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Broadband Imaging in the Barents Sea - Impact of 3D Survey Design and Data Processing on Jurassic Lead Quality

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Summary

The combination of acquisition design of a deep tow long offset 3D survey, broadband imaging and an advanced data processing sequence had a significant impact on final data quality for major leads.

High resolution broadband imaging examples from the Norwegian Barents Sea are compared with underlying 2D conventional data as a bench mark for result assessment.

Improvements are evaluated by both image quality and interpretation aspects, highlighting good examples at Jurassic level of highly defined faults and structural plays; specifically minor faulting of secondary leads at Quaternary and Tertiary level.

Introduction

The Ringvassøy (R15) 3D survey was acquired in the Western Hammerfest Basin in the Norwegian Barents Sea during the summer season of 2015 on an NNE-SSW preplot using a continuous shooting 12 x 6750 m streamer 3D vessel, with 75 m streamer separation. Streamers were towed at 18 m depth and the dual sources at 7 m, consistent with the latest trend of acquisition design that supports broadband imaging (Figure 1). The motivation behind the project was to cover both interpreted leads near the shore and close to existing fields and the infrastructure in the Hammerfest Basin.

The area covered is located between the Finnmark Platform in the South and the Southern part of Loppa High in the North, on the Western flank of the Hammerfest basin dipping down to the deep salt intruded Tromsø Basin in the West. The main structural trends are East-West Mesozoic extensional faulting that ends in the general North South trending Ringvassøy Fault Complex, centrally in the survey area. In the West, there are subtle but important NE-SSW trending faults exist in the Cretaceous package with occasional syn-sedimentary reactivation in the Tertiary (Gabrielsen et al., 1990).

The leads identified before the acquisition were; 1) Mid-Lower Jurassic proven reservoirs sourced by Upper Jurassic and/or Mid Triassic source rocks, 2) several lower Cretaceous sand prone units basin ward towards the West and 3) Palaeocene and Eocene seismic anomalies above.

In general, this area has seismic challenges with regards to a hard and rugged seafloor, and also shallow gas giving a poor signal-to-noise ratio. The acquired 3D data gave interpreters the needed confidence in their leads in this highly challenging and structurally complex area.

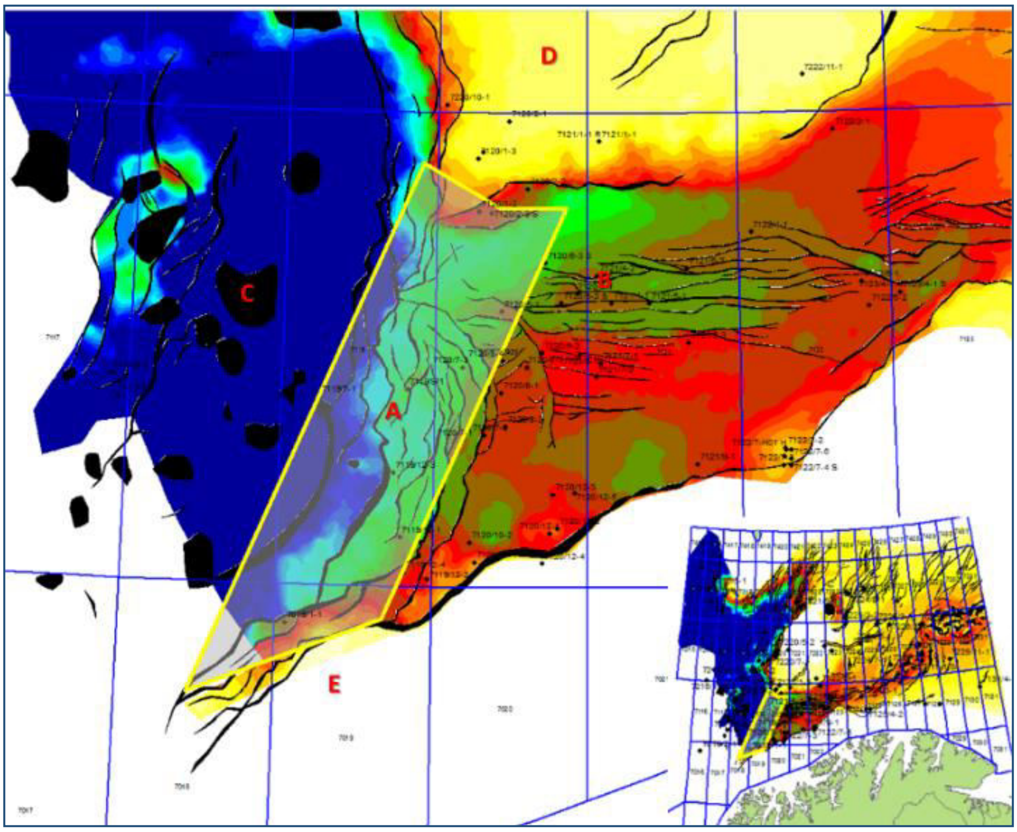

__Figure 1__ The map shows the location of the Ringvassøy 3D project (A) outlined in yellow overlaid on a regional Base Cretaceous structural interpretation. This interpretation over simplifies the structural complexity of this area. In East, close to the survey area is the Snøhvit producing field (B). In West is the Troms Basin intruded by salt diapers (C). The Loppa High (D) and Finnmark platform (E) are to North and South boundary of the survey area.

2D versus 3D Broadband Processing

TGS's most recent broadband imaging technology is implemented in the R15 processing. The quality of the final product (Figure 2) demonstrates a clear uplift when compared to the vintage 2D data in terms of fault definition, sealing potential, inversion features and minor faults, which is helping the assurance of the final structural interpretation results and key seismic attributes.

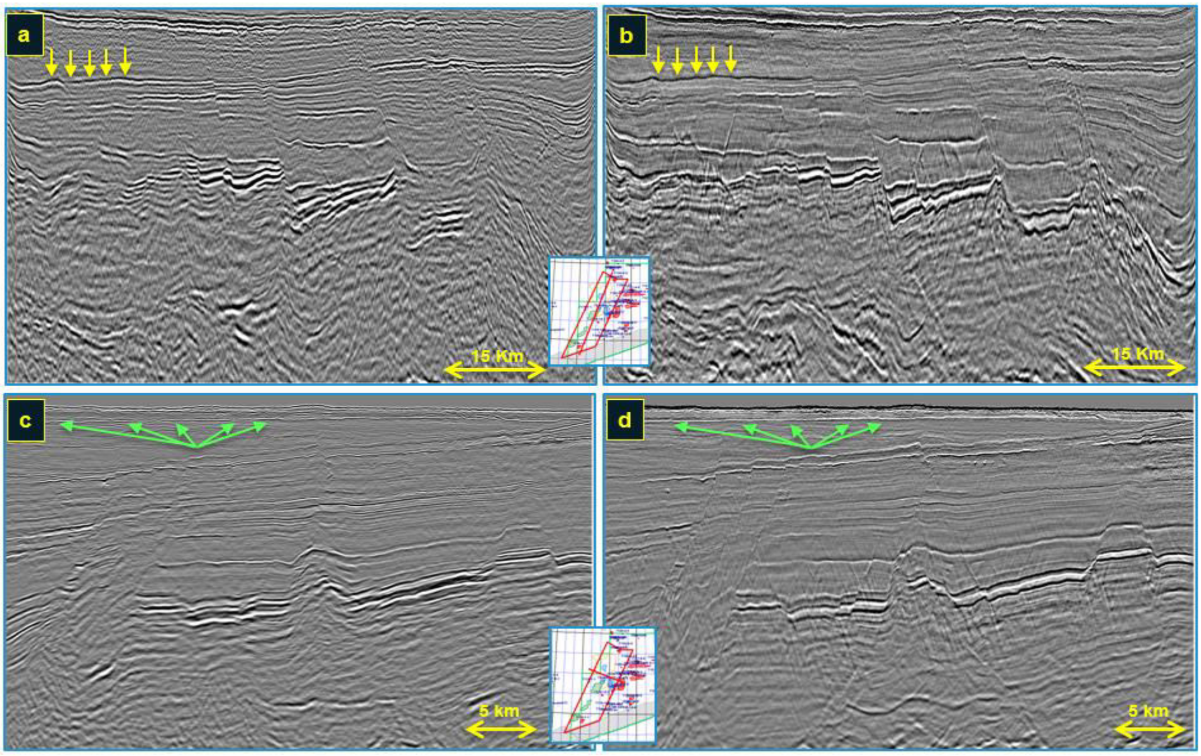

Figure 2 *Prestack Kirchhoff Time Migration stack in dip direction, a) 2D data with low frequency boost method, b) extracted line from 3D Broadband dataset, C) Strike line from 2D data and d) extracted from 3D Broadband dataset. Highlighted in yellow arrow the uplift in AWD Deghost result of deep tow cable from 3D data compared to low frequency boost method used in the 2D dataset. Arrows in green pointing some missed primaries above shallow leads in 2D data compared to nicely defined reflectors from 3D volume.*

Acquisition	2D Data	3D Ringvassøy
Source depth	7 m	7 m
Cable depth	9 m	18 m
Cable length	8103 m	6480 m

Table 1 *Key acquisition parameter differences between 2D vintage data and 3D R15.*

Optimal deterministic Deghost results require accurate receiver depth values, due to weather conditions in the Barents Sea, this has been addressed by comparing the recorded receiver depths with the calculated ones, to avoid ringing , Anthony et al., (2015), receiver depths were updated within a range of +/-1m from recorded depths using partial de-ghost method beforehand.

Adaptive Windowed Deghosting (AWD) algorithm is used to compensate for the mild 3D effect. This algorithm divides the data transformed into the 2D tau-p domain into a number of overlapping windows. In each window it finds optimized receiver/source depths and uses 2D slowness values to design and apply the deghosting operation as introduced by Masoomzadeh et al., (2015) and Zhang et al., (2016).

3D Surface Multiple Attenuation

Another challenge was the presence of strong pegleg and diffracted multiples, generated due to a hard reflector at Quaternary level (Figure 3). 3D Shallow Water Multiple Elimination (SWME) for both source and receiver sides based on multiple ray paths are modelled in conjunction with 3D Surface Related Multiple Elimination (SRME) using the same deghosted data as an input. Then the three models were subtracted by simultaneous least squares adaptive subtraction algorithm, which provided a better multiple attenuation result, compared to a cascaded approach. (Verschuur et al., 1992).

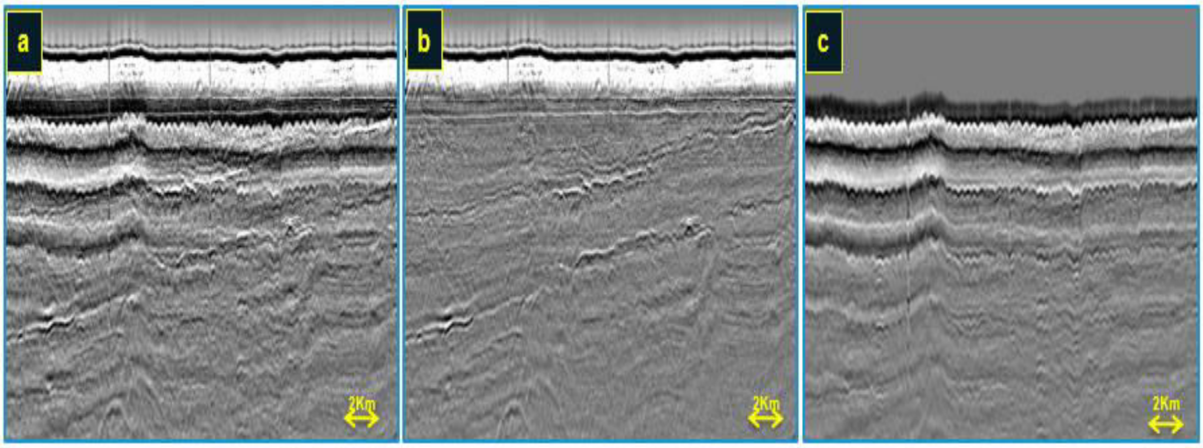

Figure 3 *A crossline stack, a) before 3D SWD/SRME Simultaneous subtraction, b) after and c) difference.*

Diffracted Multiple Attenuation (DMA)

Down to the hard seabed, diffracted multiples have relatively strong amplitude compared to the underlying primaries. Conventional 3D Surface Related Multiple Elimination (SRME) approach struggles with this type of multiples as it is NAZ data and very shallow water depths. As a result, after migration we can see typical 'smiles' which might cause difficulties in both interpretation and attribute analysis stages. To address this issue, a diffracted multiple attenuation technique (DMA) was used.

Figure 4 shows a migrated stack section with (a) and without DMA (b). Although SWME/SRME is very successful in attenuating surface-related multiples, there is still some diffracted multiple energy left in the data, which was attenuated by the following DMA, resulting in improved imaging.

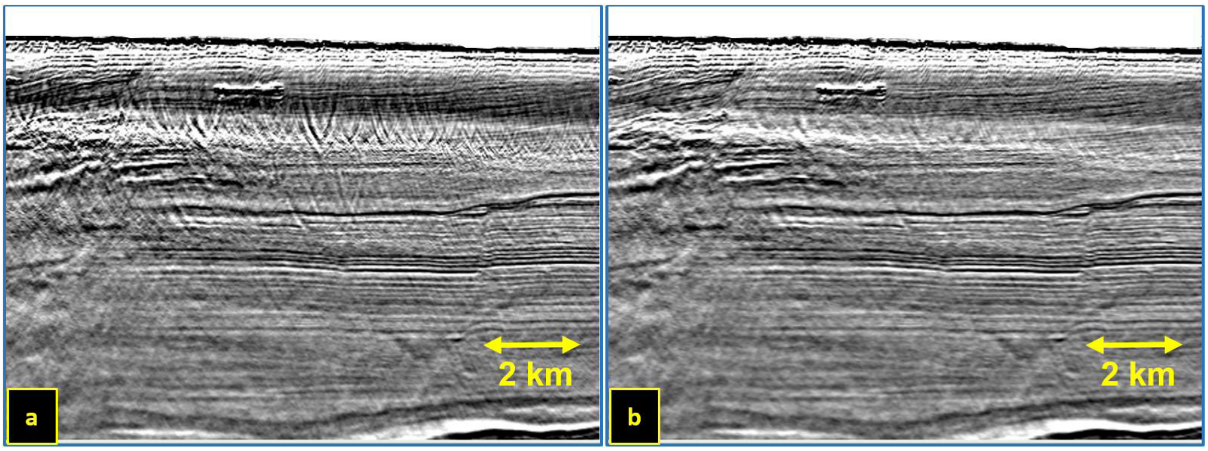

Figure 4 *Migrated stacked section (a) without DMA applied (b) with DMA applied.*

Conclusion

The Western part of Barents Sea is a challenging area due to a hard and complex seabed and also presence of shallow gas, which cause strong surface related and diffracted multiples and poor signal-to-noise ratio. We have shown that the latest acquisition technique followed by advanced data processing such as Adaptive Window Deghosting, 3D SWME/SRME and DMA allowed us to derive broadband high quality 3D data, which significantly improved imaging of potential leads on Tertiary, Cretaceous and Jurassic levels, compared with legacy 2D seismic data.

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