Extending MAZ PSDM velocity model building to land context using controlled beam migration, a case study
Olivier Hermant*, Jean-Paul Gruffeille, Serge Zimine, Sylvain Navion, CGGVeritas

Summary

3D marine and land dense wide-azimuth (WAZ) and multi-azimuth (MAZ) acquisition and processing has taken off in the industry with the associated development of specific tools for WAZ/MAZ processing. For land data, wide-azimuth information actually exists since the early 3D acquisition as land data is wide-azimuth by nature. However and unless we talk about recent dense land acquisition with short distance between source and receiver lines and very high density of receivers and source points, land data is usually limited by its trace density and its noise content. By gathering different techniques such as Common Offset Vector (COV), Controlled Beam Migration (CBM) and MAZ tomography, we present in this paper a workflow allowing the use of recent WAZ processing tools in land context without requirements of high trace density and the benefits of using such sequence on the data quality.

Introduction

CBM has proven to be one of the tools of excellence for Pre-Stack Depth Migration velocity model building, filling in the gap between Kirchhoff migration – of flexible use but single arrival only – and wave-equation based algorithms (WEM/RTM) – fully handling multi-arrivals but still time consuming (Gray et al., 2003, Vetle et al., 2008) – and also reducing the noise content and providing better imaging. Beam migrations (and CBM) require the input data to have consistent offset and azimuth information. In land (or OBC) context, this implies using vector binning in the processing sequence prior to migration. By running CBM in COV domain, we preserve the azimuth information during the migration and have full benefit of multi-pathing inherent to beam migrations together with noise reduction effect of CBM. We thus have the ability to pick the residual move-out (RMO) on the common image gathers (CIG) as a function of offset and azimuth – either using azimuth sectors (discrete number of azimuth, equivalent to a MAZ context) or in a WAZ sense (full 3D offset and azimuth RMO picking). These MAZ or WAZ RMO picks are then used as input for non-linear slope tomography, tomography engine used for updating the PSDM velocity model.

In marine environment, MAZ seismic acquisition and MAZ tomography are extensively used in Nile Delta with considerable improvements compared to narrow azimuth data (NAZ) (Keggin et al., Rietveld et al., 2007, Gruffeille et al., 2009). Based on a case study using data from onshore Nile Delta and from a velocity model update point of view, we will detail in the following article how the use of COV and CBM can allow the use of MAZ tomography in a similar approach as it is used in marine environment and with the same potential of uplift on the final image. On the imaging side, we will also show the benefits of using COV CBM compared to standard Kirchhoff depth migration.

Offset Vector Tiling for CBM

As mentioned earlier, CBM requires input data with consistent offset and azimuth information. The dataset used in this example is land data, with orthogonal shooting acquisition layout and relatively sparse source and receiver line spacing (350m between receiver lines and 350m between source lines, nominal fold 66). To honour CBM requirements, this dataset was split into COVs, each of them having homogeneous offset and azimuth distribution (Zimine et al., 2010), and minimum holes or fold variations due to acquisition irregularities (Vermeer, 2002). Later on, CBM is performed independently for each COV volume so that after migration, all traces belonging to a CIG still have the offset and azimuth information available.

In addition to this, after vector binning, further processing can be applied such as data regularisation, bin centering and trace interpolation, preserving the azimuth and offset information.

To illustrate results obtained with this processing sequence, Figure 1 is an overlay of seismic and velocity
MAZ model building in land context using CBM

This is a TTI PSDM velocity model, for practical reasons only the principal velocity (velocity along the tilt axis) is displayed. The tilt axis was extracted from the seismic (structural dips) and the anisotropic parameters used are Thomsen \( \varepsilon \) and \( \delta \).

Due to large lateral velocity variations and strong anisotropy between 3 km and 4 km deep and a velocity inversion below that, some multi-pathing is expected in the deeper part of the section.

Figure 2 shows that incremental uplift can be obtained going from Kirchhoff PSDM to COV CBM and COV with data regularization and CBM (panels from left to right, respectively).

**MAZ move out analysis on migrated gathers**

Let us focus now on the analysis of CBM migrated gathers. As each COV has been migrated separately, we can sort the gathers using the concept of ‘snail’ gather (Lecerf et al., 2009), i.e. by increasing offset ranges and within each offset range by increasing azimuth (figure 3).

As described by Zimine et al., 2010, the wobbling effect highlights a variation of the move-out with the azimuth. In this example the cycles of the wobbling effect are not always complete: although data is WAZ by nature, it is not dense WAZ and the azimuth and offset distribution is not as rich as it would be on dense WAZ acquisitions. One of the goals of this study is to assess whether such data can be used for MAZ tomography or not. Is the trace density limiting the quality of the RMO picking needed for velocity model update?

After observing the wobbling effect on the migrated gathers, we looked at dividing the COV CBM gathers in azimuth sectors. The aim is to pick RMO independently on each azimuth sector.

Figure 4 shows some migrated gathers separated in 3 azimuth sectors, both CBM and Kirchhoff gathers are displayed. The comparison between CBM and Kirchhoff gathers shows the benefit of CBM in terms of signal to noise ratio. Although the offsets are not evenly distributed amongst the 3 sectors, the number of traces in each sector is sufficient to perform automatic RMO picking on CBM gathers but would be difficult on Kirchhoff gathers due to...
MAZ model building in land context using CBM

Figure 4: PSDM gathers divided in 3 azimuth sectors, CBM on the left, Kirchhoff on the right. The azimuth are not evenly distributed with the offset, the 2nd sector having a limited range of offset. Note the variations of the move-out from a sector to the next and the improved signal to noise ratio on CBM gathers compared to Kirchhoff gathers

Figure 5: CBM stacks of each azimuth sector. Sector 0-60 degrees (left), 61-120 degrees (middle) and 121-180 degrees (right). Displays are in depth, with AGC applied. Note how the energy is different from an azimuth sector to the next, each of them illuminating different areas in the sub-surface. This effect mainly occurs below the high amplitude event at 3km, where the geology becomes more structurally complex.

the level of noise and lack of continuity of the seismic events. Similar to the wobbling effect shown on the snail gathers (Figure 3), we can observe on these gathers some variations of the move-out from an azimuth sector to the next, which stresses the importance of taking the azimuth into account during the tomographic update.

On Figure 5 are displayed the stacks of the different azimuth sectors (CBM stack of gathers from Figure 4). The stacks show the illumination variations in the sub-surface with the azimuth, described as wave path redundancy and complementary information between the different azimuths (Montel et al., 2010) benefiting to MAZ tomography.

MAZ RMO picking for non-linear tomography

We update the velocity model using non-linear slope tomography (Guillaume et al., 2001, 2008) and its extension to MAZ datasets (Montel et al., 2010). The use of locally coherent events is adapted to dense volumetric picking. In MAZ context, the dense automatic picking can be done independently for each azimuth sector, using 4th order polynomial function for the picking, well adapted in
MAZ model building in land context using CBM

\[ T(h) = T_0 + c_2 h^2 + c_4 h^4 \]

Figure 6: \((C_2, C_4)\) linear combination used for RMO polynomial picking (h being the offset)

case of presence of anisotropy as it handles complex RMO curves (Figure 6).

In addition to the RMO picks, the other attributes needed for the non-linear tomography are extracted from the seismic stacks: dips and skeleton are computed for each azimuth sector. In the non-linear tomography process (Figure 7), the kinematic de-migration is performed for each azimuth sector and the resulting invariants (Guillaume et al., 2001) are merged together prior to tomographic update, ensuring the preservation of the azimuth information. Quality control of the RMO picking is shown on Figure 8, with the overlay of CBM gathers and the picked RMO represented by a 4th order polynomial function.

Conclusions

The combination of CBM with offset vector tiling process on land data with sparse acquisition layout demonstrates the benefit of CBM for reducing the amount of migration noise compared to Kirchhoff pre-stack depth migration. As a result we can afford separating the data in azimuth sectors preserving a reasonable signal to noise ratio in each of them and thus allowing accurate RMO picking for velocity model update through non-linear slope tomography in a MAZ context. This opens further possibilities for re-processing non-dense land data with full advantage of taking into account the WAZ nature of such datasets.

Acknowledgements

We thank RWE Dea Egypt for granting us permission to show these field data examples and publishing results. We also thank CGGVeritas for the authorization to present this work and our colleagues from R&D and Processing for fruitful discussions during the life of this project.
References


