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A Novel Source-Over-Cable Solution to Address the Barents Sea Imaging Challenges; Part 2, Processing and Imaging Results

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Summary

This paper is the second part of two papers presenting the new source-over-cable marine acquisition solution. It presents the actual large-scale ~1950 km2 marine seismic acquisition as well as discusses the novel processing and imaging involved with this unique split-spread towed marine data. The acquisition setup consisted of a streamer vessel towing 14 streamers trailed by a shooting vessel in the middle of the streamer spread allowing for both positive-, zero- and negative-offsets to be recorded.
Fast track migrations along with early QC and initial demultiple results from the new source-over-cable acquisition data, indicates that the new data delivers on its promises of superior image quality. The benefits are drawn from a multitude of new aspects such as but not limited to split-spread source-over-cable acquisition, dense streamer spacing and deep towed zero- and near-offset recording of energy from the new triple wide-tow-sources with very dense shot point interval using dithered overlapping shots.

Introduction

Recent development in marine towed seismic acquisition in the Barents Sea has so far culminated with the introduction of the source-over-cable acquisition method. The method described by Vinje et al 2017, known as TopSeis, involves a two-vessel setup, deep towed streamers and a wide tow triple source firing its sources in the middle of the streamer spread, immediately above the streamers. The setup is unique in many ways and provides marine towed streamer seismic with access to split-spread near- and absolute zero -offset data. This feature of marine towed seismic has been a desire for many years and as such is a fundamental advance for the industry. This paper will present the recent acquisition of ~1950 km^2 of the new data as well as discuss the unique possibilities with processing and imaging of this type of split-spread marine data. Figure 1 shows a photo from the first ever large-scale source-over-cable acquisition. The streamer vessel is barely visible far in front (approximately 3.5km) of the source vessel close to the horizon. She is towing 14 streamers of 7km length. The streamers are towed directly underneath the sources and the source vessel, capturing all the near- and zero-offset energy. The source vessel is using a new compact wide tow triple dithered source with only 8.33m shot point interval. The high density of shots can be seen from the close spacing of white air bubbles in the water trailing behind each source in the photo.

Figure 1: *Source vessel shooting over the seismic cables in the Barents Sea. (Photo courtesy, CGG). The streamer vessel can be seen in front of the source vessel, close to the horizon. She is towing 14 streamers of 7km length. The source vessel is towing a new compact designed triple-wide-tow source with only 8.33m shot point interval.*

Full scale acquisition of source-over-cable marine seismic data

The acquisition commenced in July 2017. A total of more than ~1950sqkm was swiftly acquired in just over two months. Despite this survey being a new and relatively un-tested concept the acquisition went flawlessly with minimal technical and weather downtime. The acquisition setup consisted of a streamer vessel towing 14 streamers trailed by a shooting vessel in the middle of the streamer spread. In order to maximize the near-offset illumination both the cable separation and sail line separation were small. Then, to further reduce the crossline bin size, three wide-tow sources were used. This configuration provides very high fold and excellent near- and zero-offset coverage. Figure 2 shows an early three-dimensional shot QC display. The nature of the split-spread 3D configuration is clear. In a normal conventional type acquisition, less than half of this is acquired and there is never any near- and zero- offset data recorded.

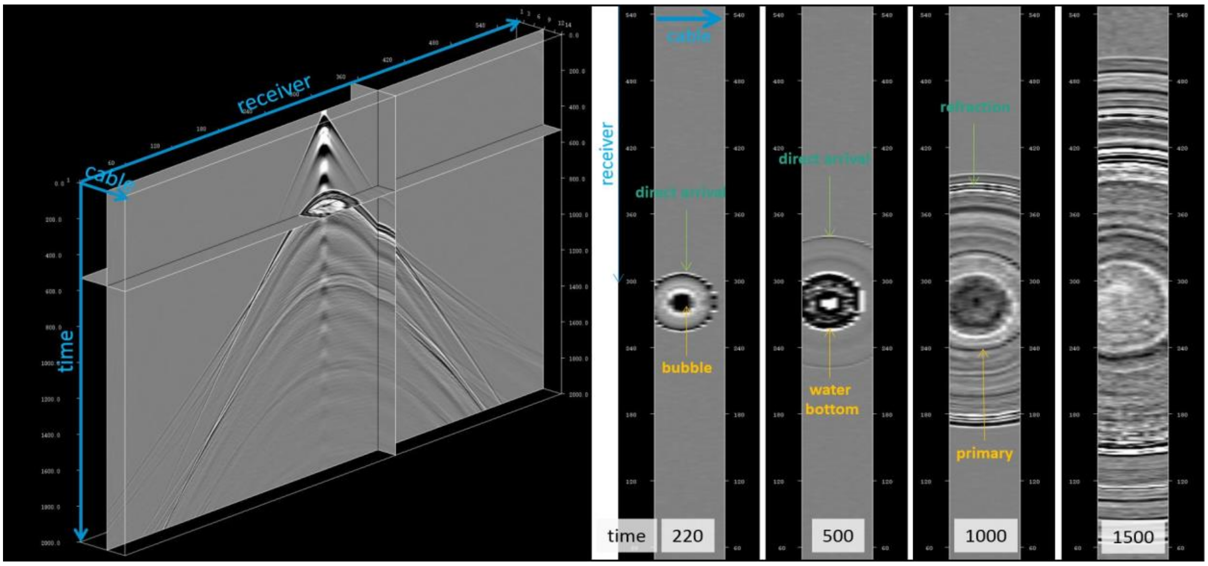

Figure 2: *An early 3-dimensional look at the raw recorded shots gathers. The right part of the figure are time slices through the shot.*

Processing of source-over-cable data

Processing of this new Barents Sea split-spread source-over-cable data has recently started so only preliminary results are available. However, the new method lends itself to some expected benefits in terms of the special characteristics of the data and how individual processes in the flow can benefit from it. Table 1 shows a list of some processing steps and unique characteristics and how we expect to draw benefits from each of them.

Processing step	Source-over-cable characteristics	Processing benefits
Deblending	Dense shooting coverage Blended data	Uniform near offset distribution High fold
Debubbling	Symmetrical offset distribution due to split-spread	Well recorded bubble energy
Denoising	Deep towed near offsets Symmetrical offset distribution	Cleaner near offsets, less swell noise. No windowing effect in shot domain
Deghosting	Direct arrival entirely recorded Very dense cable separation Special slanted streamer shape	Source and receiver accurate re-positioning. Dedicated 3D deghosting Receiver notch diversity
Demultiple	Full near- and zero-offset coverage Triple wide tow sources Full azimuthal near offset distribution	Recorded near-zero and negative offsets Higher definition multiple model Smaller bins and offset classes
Regularization	Natural small and “square” bin size Full azimuthal near offsets	Improved S/N ratio on all offsets Excellent near offset distribution – and possibilities for full azimuthal binning
Velocity model building	Full 3D recorded curvature of seismic events Denser source/receiver lines	Better estimation of velocity and anisotropy Full coverage of incidence angle
Reservoir characterization	Full 3D recorded curvature of seismic events Denser source/receiver lines Deeper average cable depth	Redundant incidence angle for constrained gradient Direct measure of intercept Strong signal low frequencies for inversion

Table 1: *Overview of key processing steps and how characteristics of the new acquisition design benefits in the processing flow.*

Imaging of seismic data from the Barents Sea has always been a prolonged battle against water-bottom generated diffractions and multiples due to the very rugose and hard seafloor. The new data with split-spread nature, access to near- and zero-offset data as well as its extremely high density and excellent distribution of shots and receiver locations, now eases this effort. Figure 3 and 4 show preliminary result of the demultiple process. Even after extensive efforts with conventional seismic, the initial results obtained from only a few multiple models with the new data are quite impressive, in comparison.

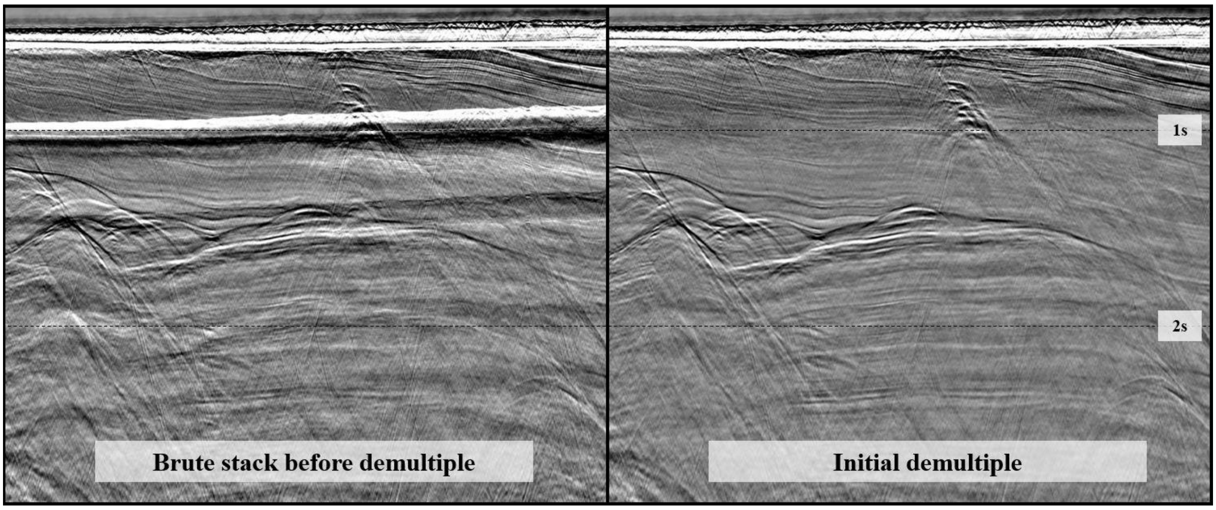

Figure 3: *Brute stack before and after preliminary demultiple testing on the new data. The results are impressive, despite only very limited testing. The inherent access to near- and zero-offset data makes the multiple models fit the real data to a higher degree, than for conventional data.*

Figure 4 shows gathers from the same line as in Figure 3. The split-spread nature of the data is a fundamental benefit, specifically as there is no need for any extrapolation of near- to zero-offset data. Out-of-plane diffractions are also capture in full 3D and as such can be modelled and subtracted easily.

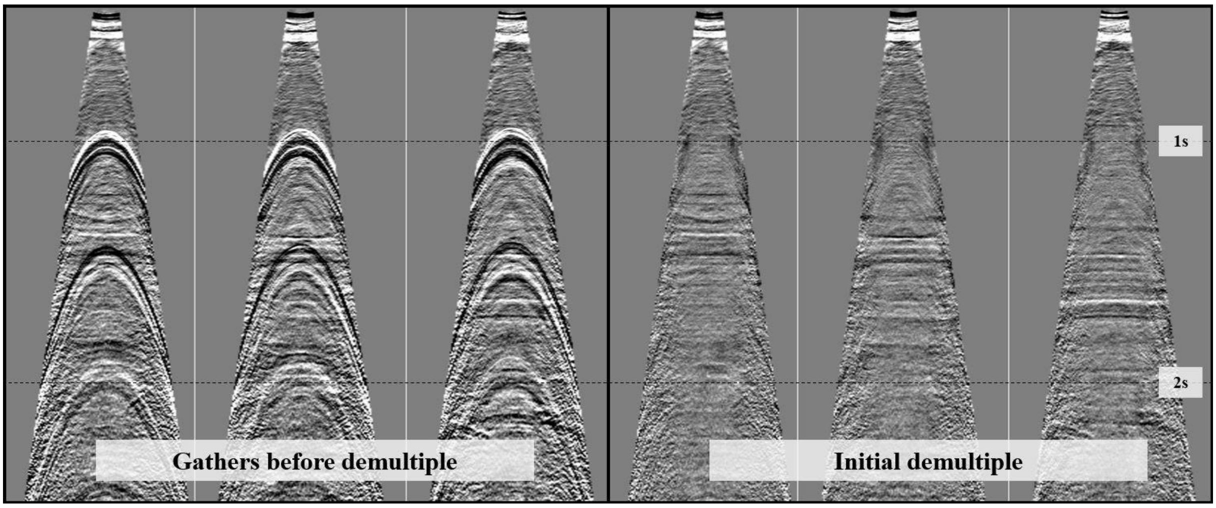

Figure 4: *Gathers from the new split-spread source-over-cable data, before and after initial demultiple.*

Overall, the new data is huge step forward in terms of overcoming fundamental imaging challenges present in the Barents Sea. Figure 5 shows a migrated image comparison between existing legacy data and the preliminary new data. Even at this early stage in the processing project, the new data is a clear improvement over the legacy data.

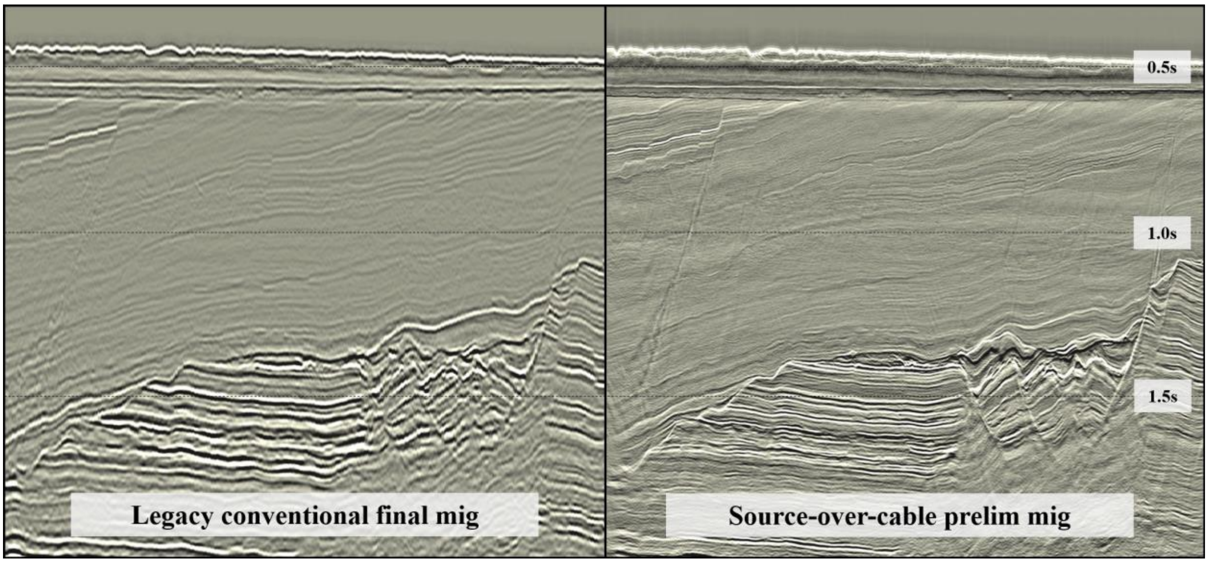

Figure 5: *A preliminary 3D migrated image comparison between legacy data (left) and the new source-over-cable data (right). Notice the improved details in the new data.*

Conclusion

Fast track migrations along with early QC and initial demultiple results from the new source-over-cable acquisition data, indicates that the new data delivers on its promises of superior image quality. The benefits are drawn from a multitude of new aspects such as but not limited to split-spread source-over-cable acquisition, dense streamer spacing and deep towed zero- and near-offset recording of energy from the new triple wide-tow-sources with very dense shot point interval using dithered overlapping shots. Processing of the new data is currently ongoing. The very small bin size achieved from this new setup (6,25 x 8,33m) along with very high fold is already giving seismic images with very high degree of details, both spatially and temporally.

Acknowledgements

The authors would like to thank the crews onboard the Geo Coral and Geo Caspian for the swift and high-quality seismic acquisition they performed. We would also like to thank staff at CGG Oslo, Massy and Crawley for their relentless efforts in planning, modelling and refining the solution until it achieved its current design. Finally, the authors would like to thank their partners AkerBP, DEA, Idemitsu and Petoro as well as Lundin Norway for permission to publish this material.

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