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Capturing the Value of High Resolution Source-Over-Streamer Acquisition at Barent Sea

N. Salaun[1]*, G. Henin[1], A. Wright[1], S. Pellerin[1], J. Deprey[1], B. Deschizeaux[1], V. Souvannavong[1], P. Dhelie[2], V. Danielsen[2]

[1] CGG; [2] Lundin

Summary

New source over the streamer acquisition has been designed to record a wide range of incidence angles, excellent near offset coverage and low levels of ambient noise due to the deep streamer tow. Along with this optimal acquisition, a specific processing sequence needs to be applied to ensure a high resolution image from top to bottom of the seismic section. This is presented on a large scale Barents Sea case study.
An advanced demultiple sequence, benefiting from the full recorded water bottom, was implemented to reveal thin details hidden by complex multiple content at target levels. This and the favorable signal to noise ratio gives us access to the enhanced AVO attributes compared to the conventional acquisition. This new seismic information was accurately located in the subsurface by having both the correct surface device position and an improved velocity field. The first one has been obtained by taking advantage of the direct arrival recorded while the second one relies on an accurate Residual Move-Out (RMO) analysis.

Introduction

The advent of marine broadband data has led to significantly improved high-frequency content in seismic data. However, assuming that the energy from the ghost wave-field has been properly eliminated, the resolution potential of a dataset is directly linked to its acquisition design, as the natural bin size depends on the source and receiver spacing. In the Barents Sea context, the large minimum offset of conventional off-end towed streamer acquisition, means most of the recorded traces are beyond the critical angle at the target depth (Lie et al., 2017). High-resolution acquisition designed for site surveys has been used as an effective solution to increase the number of recorded traces contributing to the final image (Garden et al., 2017). These surveys can give an improved image but are almost 2D in design and are of limited use in velocity model update because of their short maximum offset. Having very shallow source and receiver depths, these site-survey acquisitions may suffer from ambient and bubble noise, and lack low frequency content. In order to overcome these drawbacks while keeping high-resolution, a source-over-streamer design was developed (Vinje et al., 2017). The first full-scale production survey using this design was shot in the Barents Sea during the summer of 2017, and the processing and imaging of the seismic data was completed in the autumn of 2018 (Dhelie et al., 2018). This geometry leads to a wide range of incidence angles, excellent near offset coverage (see Figure 1), and low levels of ambient noise due to the deep streamer tow, but also some unique challenges. This paper discusses some of the various challenges and benefits of processing source-over-streamer data.

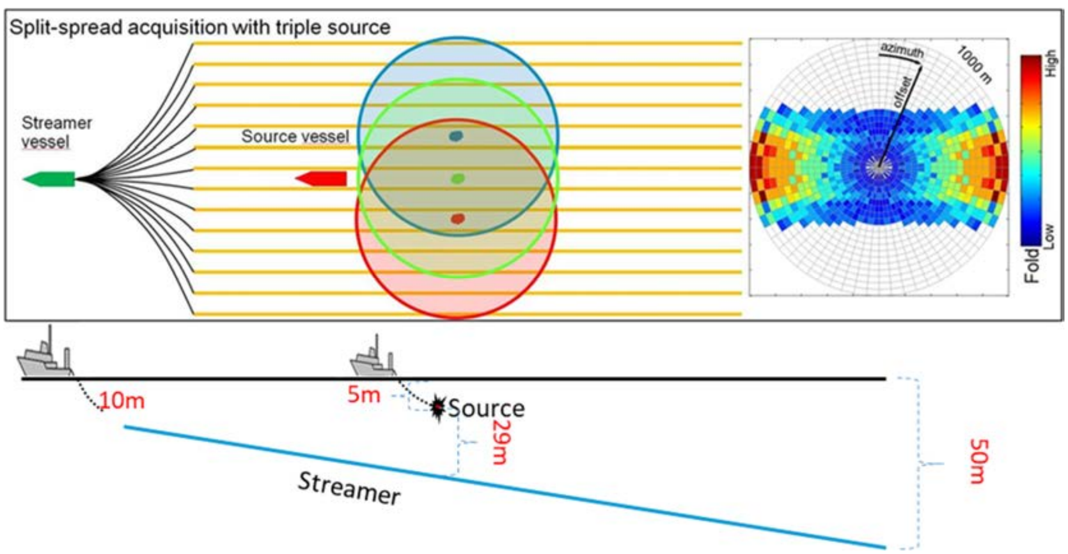

Figure 1 *Split spread source-over-streamer design. Emitted wave front is now well recorded while with a traditional towed-streamer design less than half of the wave-front is recorded. This opens up new ways to process and image seismic reflection datasets.*

Challenges and benefits

Reliable positioning information is key for high-resolution imaging. For the source side, the GPS located at the front and rear of the sources will provide fairly accurate positioning. On the receiver side, the accuracy is limited by the navigation, which mainly relies on acoustic systems for the center of the spread; cable stretching and drifting will further increase navigation uncertainties. Having the source over the spread gives access to the full direct arrival cone, which makes it possible to invert for the receiver locations. The direct arrival model generated by the inversion and driven by near-field hydrophone (NFH) information contains the direct arrival bubble and can then be subtracted from data thus simplifying the de-signature process, where strong interference between direct-arrival bubbles and reflections are observed. Separating the bubble trend from multiple energy is one of the keys to obtaining an accurate multiple model for the low frequencies. Thanks to the cable depth, the ambient noise level is low and swell noise is only visible near the receiver vessel, where the cable is shallowest.

A big advantage of recording the very near and zero offsets will be for multiple modeling. SRME relies on the assumption that all the multiple generators have been recorded. In most cases this assumption is not true and data extrapolation has to be done to compensate. Also, the SRMM method (Pica et al., 2008), which is based on wave-field extrapolation from known reflectivity, will be adversely affected by the incomplete primary wave-field used to create the reflectivity volume. The Barents Sea has a very strong and complex water bottom, leading to heavily diffracted multiples. In some places, there are strong reflectors located just below the seabed which are not taken into account using classical methods based on modelling the Green's functions of the Water-Layer Primary Reflection to predict the multiples (Wang et al., 2011).

For the processing of this survey, multiple models generated by SRME and SRMM methods are used to generate a primary model via an iterative process starting with harsh subtraction of multiple models plus strong preconditioning and polynomial fitting (Sablon et al., 2016). Then, an adaptive subtraction using both multiple and primary models is carried out, in order to further improve the primary model while ensuring that multiples are not interpreted as primaries. Subtraction is performed in the complex wavelet domain, using an adaptive window with operator length varying as a function of frequencies and dips. For the final subtraction a dedicated diffracted multiple model (Pica et al., 2018) is included as well as a multi-sail line deconvolution, as shown in Figure 2. QCing the residual, which should only contain white noise, is an efficient way to control the tradeoff between multiple suppression and primary leakage.

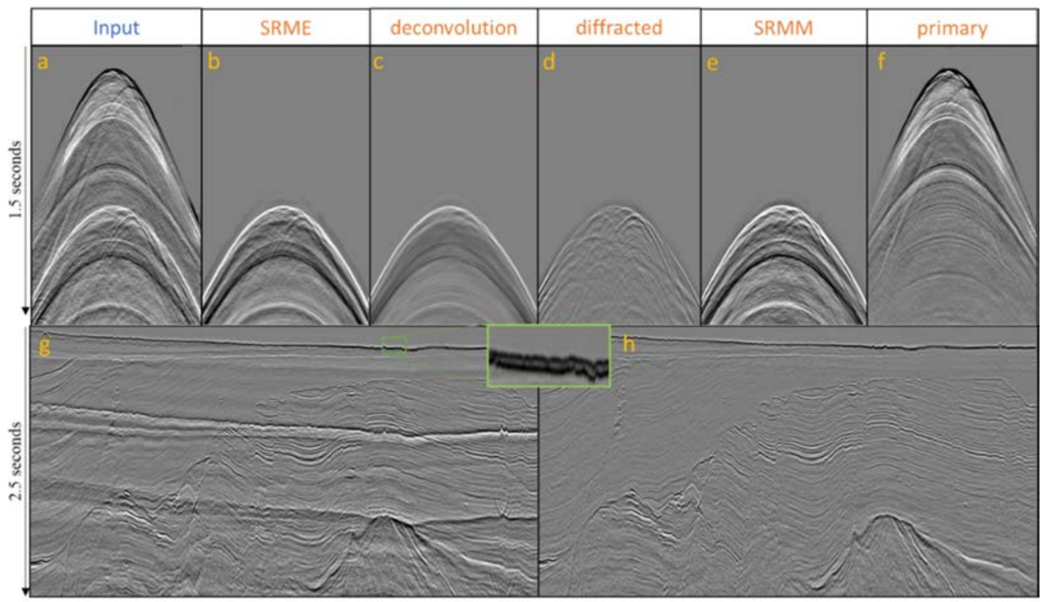

Figure 2 *Top panels show shot-point input to demultiple (a) plus the various models used for multiple attenuation (b-c-d-e-f). Strong diffractions can be observed on both primary and multiple. Panels g and h show PSTM before and after demultiple. Zoom in green square shows doubled water bottom, which is true geology.*

Results and discussion

In this Barents Sea case study, where targets are composed of very thin layers hidden below a strong multiple curtain, the new source-over-cable acquisition design has been crucial in insuring both the broad spectrum needed and efficient multiple attenuation. On the seismic image, it is now possible to observe thin details (Figure 3) thanks to the high frequency content. The clean low frequency content and fine sampling of the subsurface also reveals faulting and complex structures on timeslices. In shallow water, we often rely on very little information to build velocity models in the first hundred meters below the surface. With the source over the streamer, we have access to the near- and zero-offsets at any location; thus accurate Residual Move-Out (RMO) analysis. Having the full range of incidence angles allows us to better determine the horizontal and vertical velocities, giving a proper estimation of the anisotropy at any depth.

This results in both a high-resolution seismic image and an accurate velocity field, which are critical for shallow hazard studies and geological understanding. Having a reliable velocity field and full bandwidth data leads to a high quality acoustic inversion result (Figure 4) when compared to vintage.

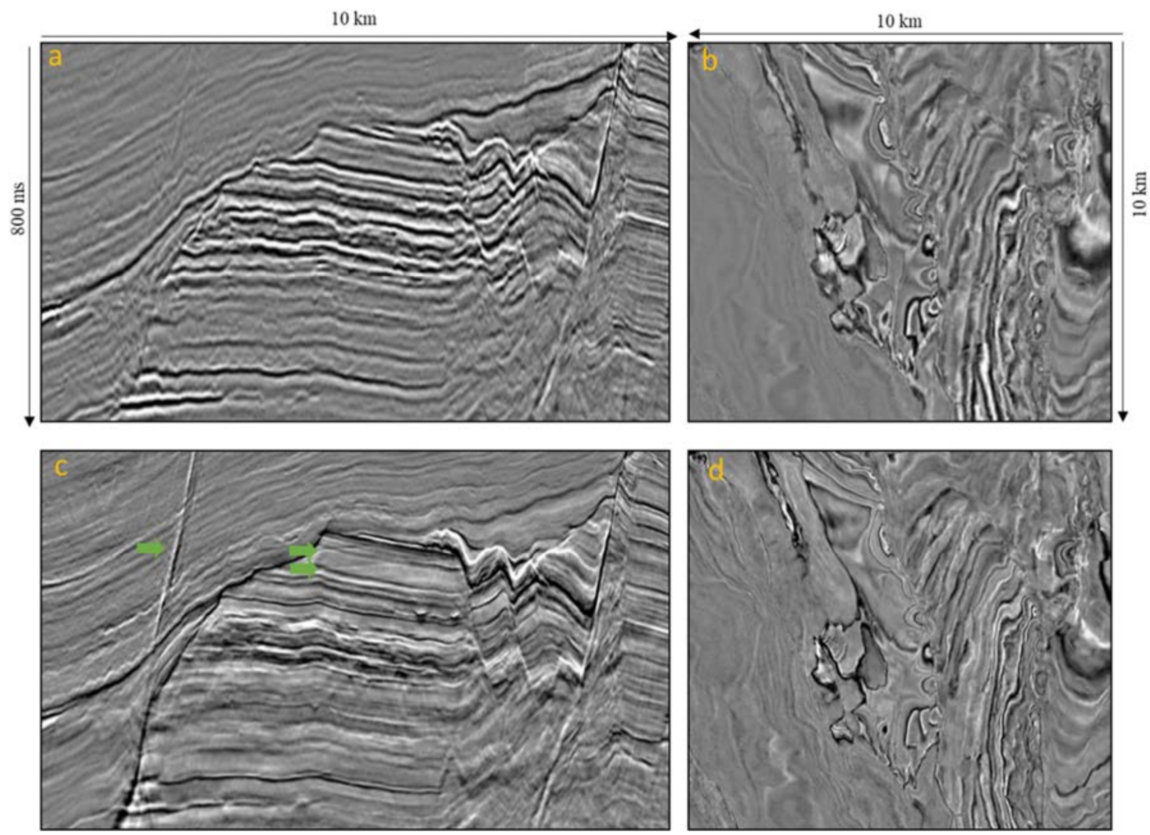

Figure 3 *Pre-stack Time Migration section over Hufsa field showing for a and b inline and time slice of vintage cube (flat streamer) versus on c, d source over the streamer result. Green arrows show fault and thin geological details which could not be imaged with conventional acquisition.*

Conclusions

This new source-over-streamer acquisition allows for a final seismic volume that has potential for great seismic imaging. Despite the extra information recorded with this design, specific processing is still required to solve the new challenges such as strong direct arrival energy, positioning uncertainties and complex multiple content. When these problems are addressed, these data reveal the hoped-for uplift by revealing a high-resolution image from top to bottom and giving us access to accurate AVO attributes and velocity information.

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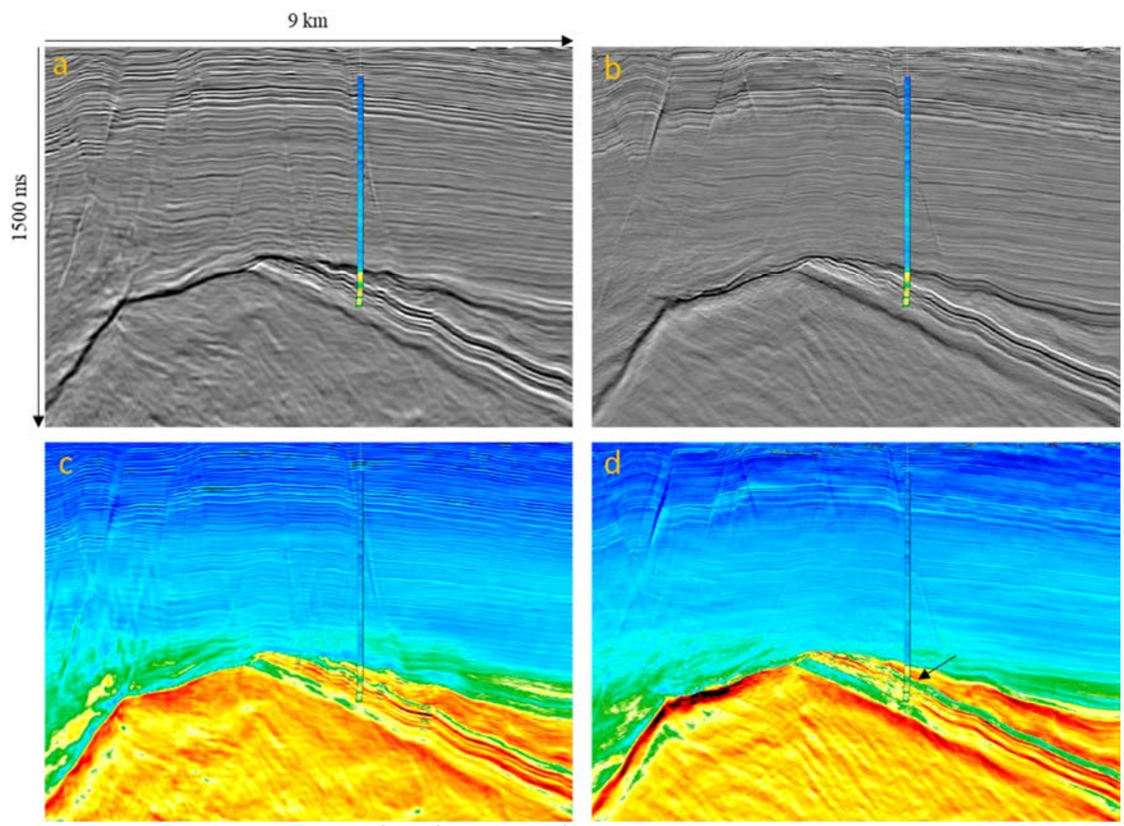

Figure 4 *PSTM section over Alta field for vintage flat streamer deghosted data set (a) and source over the streamer dataset (b) and their related acoustic inversion (c and d). Panel d shows nice low frequency layer (black arrow) appearing on new dataset and well matching with the well*