

HIGH RESOLUTION MEETS HIGH EFFICIENCY WITH AN ULTRA-WIDE-TOW PENTA SOURCE SOLUTION IN THE BARENTS SEA

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Summary

This paper presents a case study of a 3D marine streamer seismic acquisition using an ultra-wide-tow penta source set-up to improve trace density and near offset coverage without compromising acquisition efficiency. The survey was shot in 2020 in the Barents Sea where the water depth is approximately between 300 m and 400 m. The total source separation in crossline direction was 315 m. The acquisition and processing grid was 6.25 m x 6.25 m and the processing was carried out at 2 ms temporal sampling. The high number of sources introduces additional blended signals which were simultaneously separated using an iterative deblending method. We then demonstrate the effectiveness of a standard demultiple workflow which benefited from the rich near offset distribution and the early out migrated images show high resolution quality in the very near surface.

High resolution meets high efficiency with an ultra-wide-tow penta source solution in the Barents Sea

Introduction

We present a case study of an ultra-wide-tow penta source acquisition that took place in the western area of the Norwegian Barents Sea. The survey is located near recent discoveries in the Loppa High where the water depths range from 300 m to 400 m and reservoir targets can be found as shallow as 600-700 m depth. The penta source survey was acquired at the end of 2020, adjacent to a triple source survey to provide a contiguous dataset and allowed for a direct comparison between the two source templates in an area where near offset sampling and resolution is critical for prospectivity analysis. We demonstrate the benefits of the ultra-wide-tow penta source set-up for general sampling, demultiple and velocity estimation resulting in much improved shallow overburden images.

Dense and efficient acquisition

Towing more than two sources has become standard in marine seismic operations as it provides benefits in survey efficiency and/or data quality via increased data sampling in each vessel pass. In addition, the industry has seen significant progresses in towing sources with wider separations, which further enhances those benefits, i.e. opportunities for larger sail line separation and better near offset sampling (Widmaier et al. 2020). Following a wide-tow triple source acquisition in the summer of 2020, 14 additional sail lines were acquired after reconfiguring to a wide-tow penta source (Figure 1). The streamer spread and the nominal sail line separation were kept the same. The wide-tow penta source improved both the spatial sampling and the near offset coverage without compromising acquisition efficiency.

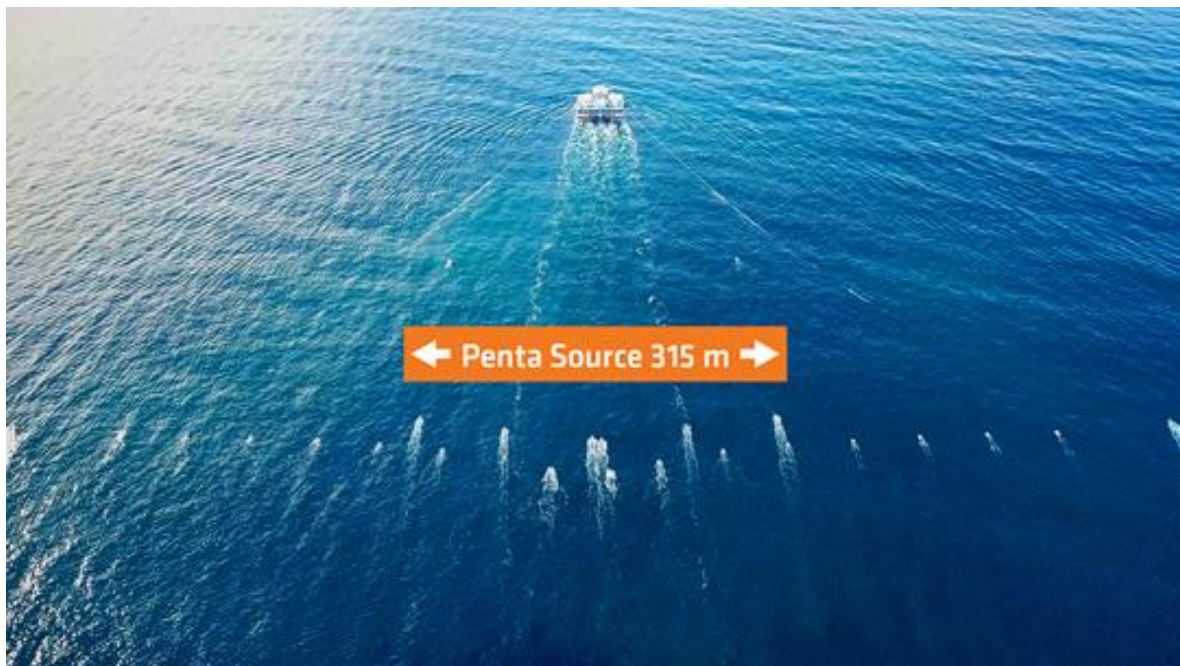


Figure 1. Drone picture of the wide-tow penta source layout towed by Ramform Tethys in the Barents Sea in 2020. For practical reasons, the center sources consisted of two source strings.

The streamer spread consisted of 16 cables of 7 km length towed with a 56.25 m nominal separation including three 10 km long streamers for velocity model building (Naumann et al. 2019). In the wide-tow triple source case, the nominal source separation was 93.75 m (total source separation of 187.5 m). The nominal Common Midpoint gather (CMP) acquisition grid was 6.25 m x 9.375 m. In the wide-tow penta source case, the separation between adjacent sources was 78.75 m resulting in a total source spread width of 315 m. The corresponding CMP grid was 6.25 m x 5.625 m. The inline offset between the sources and the streamer front-end was as little as 65 m. The acquisition set up led to enhanced coverage

of data with offset smaller than 100 m, as illustrated in Figure 2. The near offset coverage map also demonstrates that the sail line imprint is no longer visible in the nearest offset class.

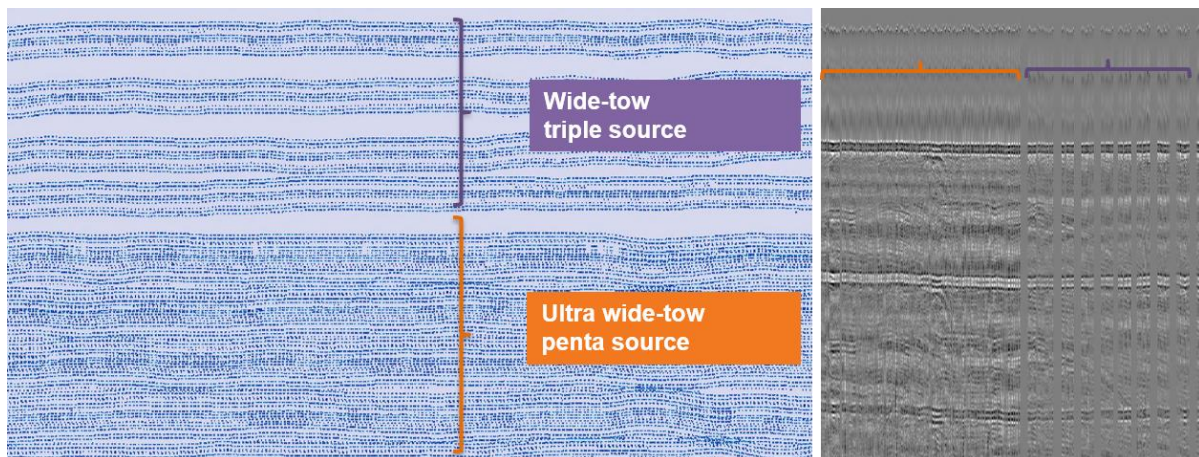


Figure 2. Near offsets (0-100 m, 0-1700 ms TWT) coverage map and cross-section of raw data. Differences in bubble responses can still be seen at this stage (raw traces prior to designature).

In order to retain a comparable CMP fold, the pop interval was reduced from 12.5 m (triple source) to 7.5 m (penta source) which translated into an average firing interval of 3 sec (Figure 3 and 4). Dithers of up to 1 sec were introduced to facilitate deblending. The deblending technique that was applied to the data is a multi-domain iterative approach which simultaneously estimates the signals of all previous and subsequent shots present in the desired output record length. Advanced deblending is required in such shallow water settings as various waveforms interfere (Duan et al. 2019).

Another challenge came with the deployment of the five individual sources as each source consisted of one string delivering a volume of 1225 cu.in., as opposed to two strings delivering 3260 cu.in. for the triple source set up. Consequently, the raw signal in the penta source data is weaker at the single trace level (Figure 2). However, the reduction in source volume is counteracted by the increased shot density (factor 5/3). In other words, high trace density ensures high quality images with good signal-to-noise ratios for imaging the deeper structures, in particular in combination with deep tow multisensor streamers. The tow depth was 25 to 28 m. Ultimately, a better lateral distribution of sources not only mitigates the typical acquisition footprint at the imaging stage but can also provide more diverse illumination of the subsurface.

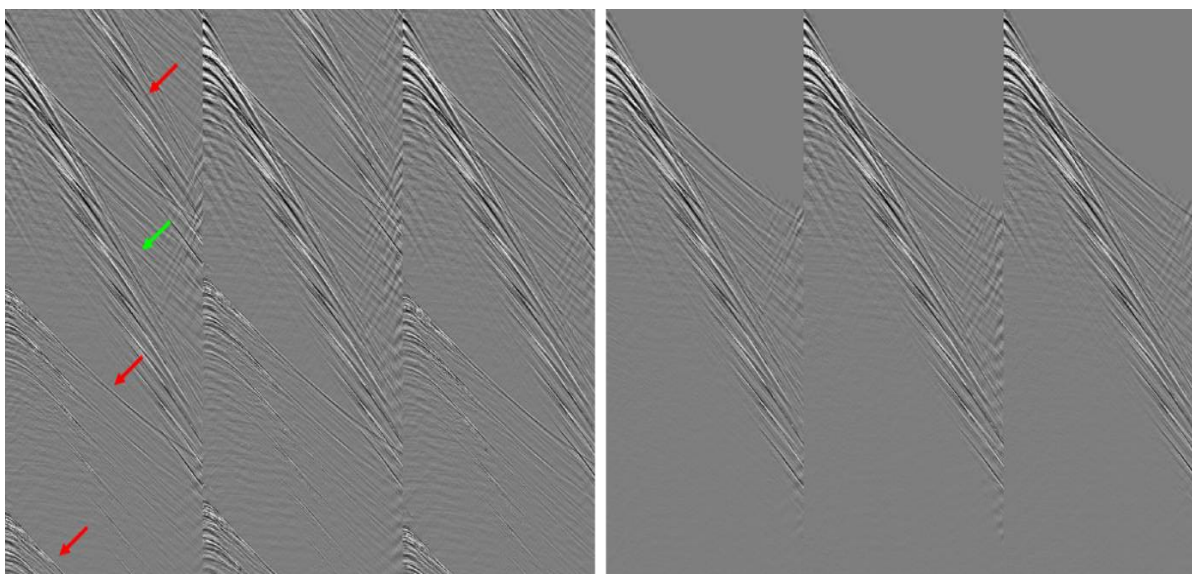


Figure 3. Shots from wide-two penta source survey before (left) and after (right) inversion-based deblending. Up to three interfering shots (in addition to the main signal) indicated by red arrows are visible on the 7 sec long gathers. The average pop interval was ca 3 sec.

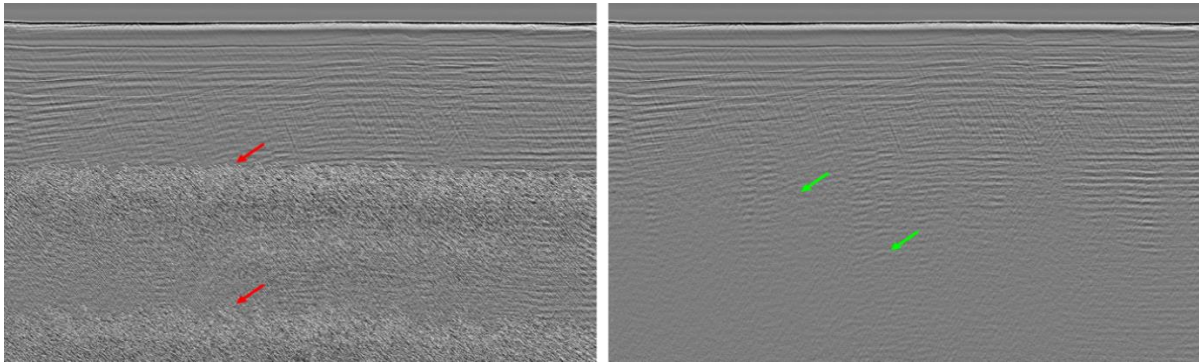


Figure 4. 2D QC stacks before (left) and after (right) inversion-based deblending of 7 sec record length. The interfering shot energy (red arrows) is effectively suppressed by the deblending and primary and multiple energy uncovered (green arrows).

Benefits for imaging and interpretation

In the shallow subsurface, near offset imaging as well as demultiple are critical for robust AVO analysis. However, it is worth remembering that resolving the shallow overburden with high accuracy may have benefits for imaging of important geological structures at greater depths.

A simplified pre-processing sequence and a preliminary velocity model based on reflection tomography allowed for a fast-track product in early 2021. The data conditioning prior to demultiple consisted of denoise, wavefield separation, source deghosting and designature. Since all processing steps are 3D, and take into account the real positions of the sources with respect to the streamer spread, these were applied in an equivalent manner to the wide-tow penta source part as they were for the wide-tow triple source data.

The Barents Sea has historically been very challenging for multiple removal due to the very high impedance contrast at the seafloor and its roughness, in addition to often complex and strong reflectivity just beneath it. With a small critical angle at the seabed, recording near angle information becomes even more important for successful multiple prediction and attenuation. The simplified flow for the fast-track consisted of a simultaneous subtraction of models generated by one pass convolutional 3D SRME and one pass 3D wavefield extrapolation SRME, though the latter was performed using bathymetry information only. No additional demultiple processes, including velocity based filters were applied to produce the images in Figures 5 and 6. Although residual multiples, in particular diffraction like waveforms, are still visible in the demultiple output data and will be addressed in the full integrity processing, the main surface related multiple reflections are practically eliminated. In this case, the more accurate prediction of multiples is attributed to the greater near offset sampling and the better distribution of source points, which are both interlinked.

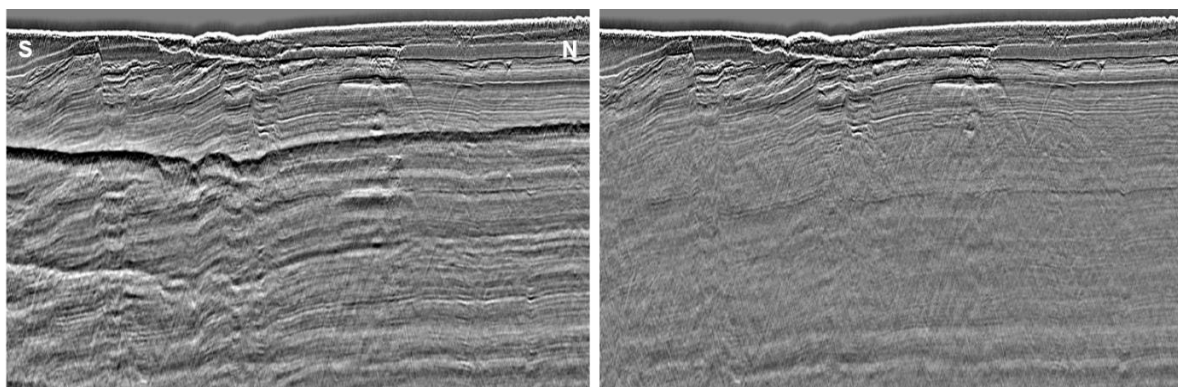


Figure 5. Unmigrated 3D QC stack before (left) and after (right) the fast-track demultiple step, from 0.4 to 2 sec TWT. Despite the complexity of the shallow near surface and the simplified sequence for the fast-track delivery, free surface multiples are largely attenuated even without additional demultiple effort.

The increase in data sampling enables more innovative imaging strategies to address the interpretation requirements. As previously mentioned, the nominal grid allows for migration on a 6.25 m x 6.25 m grid, and an offset increment of 75 m with minimal regularization efforts. These were used to produce the early out images. However, dense spatial sampling may not be required for deeper imaging, and instead the offset and/or azimuth dimensions may benefit from the dense data sampling. Figure 6 illustrates the consistency in imaging quality in both inline and crossline directions.

Whilst further studies will be conducted to quantify the impact of the dense sampling on various processes and the final image, the full integrity processing is currently following the full area work including the triple source part, and is expected to complete before the summer of 2021. Direct comparisons to the adjacent triple source data will be available for the full record length seismic data and the velocity models. Although the latter will be updated in a combined effort, a more detailed analysis will focus on the signal-to-noise ratio of shot records input to Full waveform inversion (FWI).

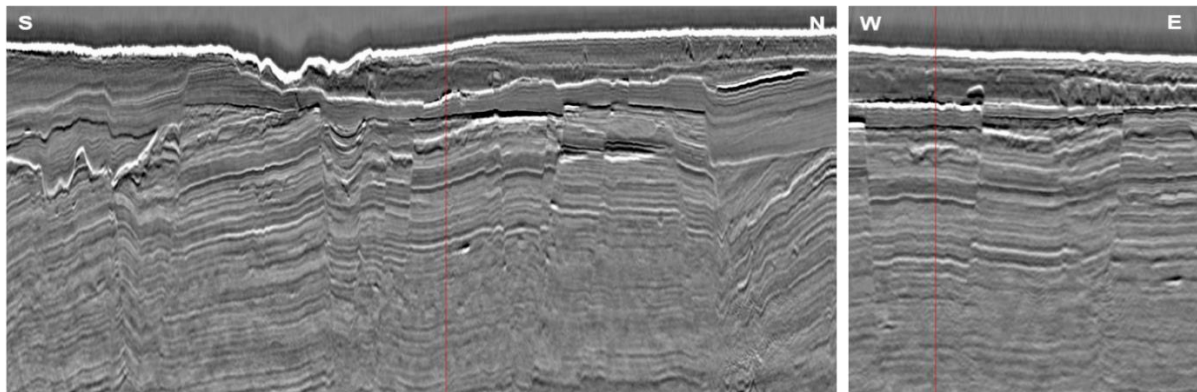


Figure 6. Fast-track PSDM QC stack after demultiple (400-1200 ms TWT), inline (left) and crossline (right). The stack is obtained using data with offset from 50 m to 275 m. Acquisition footprint is negligible and fine details are present up to the water bottom reflection (white) at the top.

Conclusions

A high density streamer survey was acquired with a novel ultra wide-tow penta source in the Barents Sea in 2020. The resulting data is sampled very densely in all directions and has high trace density also for the nearest offset. Acquisition efficiency was not compromised compared to a triple source survey. Fast track processing – following an advanced deblending step - generated high quality images of the subsurface, even with simplified processing. Although the survey was acquired with relatively small source volumes, the high trace density and good spatial sampling enables good signal-to-noise ratios. Continuous progress is being made in the industry to further develop advanced integrated acquisition designs, which are highly flexible and cost efficient, as well as their corresponding imaging solutions.

Acknowledgements

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