Introduction

In practice, imaging and processing solutions to poor seismic illumination of narrow azimuth towed streamer marine data is limited due to acquisition design. We show here several examples of marine data from different fields located on Norway Continental Shelf where the multi-azimuth approach of the velocity model building and imaging has helped to improve the definition of structural geometry, to perform a more reliable interpretation on the seismic data and as a result to achieve a better understanding of the reservoir for planning production wells.

The workflow included advanced multi-azimuth depth processing as well as multi-azimuth velocity model building and imaging.

Seismic surveys

In order to apply a multi-azimuth approach of velocity model building and imaging several datasets with different marine acquisition have to be available and pre-processed through the same processing sequence with preservation of azimuthal information.

We show here an example of a field where two datasets with different marine acquisition parameters were available (see figure 1):

- conventional PGS survey from 2007 (HT2007);
- geo-streamer PGS survey from 2015 (PGS14005).

These surveys have different shooting directions; the difference is very minor, 26 degrees only.

![Figure 1 Survey fold maps: PGS survey from 2007 on the left, PGS survey from 2015 on the right.](image)

For a better understanding of the discovery and upside potential it was decided to do reprocessing of the existing data using modern techniques of data conditioning and depth imaging. With newly reprocessed data it was decided to update the velocity model with the intention to extract more information due to the data being available from different azimuths.

Multi-azimuth approach of velocity model building and updating

An existing depth anisotropic TTI velocity model had been built for this field. The workflow included geo-statistical extrapolation of the sonic logs based on horizon interpretation. It was then updated using a number of iterations of the grid-based tomography of the Kirchhoff migrated gathers.
In order to QC the velocity model CRAM (Common Reflection Angle Migration) was carried out (Koren Zvi, 2008, 2011). The Residual Moveout curves were picked on migrated data and analysed along the target horizons. Figure 3 shows how different the RMO curves look at the same CRP point depending on azimuths.

**Figure 2** Example of RMO picking on depth migrated angle gather for each azimuth separately: CRAM depth migrated angle gathers with residual moveout curves overlaid (HT2007 azimuth on the left, PGS14005 on the right).

As moveout analysis indicated differences in interval velocities depended on azimuth direction, the multi-azimuth approach of velocity updating was applied. General tomography workflow is shown on figure 3.

**Figure 3** Multi-azimuth tomography workflow.
Using azimuthal information in tomography allowed velocity updates using relatively small cell grid size (Bartana, 2009). This was not possible with conventional approaches. For each current tomographic update we calculated the residual RMS velocities maps (Jones, 2010) along the target horizons with the intention of evaluating the results. The maps along the base of the reservoir before and after velocity updates for each azimuth are shown on figure 4. The residual RMS velocities for PGS14005 azimuth before and after updates are almost equal to zero, but there are changes for HT2007 azimuth. The relative RMS velocity field became much closer to zero, though the velocity updates simultaneously preserved zero moveouts for the other azimuth (PGS14005).

Figure 4 Multi-azimuth Residual Moveout Analysis and QC: residual RMS velocity fields calculated along Base reservoir for PGS14005 survey before velocity updates (left top), after velocity updates (left bottom); for HT2007 survey before velocity updates (right top), after velocity updates (right bottom).

Depth-imaging of marine surveys

As a final product, CRAM migration of pre-merged time gathers was carried out. Two options were implemented:
- joint CRAM without azimuth preservation;
- Full-azimuth CRAM migration.

The second option looks more promising from a point of extraction of additional information from the azimuthal component of migrated data. We show here an example of an angle migrated full-azimuthal gather in a cylindrical view. The azimuth is continuously increased from 0 to 360 degrees for each reflection angle.

The advantage of azimuthal preservation on migrated gathers is the ability to apply azimuth exclusion in order not to bring the noise to the final stacked image. For marine surveys there is an azimuthal sector where we have good reflection mainly corresponding to the survey shooting direction, other parts consists of migration noise only. With azimuthal exclusion during angle stacks creation we have ability to free it of noise. The results of migration with azimuthal preservation and then exclusion shown in figure 5 demonstrates significant improvements of the final seismic image.
Conclusions

Advanced multi-azimuth depth processing improved the resolution of the data. Subtle structural information was easier to map in the new data. This approach helped to understand complex geology and improve reservoir definition.

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References


