NJORD, Multi Azimuth, Multi Vintage Pre-Stack Depth Migration for Improved Image of Structure and Reservoir - A Case History from Offshore Norway

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Summary

A multi azimuth and multi vintage pre-stack depth migration (PreSDM) study conducted in the NJORD field offshore Norway significantly improved the image quality in the area of the reservoir over the existing post- and pre-stack time and depth migrations.

In this case history we present:

- A description of the existing data sets with different azimuths and vintages in the project area and simulation of a full (multi azimuth) seismic data volume combining limited azimuth data volumes to obtain an improved image in the area of reservoir showing better reflector continuity and enhanced fault block definition
- The Velocity Depth Model Building and Imaging strategy
- Amplitude, Frequency and Phase Matching methods applied to match the Repeat and Azimuth surveys to the Base Line survey and merging multi azimuth and multi vintage data
- Comparison of the imaging results from multi azimuth and multi vintage processing data and conclusions

Introduction

Pre-stack depth migration is considered to be the most appropriate method for imaging targets in the presence of complex reservoir structures. The advantage of PreSDM in this type of environment is the ability to position reflection points correctly and to account for the non-hyperbolic nature of reflection move-out. The accuracy of the velocity-depth model of the target overburden is the key to successful pre-stack depth imaging.

The NJORD concession is situated at Haltenbanken, west of Norway in block 6407/7.The structure is characterised by complex faulting and strong compartmentalisation. The entire structure is bounded by a major listric growth fault. The main reservoir TILJE formation, is located within the interval of 2600-3000ms.There are six wells within the area; 6407-1, 6407-2, 6407-3 6407-4, 6407-5 6407-6.

A pre-stack depth Migration study was conducted on three existing surveys (base line, repeat, and azimuth surveys) to build multi-azimuth and multi-vintage summation volumes in order to achieve the correct positioning and improved illumination of the Base Cretaceous marker horizon and structures beneath. It was expected that the multi vintage data may show some genuine changes due to production while the multi azimuth data to give an improved illumination of the target structures including faulting in the area of the main reservoir and resolve the strata within the reservoir fault blocks.

This study describes the PreSDM processing of the surveys NH9701 (base line survey, NW-SE azimuth, shot in 1997), NH0104 (monitor survey, NW-SE azimuth, shot in 2001) and NH0105 (azimuth survey, E-W azimuth, shot in 2001) and the processing to build multi azimuth, multi vintage summation or difference volumes (Figure 1)

Strategy

The dependence of the reflection amplitude on azimuth was observed and explained by Lynn, H.B., KM. Simon Bates, C.R., Van Dok, R., 1996. In order to achieve the best image in the area of the main reservoir and resolve the strata within the very complex reservoir fault blocks it was necessary to incorporate all three surveys to simulate multi-azimuth seismic data volumes by merging the surveys with different azimuth ranges.

The common strategy for all surveys was to build a single interval velocity-depth model based on the original

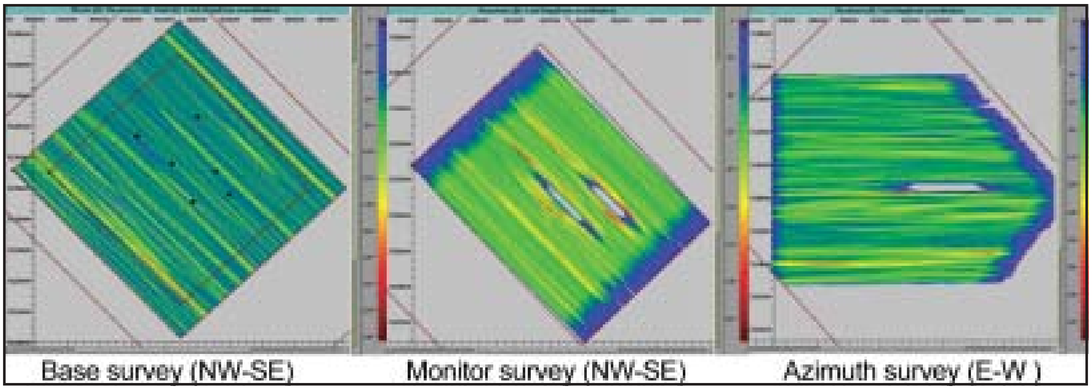

Fig. 1: Fold Maps - Base Line, Monitor and Azimuth Surveys

survey NH9701 (base line survey) for the project area and to perform pre-stack depth migration on each survey (after phase matching the repeat and the azimuth survey to base survey). The quality of the final velocity-depth model was reviewed on target oriented Pre-Stack Depth Migration results of all three volumes; the migrated gathers were compared to ensure that residual move-out correction would be suitable to flatten the migrated gathers of different azimuths to correct minor residual errors.

The frequency, amplitude and phase matching were tested on pre-stack and post-stack data using different methods; the migrated data volumes NH0104 and NH0105 were successfully matched to migrated NH9701 volume (base volume) using the selected matching operators. These matched volumes were then merged to create multi azimuth, multi vintage and multi azimuth +multi vintage volumes resulting in 16 individual Pre-SDM volumes in time and depth domain.

Velocity - depth model building

A 6 layer interval velocity depth model was built to represent the velocity changes present in the 3D data set. Initial interval velocities were based on Dix conversion of RMS velocities and checked against the well velocities. Sonic logs from the available 6 wells were used to derive best vertical compactions gradients for Base Pliocene, Top Paleocene and Base Cretaceous. The time horizon maps from the vintage time migration were image ray migrated to create the initial depth model.

Six iterations of velocity updating were required to create the final velocity-depth model using a combined approach of Horizon and Grid based tomography. Firstly we performed a layer-based modeling of the shallow part where time interpretation is reliable. First four horizons, Base Pliocene, Top Paleocene, Top Cretaceous and Base Cretaceous were updated using a target oriented 3D pre-stack depth migration followed by horizon-based residual move-out analysis and 3D horizon-based tomography (Fagin, 1999), Secondly, beneath the Base Upper Cretaceous, where time interpretation is less reliable, two iteration of grid-based tomography was performed for a structure-independent velocity update which included a 3D pre-stack depth migration followed by vertical residual move-out analysis and 3D grid-based tomography (Figure 2).

Survey matching

Differences in data geometry and pre-stack processing are the most likely reasons for time-variant amplitude differences between the three surveys to be matched. Thus, it was necessary to design scalars to match the amplitudes before performing any frequency and phase matching in a target window for all three surveys. These

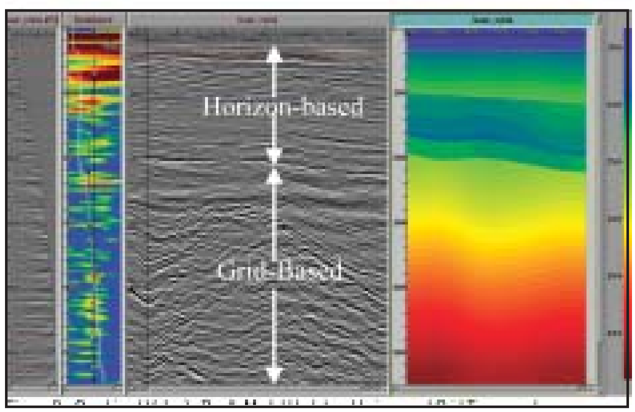

Fig.2 - Combined Velocity Depth Model Update - Horizon and Grid Tomography

scalars were derived from windowed RMS amplitude analysis of the selected traces and applied to NH0104 and NH0105 data in order to match the amplitudes to NH9701 survey

After the amplitude matching, monitor and azimuth surveys were matched to the base-line survey data by applying the respective frequency matching filters derived for the monitor and azimuth survey data.

Finally constant phase shift filters were applied to deal with the residual phase differences between the base-line survey and monitor survey and between base-line survey and azimuth survey respectively without changing the amplitude spectrum of the traces.

Pre-SDM Results and Conclusions

- Pre-stack depth migration of the single volumes yielded greatly improved overall seismic image quality, especially through the strongly compartmentalised and heavily faulted reservoir area compared with previous projects performed in 1997(Time migration/Pre-SDM), 2001 Pre-STM (Figures 3-5).
- A robust velocity model building technique resulted in a reliable final velocity-depth model, the quality of which was reviewed on Pre-Stack Depth Migration results of all three volumes. The residual move-out corrections applied to CRP gathers of different azimuth data sets have perfectly eliminated the minor residual errors and enhanced further the quality of the final images
- The frequency, amplitude and phase matching were tested on pre-stack and post-stack data; the monitor and azimuth surveys were successfully matched to base line survey using the selected matching operators. These volumes were then merged to create multi azimuth, multi vintage and multi azimuth +multi vintage volumes resulting in 16 individual Pre-SDM Volumes in time and depth domain.
- Multi azimuth Pre-SDM (azimuth summation) yielded the best image in the area of reservoir where lateral reflector continuity, the fault block definition and the interpretability of the data are significantly enhanced. (Figs. 3 -4)

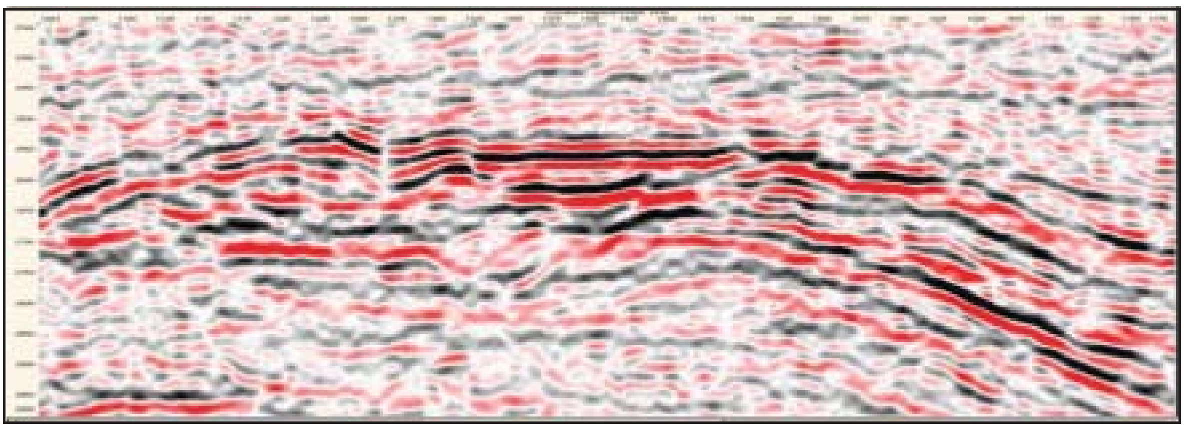

Fig. 3: NH9701 (NW-SE azimuth) - Post-Stack Time Migration

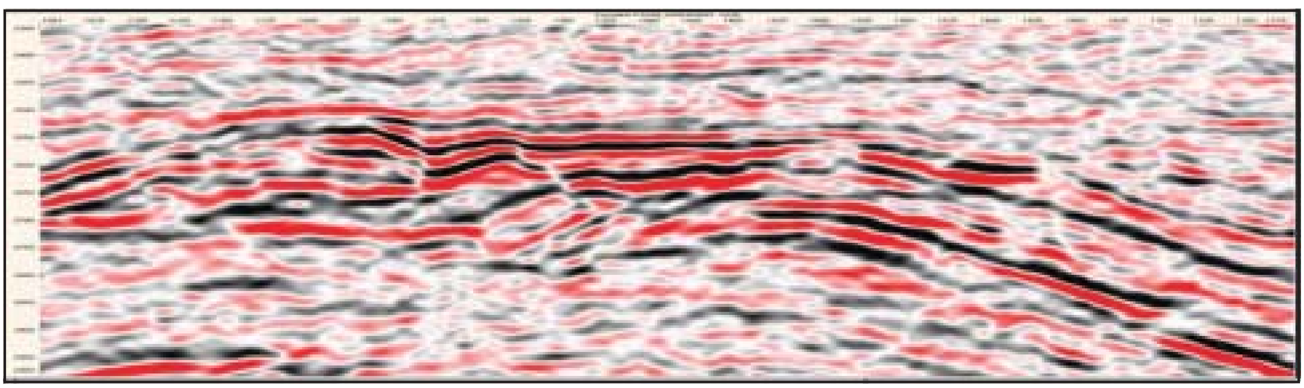

Fig. 4: NH0104 & NH0105 - Multi Azimuth PreSDM Time Converted

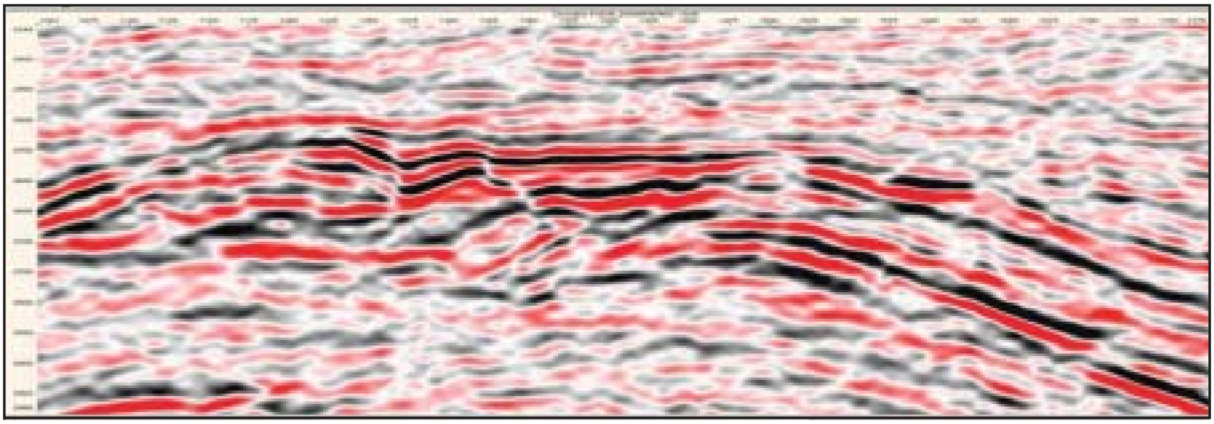

Fig. 5: NH9701 & NH0104 & NH0105 - Multi Azimuth - Multi Vintage PreSDM Time Converted

- Multi azimuth-multi vintage Pre-SDM achieved a similar result like multi azimuth Pre-SDM as there are no large 4D effects. (Figs. 4-5)

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