain definitely improves focusing and fault delineation compared to time imaging even in the case of this mild-geological complexity.

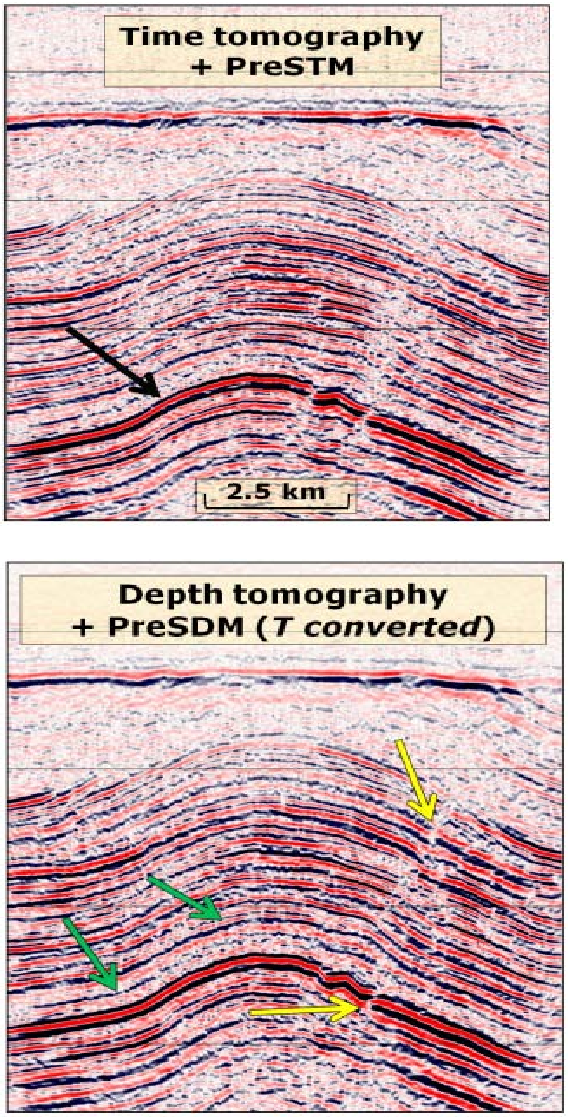

Figure 4: Depth imaging leads to better focusing (green arrows) and fault delineation (yellow arrows). The fault network on the right flank of the anticline is sharper after depth tomography. Black arrow indicates the location of the CIP gather shown on figure3.

Conclusion

Using kinematics invariants obtained from azimuth-dependent RMO and dip picking in time migrated domain, we applied our WAZ non-linear slope tomography that preserves all the geometry information in both time and depth domain. Using the same set of kinematic invariants, even if time tomography managed to substantially improve the time migration result, depth workflow only made it possible to solve the azimuth dependant kinematic effects that were observed in the time-migrated gathers. Moreover, fault delineation has been clearly improved. Those results suggest that depth rather than time processing should be applied to high-density wide-azimuth data, even in the context of mild geological complexity.

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References

-Chauris, H., M. Noble, G. Lambaré, and P. Podvin, 2002. Migration velocity analysis from locally coherent events in 2-D laterally heterogeneous media, Part I : Theoretical aspects. Geophysics, 67(4): 1213-1224.

-Guillaume, P., F. Audebert, P. Berthet,, B. David, A. Herrenschmidt, and X. Zhang, 2001. 3D Finite-offset tomographic inversion of CRP-scan data, with or without anisotropy, 71st annual SEG meeting, Expanded Abstracts, 718-721, INV2.2.

-Guillaume, P., G. Lambaré, O. Leblanc, P. Mitouard, J. Le Moigne, J.-P. Montel, T. Prescott, R. Siliqi, N. Vidal, X. Zhang and S. Zimine Kinematic invariants: an efficient and flexible approach for velocity model building, 78th annual SEG meeting, Las Vegas 2008, SEG workshop "Advanced velocity model building techniques for depth imaging".

-Lambaré, G., P. Herrmann, P. Guillaume, S. Zimine, S. Wolfarth, O. Hermant, S. Butt , 2007. From time to depth imaging with 'Beyond Dix', First Break, 25 (9).

-Lambaré G., N. Deladerrière, Y. Traonmilin, J.P. Touré, J. Le Moigne, P. Herrmann, 2009. Non-linear Tomography for Time Imaging, Extended Abstracts, 71st EAGE Conference & Exhibition - Workshops and Fieldtrips. U029.

-Lecerf, D., S. Navion, J.L. Boelle, A. Belmokhtar, A. Ladmek, 2009. Azimuthal Residual Velocity Analysis in Offset Vector for WAZ Imaging, EAGE extended abstracts, V013.

-Montel J.P., P. Guillaume, G. Lambaré, O. Leblanc, 2010. Non-linear slope tomography: extension to MAZ and WAZ configurations, 72nd EAGE Barcelona.

-Siliqi R., Talaalout A., 2009. Structurally coherent Wide Azimuth Residual Move Out surfaces. 79th Annual International Meeting, SEG, SEG, Expanded Abstracts, 4039-4043

-Traonmilin, Y., P. Herrmann, 2008, Structurally consistent f-x filtering, On the Estimation of Local Slopes, SEG Technical Program Expanded Abstracts, SPNA P1.4

-Vermeer, G., J., O., [2002], Processing with offset-vector-tile gathers: 63rd EAGE Amsterdam

-Zimine, S., G. Lambaré, P. Guillaume, J.-P. Montel, J.-P. Touré, N. Deladerrière, X. Zhang, A. Prescott, D. Lecerf, S. Navion, J.-L. B., A. Belmokhtar and A. Ladmek, 2010.Can we correct for azimuthal variations of residual move-out in land WAZ context, using depth non-linear slope tomography? An imaging case history. 72nd EAGE Barcelone