Nearer, Denser, Longer

With a smarter solution for resolving mixed depth targets in the Barents Sea, PGS expects beds as thin as 8 m to be resolved for Realgrunnen Subgroup.

Ultra-dense 16 x 56.25 m streamer spread combined with a triple-source for high-resolution imaging. Three 10 km long long-offset tails were deployed for FWI and imaging of deeper structures.

PGS is currently processing an ultra-high density seismic dataset from the Norwegian Barents Sea with the aim of producing breakthrough images of both shallow highs and deeper basins, as well as a foundation for detailed stratigraphy and reliable AVO analysis.

In 2018, Ramform Atlas acquired the 4200 sq.km PGS-TGS JV multi-client program with a novel, high-density, variable streamer length solution over parts of the shallow Finnmark Platform and the deeper Hammerfest Basin.

The survey area contains targets on the basin flanks and platforms, with additional exploration potential in the basin. This presents a challenge for seismic imaging, as surveys are usually designed for optimum imaging of a certain stratigraphic unit, with a slight degradation of the data elsewhere.

In this case study, we demonstrate how a smart acquisition solution, coupled with high-end imaging technology made it possible to create a high-quality dataset that meets all requirements for this mix of target depths: dense sampling, with sufficient near-incidence angle coverage to preserve the high frequencies for detailed stratigraphy and reliable AVO analysis; plus long offsets for imaging and accurate velocity analysis of all targets.

High-density Seismic Acquisition

Barents Sea case studies, like the group shoot program in the Barents Sea South East (2014), demonstrated that frequencies in the range from 2-200 Hz contribute to high-resolution images of shallower plays. Preservation of the recorded high-resolution frequency content throughout a 3D imaging workflow requires much denser spatial sampling than is typical for seismic exploration surveys.

The design for this exploration survey followed the principles and concepts outlined in the publication by Widmaier et al. (2017). PGS towed a narrow, high-density 16 x 56.25-meter multisensor GeoStreamer spread. The dense streamer spread was combined with a triple source configuration resulting in a natural acquisition bin size of 6.25 m x 9.375 m. The triple source set-up was actuated with a pop interval of 12.5 m to ensure good shot-point sampling in all domains where signal processing is applied. Proprietary shot-dithering technology enabled advanced deblending in the processing stage.

The tow depth for the multisensor GeoStreamers spread was 25 m. The deep tow provided a high signal-to-noise ratio of the low frequencies for **Full Waveform Inversion** (FWI) and Quantitative Interpretation (QI) work, while the use of multisensor GeoStreamer guaranteed the recording of true broadband receiver-ghost free data.

The streamer spread design was a first, using variable cable lengths tailored to meet advanced imaging and velocity building objectives and optimal utilization of the seismic vessel's streamer inventory. The high-density 16 x 56.25-meter spread was maintained up to 7 km offset, to enable high-resolution imaging and angular coverage at all target depths. The densely sampled near offset range also supports imaging of the near surface with multiples, as demonstrated in recent Barents Sea case studies by Rønholt et al. (2015).

Three of the 16 cables had an extended cable length of 10 km, i.e., the vessel deployed a high-density spread with sparser long offset tails. These tails provide long offset refracted energy for FWI velocity model building at all target depths.

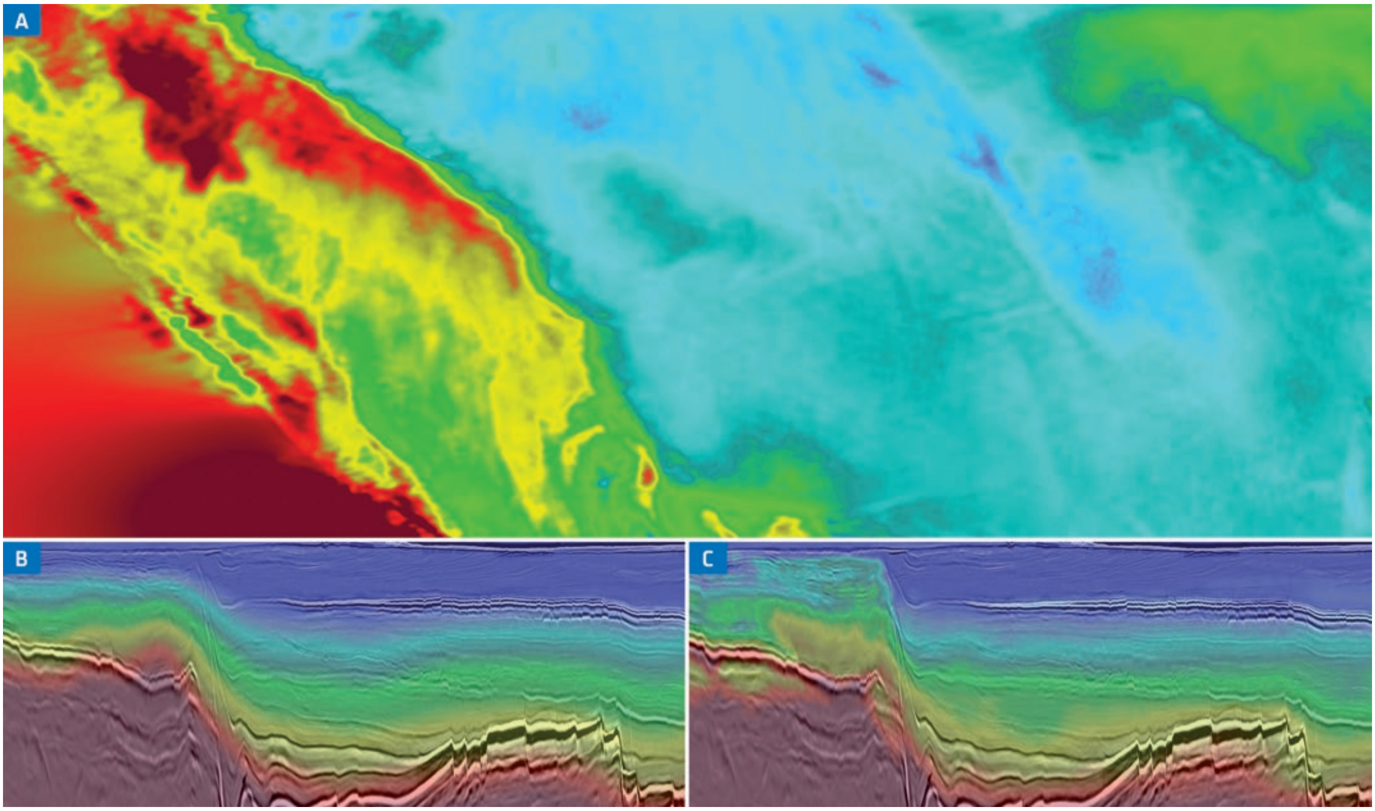
Another special feature of this survey was the set-up of the streamer front ends. The inline offsets were as short as 88 m and further optimized by staggering the streamer fronts (U-shaped) around the location of the seismic sources.

The survey is unique in terms of spatial sampling, streamer spread design and offset ranges provided for large-scale exploration surveys. It is the first time that a seismic vessel has towed 10 km long streamers on a 3D survey offshore Norway.

Early results

The Finnmark Platform and the Hammerfest Basin exhibit large lateral velocity variations. However, as a starting point for FWI a low wavenumber velocity model was constructed that included a smooth transition between the two geological regimes.

FWI was started at frequencies as low as 2-4 Hz and used a maximum offset of 7 km for the first pass. Only refracted events have been selected in the inversion and once a sufficient match between recorded and modelled shots



Depth slice of the 15 Hz FWI velocity model (a) at a depth of 1 km. Beam migrated inline stacks with initial (b) and FWI (c) velocities overlaid show the structural consistency of the updates.

was achieved, the frequency range was gradually increased to 2-15 Hz.

The figure above shows examples from the initial and final FWI velocity models. The updated model shows the delineation of the high-velocity Finnmark Platform, which is further described by large velocity variations within itself. The Hammerfest Basin on the other hand is defined by a more uniform velocity distribution with some pronounced lower velocity zones and faulted structures, which are clearly visible on the depth slice (white arrows in the figure above).

For the shallow updates down to approximately 2.5 km depth, a maximum offset of 7 km has been used. The additional recorded long offsets allowed us to build a high-resolution velocity model to ~5 km depth. As FWI utilizes raw input data, the migration velocity model can be built at the very early stage of an imaging project. This velocity model not only helps to improve the quality of the data, it also includes valuable information in terms of reservoir characterization. Low velocities can be an indication of porous sands, karstified carbonates, hydrocarbons or high-porosity areas in general.

An example of the Fast Track Imaging achieved with this particular acquisition configuration is shown in the figure below. The results so far are very encouraging. For the final, **Full Integrity Imaging**, we expect the densely recorded data and the detailed velocity model to resolve sedimentary beds as thin as 8 m for the Realgrunnen Subgroup .

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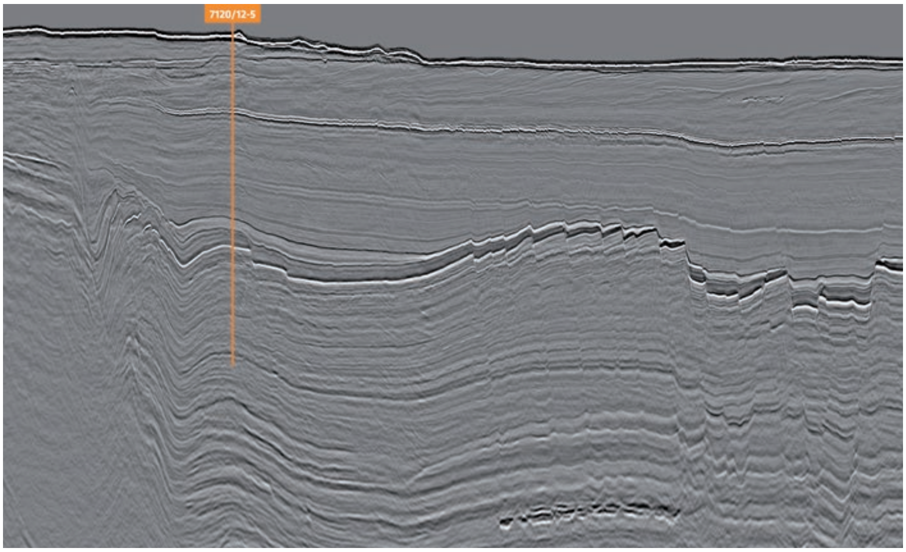

Fast Track PSTM example. Inline through well 7120/12-5 illustrating the Hammerfest Basin on the right and the Finnmark Platform on the left. The Permian structure seen in the platform area is expected to be much improved for the final, Full Integrity PSDM.