Diving deeper to reveal hydrocarbon potential in the Barents Sea

The south-western Barents Sea is characterised by a complex geological regime with a heterogeneous overburden. A key challenge in producing an accurate image of the subsurface lies in creating a velocity model which describes the recorded data well. Refraction-based Full Waveform Inversion (FWI) has become the standard tool for high resolution velocity model building in the Barents Sea. Nevertheless, due to the lack of recorded long offsets, model depths have been limited to the shallow overburden in the past.

In 2018 PGS and TGS utilised a novel acquisition setup for acquiring an ultra high density 3D seismic dataset in the Barents Sea, covering parts of the Hammerfest Basin and Finnmark Platform. In addition to 16 densely spaced streamers, three streamers were extended from 7 km to 10 km length, allowing the recording of deeper diving waves (refractions) and thereby enabling FWI to produce velocity updates to greater depths.

Seismic section (initial fast track Kirchhoff prestack depth migration) extending from the Finnmark Platform in the south-west into the Hammerfest Basin in the north-east. The initial depth migrated fast track data shows clear improvements in resolution and structural imaging compared to vintage data available in this complex area.
An unusual acquisition configuration resolves the challenges of the Barents Sea through an innovative combination of streamer setup and advanced imaging technologies.

The Barents Sea is one of the remaining frontier exploration areas on the Norwegian Continental Shelf (NCS); it accounts for around half of the undiscovered resources on the NCS, according to the Norwegian Petroleum Directorate. In order to fully explore the exploration potential and to understand these frontier areas, high quality seismic data are required. PGS has added a unique ultra-high density streamer dataset to their Barents Sea data library, utilizing an innovative acquisition solution to enable PFI and high resolution imaging of this complex area.

Hammerfest Basin (Figure 1).

Figure 2: Fast track KPSTM stack with FWI velocity overlay through the Goliat reservoir (A) and the corresponding gas cloud (B). Velocity depth attribute (B) that show a clear delineation of the carbonate trend (B). The high resolution depth velocity model enables a more accurate imaging of the subsurface without being biased by distortion effects caused by the shallow heterogeneities overburden. Both the velocities and the resulting imaging provide further insight into the reservoir.

An example of the FWI velocity model around the Goliat field is shown in Figure 2. At the reservoir level, the model shows deep low velocity anomalies, potentially indicating a porous and hydrocarbon filled mud and shale in the shallower overburden above the reservoir; a gas cloud can be clearly identified well above the velocity model considering well data and amplitude brightening on the underlying stack. On the velocity depth slice, it is obvious how FWI clearly delineates the actual extent of the gas cloud above parts of the Goliat Field. The detailed and large velocity contrasts captured in the depth velocity model allow a better imaging of the subsurface without being biased by distortion effects caused by the shallow heterogeneity overburden. Both the velocities and the resulting imaging provide further insight into the reservoir.

Detecting Potential Hydrocarbon Plays
FWI velocity updates do not just provide a migration velocity model to enable accurate imaging of the subsurface, the result around the Goliat field demonstrates the ability of FWI to capture small-scale velocity anomalies which are potentially associated with hydrocarbon accumulations. Figure 3 highlights a section area around Top Realgrunnen as a depth of around 2.5 km (inset of fold out line on previous pages). Within such fault-block, low velocity zones are present at the top of the structure. These anomalies velocity correlates well with the seismic attribute showing high and bright areas associated with a possible fluid accumulation in fault transected by the heterogeneous overburden.

Refraction FWI for Detailed Velocity Models
In the Barents Sea, the combination of relatively shallow water depths and rugged terrain may cause a tremendous amount of noise. This complicates the use of conventional imaging techniques for velocity updates. On the other hand, this geological setting promotes relatively strong and stable reflection behavior which allow robust refraction based FWI results to be achieved. Details about the workflow and approach were described in previous papers by conventional seismic, and allows the performance of absolute seismic impedance inversion. In addition, several studies indicated FWI include valuable information in terms of reservoir characterization.

High velocities can be an indication for accumulations of salts or hard, rugose sea floor creates a tremendous amount of noise. This complicates the use of conventional imaging techniques for velocity updates. On the other hand, this geological setting promotes relatively strong and stable reflection behavior which allow robust refraction based FWI results to be achieved. Details about the workflow and approach were described in previous papers. Although FWI results can be interpolated into a quantitative interpretation (API) workflow, in the absence of any direct well information, the derived FWI velocity grid can be utilized as a low frequency model within a seismic attribute workflow. The long tails in the acquisition configuration enable deeper refraction FWI, lifting the gap between 0 Hz and the lowest frequencies provided by conventional seismic, and allows the performance of absolute seismic impedance inversion. Furthermore, the velocities derived from FWI include valuable information in terms of reservoir characterization. Low velocities can be an indication for porous sands, karstified carbonate, hydrocarbon, or high porosity areas in general. PGS considered imaging needs when designing this acquisition configuration to fulfill the best solutions were provided to resolve the challenges of the Barents Sea using an innovative combination of streamer setup and advanced imaging technologies.

Figure 3: (A) FWI velocity model overlaid on a KPSDM stack and (B) KPSDM stack showing reflectivity and velocity anomalies correlate well and this can be an indication of increased fluid accumulation. Figure 4 shows velocity extractions at different stratigraphic levels, including Top Kolmule and Top Realgrunnen. These velocity attribute maps highlight the spatial distribution and, in combination with the seismically derived, several areas of anomalous low velocity zones within the reservoir are correlated with potential structural closures. The detail in the FWI velocity model provides a more complete view into geology and hydrocarbon plays. Thanks to the additional long-offset streamers and therefore acquired model depth, detailed attribute maps can be extracted for both shallow and deep target horizons.

Figure 4: Fast track 3D VSP stack with FWI velocity overlay through the Goliat reservoir (A) and the corresponding gas cloud (B). Velocity depth attribute (B) that show a clear delineation of the carbonate trend (B). The high resolution depth velocity model enables a more accurate imaging of the subsurface without being biased by distortion effects caused by the shallow heterogeneity overburden. Both the velocities and the resulting imaging provide further insight into the reservoir.

FWI results can be interpolated into a quantitative interpretation (API) workflow, in the absence of any direct well information, the derived FWI velocity grid can be utilized as a low frequency model within a seismic attribute workflow. The long tails in the acquisition configuration enable deeper refraction FWI, lifting the gap between 0 Hz and the lowest frequencies provided by conventional seismic, and allows the performance of absolute seismic impedance inversion.

In addition, several studies indicated FWI include valuable information in terms of reservoir characterization. Low velocities can be an indication for porous sands, karstified carbonate, hydrocarbon, or high porosity areas in general. PGS considered imaging needs when designing this acquisition configuration to fulfill the best solutions were provided to resolve the challenges of the Barents Sea using an innovative combination of streamer setup and advanced imaging technologies.

GEOExPro© June 2019 - 23

The GeoStreamer survey was acquired during the June 2019.

...