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Seismic Re-processing and Q-FWI Model Building to Optimise AVO and Resolution in the Shallow Wisting Discovery

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Summary

The Wisting discovery in the south-west Barents Sea is a laboratory for geophysical studies due to its shallow reservoir and complex geological history. This discovery is constantly highlighting aspects of conventional seismic processing that require new approaches and technologies to allow AVO to be preserved and understood. Previous studies at the Wisting discovery have highlighted the importance of imaging in the depth domain with an accurate earth model for AVO preservation, including accounting for absorption within the imaging itself. In addition, AVO studies over the discovery have highlighted shortcomings with conventionally acquired and processed seismic datasets; The lack of near angles has made AVO studies over the discovery challenging and the AVO extracted from the seismic has not matched the modelled AVO at well locations. Following on from the recommendations of the previous AVO studies, OMV and partners initiated a reprocessing project that would focus on combining all previous experience with the Wisting seismic data. This paper describes the FWI model building and time reprocessing performed, and how we tailored the processing and QC to optimize the AVO response in the shallow section.

Introduction

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Following on from the recommendations of the previous studies, OMV and partners initiated a reprocessing project that would focus on combining all previous experience with the Wisting seismic data. This paper describes the FWI model building and time reprocessing performed, and how we tailored the processing and QC to optimize the AVO response in the shallow section.

Seismic data and re-processing

The Wisting discovery in the South West Barents Sea is sampled by multiple vintages of seismic data that were acquired with different resolutions and acquisition geometries. For early exploration and development purposes at Wisting, a legacy 3D seismic dataset was used for interpretation. This conventionally acquired and time-imaged dataset lacks crucial near angle information at the reservoir level and the AVO response generally does not match the modelled response from well data. In addition, a large number of high resolution 2D site survey data covering the field exists. These data have a short near offset, giving a good angle coverage in the shallow, however previous processing of this data focused on rapid processing for hazard identification and was not optimal for interpretation purposes.

The scope of work included reprocessing 600 km2 of 3D and 3000 line km of 2D surface seismic from field tape, and Q migration with a model built using Q-FWI which accounts for Q absorption in the forward modelling. A key focus during processing was to leverage the information contained in all seismic and borehole datasets during testing and QC, and ensure final data consistency to enable simultaneous use of the data during interpretation. An extensive AVO QC was done at key stages of the processing, comparing modelled and extracted amplitudes at the reservoir level. In addition to the existing data, OMV had also recently acquired data with an Ultra High Resolution (UHR) acquisition (Garden et al. 2017), whose migration and post-migration processing were also included in the project scope.

The 3D data were acquired using two different vessels with different source output and at different times. For one vessel, the streamer depths have un-systematic deviations of several meters from the nominal streamer depth. This causes receiver ghost variations which results in both phase, amplitude and timing distortions. We show that a deghosting technique that adapts to the un-systematic ghost delay variations (Rickett et al. 2014) can compensate for these differences and stabilize amplitudes for AVO work (Figure 1). The 2D site survey data are of several vintages, and acquired with very shallow source and receiver depths. Deghosting resulted in a significant boost of the low frequency content, and enhanced noise attenuation sequences were applied both before and after deghosting to ensure the low frequency content was of a sufficient signal to noise ratio for AVO analysis.

The Wisting reservoir lies above the first water bottom multiple. However, the previous integrated study suggested that interbed multiples with a downward reflection at the water bottom and potentially from the shallow and hard Kolmule horizon may impact the AVO response at the reservoir level. A 3D interbed prediction technique was used to suppress these multiples.

To increase the near angle content at the reservoir level we used a matching pursuit technique which can interpolate beyond aliasing (Schonewille et al. 2013). Sparsely populated near offsets were interpolated using x, y, z and offset direction. Co-located 2D site survey data and modelled AVO response at well locations were used to test and validate the interpolation. We could reliably extend several offset bins beyond previous processing and thereby significantly improve the near angle coverage (Figure 2).

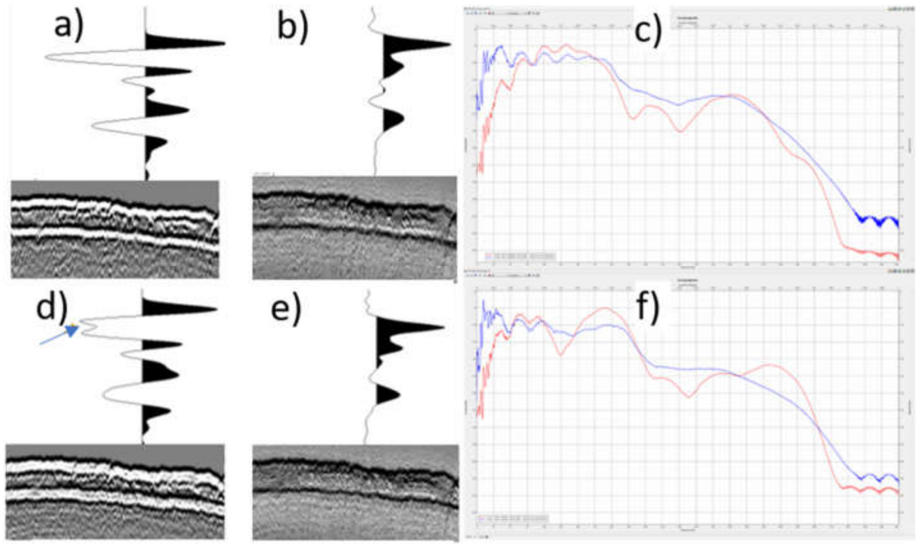

Figure 1 *Analysis on data with similarly-located midpoints; Vessel 1 with nominal streamer depth (top) and vessel 2 with anomalous streamer depths (bottom). Near traces and extracted wavelets pre-deghosting (a, d) and post deghosting (b, e). Amplitude spectra pre deghosting (red) and post deghosting (blue) (c, f). The arrow indicates where the receiver ghost separates due to the anomalous deep streamer, creating a 'double wavelet' effect. This is also seen in the near trace images. After deghosting the datasets are equalized, which is also seen in the amplitude spectra.*

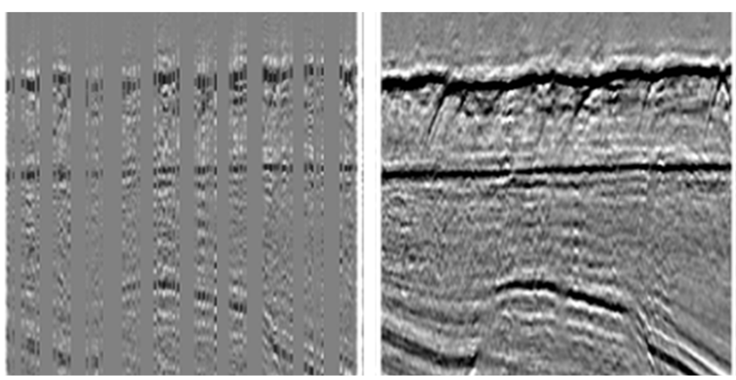

Figure 2 *Pre-migration example of a cross line of a sparsely populated near offset being interpolated through a matching pursuit Fourier interpolation technique using x, y, z, and offset direction. The patches of data and holes are both around 200m wide. Where co-located site survey data existed, these were used to check the results and refine the parameterization. At well locations AVO QC of seismic after interpolation was compared against modelled AVO response to validate the interpolation.*

Depth model building

Depth model building had not been previously performed at Wisting, so the starting point for this study was a full analysis of the available data at all existing well locations. The detailed anisotropy functions derived at the focus well from the previous study were validated at the other well locations and found to be appropriate within the same geologic units. Additional processing of existing wireline sonic borehole measurements was included in the project, resulting in Thomsen's Gamma property logs which were utilized to provide further anisotropy model validation. The existing zero-offset vertical seismic profiles (ZO-VSP) were also re-processed to extract Q models at an additional two wells. Smoothed versions of the existing check-shot velocities formed the foundation for the initial model velocity field. All velocity, anisotropy and Q properties derived or calibrated at the well locations were then propagated in a structurally consistent manner to form the initial, smooth model for FWI model building. The initial model was then converted to TTI using structural dip information and assuming the slowest axis perpendicular to sediment layering.

Due to the shallow setting of the Wisting reservoir (250 m below the sea-bed at its shallowest), the early arrival energy utilized by FWI in this workflow penetrates the full depth range of interest in this area. We began the FWI model building with the smooth, bore-hole derived initial model. We can overcome the conventional cycle skipping challenges to FWI that this might pose by utilizing Adjustive FWI (Jiao et al. 2015) for the early velocity updates. This approach can be particularly valuable in this area, where the missing near reflection angles makes reflection tomography challenging. We included the structurally varying layered Q model in the model building by employing Q-FWI, in which the wavefield propagation and property update accounted for inelastic absorption using the borehole derived Q property field. Considering the previously highlighted importance of anisotropy for optimal AVO, we performed multi-parameter FWI, updating the epsilon model to refine the initial borehole derived model. The epsilon update took place at the first frequency band, after the updates for velocity.

This workflow could rapidly detect velocity anomalies associated with the reservoir and the faulted geological structure of the field. These features were enhanced in the FWI velocity model as we progressed to the second frequency band velocity updates. The resulting model is highly conformant with structure and with expected velocity trends (Figure 3).

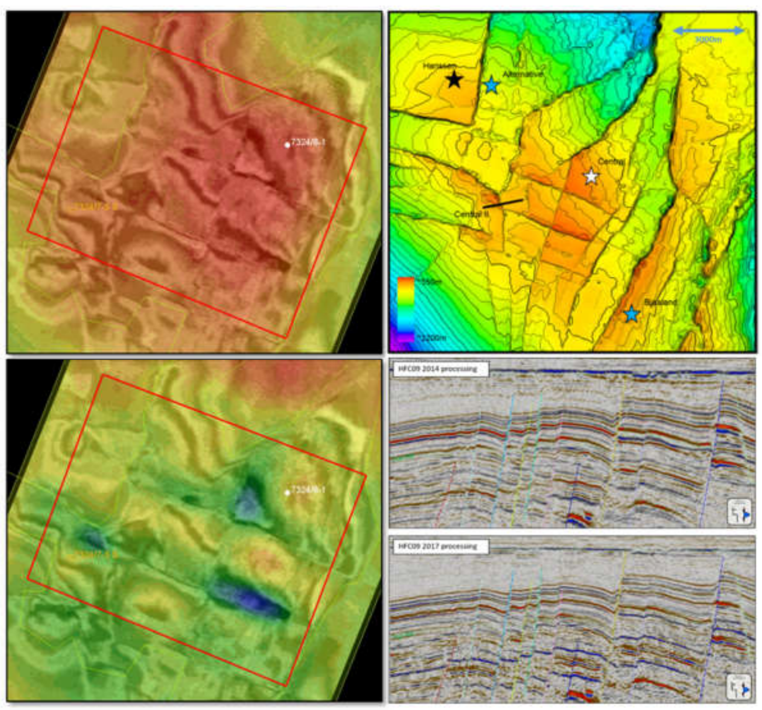

Figure 3 *Depth slice at reservoir level showing the FWI initial model (upper left panel), the final FWI velocity model (lower left panel), an illustration of the study area: The Wisting discovery in the Barents Sea (upper right panel). The lower right panel shows the image improvements after the reprocessing and model building workflow application. Upper seismic section shows the legacy PSTM image and the lower section shows the reprocessed data.*

Results

The FWI model is conformant with geology with accurate depiction of the fault blocks at the reservoir level, and the final seismic products have a higher resolution and more reliable amplitudes than those obtained from previous pro-cessing (Figure 3). The joint processing of the 3D and 2D seismic data has provided a suite of datasets that can be used for simultaneous interpretation and amplitude work, where advantages of each dataset can be utilized. Perhaps the most striking change is in the 3D dataset, where we observe a marked improvement in resolution and amplitude reliability compared to previous processed products. For the first time, we also observe a good match between the seismic and well modelled AVO, including the additional near angles which are crucial for AVO studies in shallow reservoirs.

Conclusions

Reprocessing the legacy seismic data over Wisting using the latest processing technology and guided by the recommendations from the integrated project has improved the match between the AVO response in the data and the AVO from well logs, and increased the resolution in the seismic image, and we point to several steps contributing to these improvements. Integrating knowledge from several disciplines to ensure that our model and understanding explains all available borehole and seismic datasets was key to the success of this project.

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