Tu P3 01

Broadband Processing of P-Cable Data in the Barents Sea

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SUMMARY

The P-Cable system is an efficient method of acquiring high resolution 3D seismic data and this has recently been used extensively in the Hoop area of the Norwegian Barents Sea. Source and receiver depths around 3 m resulted in the data being deficient in low frequencies. This reduced the bandwidth and hence the resolution of the final conventional product. The data recorded were very densely sampled in the inline, crossline and time dimensions, but the native CMP fold and the range of offsets were poor. This resulted in a low signal-to-noise ratio in the final stack.

These issues were successfully addressed in processing. The ghost notches were handled by a deghosting technique extending the low frequencies from 50 Hz down to below 8 Hz. On the 2D data a shot stack, rather than a CMP stack raised the fold to 128 and this was used to deliver a high signal-to-noise section. On the 3D data a post-stack frequency dependent radial mix and FXY deconvolution achieved similar results.

Having produced a high bandwidth, high resolution dataset the geologists were able to produce a much more detailed interpretation and even use the data for detecting potential geohazards.

Introduction

Data acquired using P-Cable 3D seismic acquisition has become a valuable, proven technology yielding ultra-high resolution seismic. Since the Wisting oil discovery, Barents Sea exploration has expanded to even shallower targets. As a direct result, higher temporal and spatial resolution seismic data is necessary. P-Cable data, coupled with TGS's Clari-Fi™ broadband processing technique enables these shallow targets to be resolved. The examples below are from the Hoop area of the Norwegian Barents Sea.

P-Cable has a history stretching back about 15 years. The concept was first field tested in 2001 and a prototype system was built by the National Oceanography Centre, Southampton in conjunction with P-Cable 3D Seismic three years later (Planke and Berndt, 2004; Figure 1). Development continued in both the academic and industrial environments with a new generation system in 2010. This new commercial system was developed in collaboration with Geometrics Inc. and acquired its first survey for Tullow Oil. The location of the first commercial acquisition was in the Barents Sea and this was performed by WGP. This was followed by the first multi-client survey in the Barents Sea in 2014. This was a joint venture between WGP and TGS.

Method

The P-Cable method allows the collection of high resolution 3D data in an efficient manner. Figure 1 shows a typical layout with a single source and several mini-streamers hung from a cross-cable. The cross-cable is tethered to two paravanes and thus maintains an approximate catenary. A typical towing depth for the airgun array and the mini-streamers would be about 2 m, and the range of offsets would be from 120 to 175 m. However, this range of offsets is by no means continuous on all sub-surface lines formed by one sail line. Due to the shape of the cross-cable and the position of the source the maximum offset on an outer cable is less than the minimum offset of an inner cable.

For the Hoop surveys, both the 2D swaths and the 3D mini-surveys, the acquisition set up consisted of 16 mini-streamers each containing 8 groups at 3.125 m spacing. For all surveys the cable separation was 9.5 m. Data were recorded at 0.5 ms sample rate with a record length of 2 s. With a single source array and a shot interval of 12.5 m the natural CMP fold was 1. This had some implications for processing.

The acquisition set up for the 2D and 3D was identical in that data were recorded from the 16 mini-streamers for both. The 2D lines were narrow swaths of 16 subsurface lines. These 2D lines snaked between areas of interest designated by the interpreters and they were used to determine the locations of the 3D surveys which were conventional in their style of acquisition. The total volume of P-Cable data acquired in 2014 in the Barents Sea was 575 km^2 , this comprised six small 3D surveys ranging in size from 18 to 185 km^2, plus three 2D swaths linking possible targets.

The processing of these data followed TGS's Clari-Fi™ (Masoomzadeh and Woodburn, 2013) sequence in order to provide broadband dataset to the interpreters. The source ghost was at approximately 300 Hz (source depth of 2.5m) and the receiver side ghost was at 250 Hz (receiver depth of 3 m), both towards the upper end of the frequencies expected. However, it is from suppressing the ghosts at 0 Hz that the biggest extension of the bandwidth in octave terms is expected. The very shallow shot and receiver depths meant that the low-end ghost effects could be seen well above 50 Hz (probably above the peak frequency of some conventional seismic data) and the depth of the notch was approximately 20 dB relative to the peak of 100 Hz. One of the key aspects to producing a good broadband section was to correctly handle the deghosting in terms of both amplitude and phase at the 0 Hz notch as well as the higher frequency notches.

The data received from the field crew was in SEG-Y format where the trace co-ordinates and offsets had been calculated and put in the headers. The co-ordinates were calculated by using the GPS positions of the buoys, and the shape of the cross cable (assumed to be a catenary). The processing of the 3D P-Cable data went through a fairly conventional proprietary deghosting route (see Figure 2). The broadband technique has been covered by others previously so that will not be repeated here.

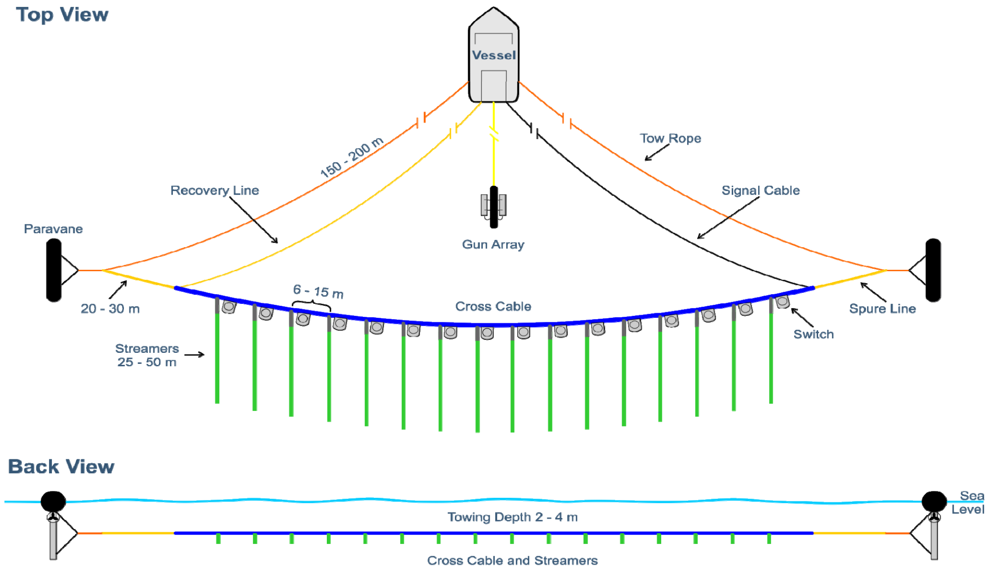

Figure 1 *Example layout for P-Cable acquisition (courtesy of P-Cable).*

The 2D data were processed in a similar fashion but rather than producing CMP stacks, shot stacks were created. If subsurface lines were stacked with a CMP spacing of 6.25 m then the fold would be 4. Two versions of the shot stacks were produced; the first version stacked the traces from the inner two cables and the second version stacked all traces from the 16 cables. This produced stacks with a 12.5 m trace interval and folds of 16 and 128. The extra traces in the second stack significantly helped the signal-to-noise ratio but at the expense of some of the fine detail. The shot stacking helped solve one of the inherent problems of this acquisition, the low fold.

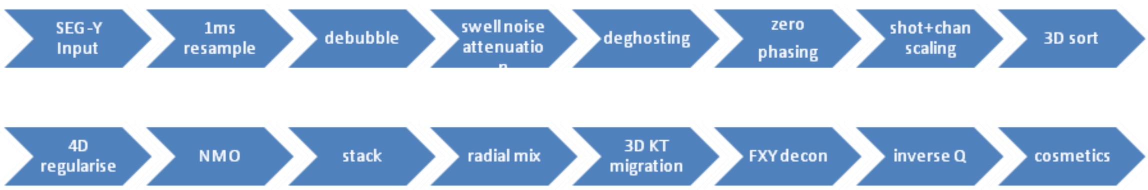

Figure 2 *Outlining the processing flow for the 3D P-Cable data.*

The 3D data after 4D regularisation produced a stack with a CMP fold of 4. This stack did have some problems with the level of random noise. The goal for the 3D data was to produce a section that demonstrated the benefits of both the 16 and 128 trace shot stacks on the 2D data. This was achieved by doing a frequency-variant 3D mix. At the high frequencies the mix was 1-by-2 (1 trace inline and 2 crossline giving a mix over 6.25 x 9.5 m) while at the low frequencies it was 23-by-31 (143.75 x 147.25 m). This mix was found to provide better results when applied post-stack but pre-migration. The FXY deconvolution after the 3D migration also contributed to the improvement in the signal-to-noise ratio.

For each of the 2D or 3D datasets a fast-track volume was delivered as well as the fully processed data. The fast-track had limited noise attenuation and no broadband processing. Figure 3 demonstrates the amount of low frequencies recovered by the application of the proprietary deghosting. Additionally there is an increase in bandwidth at the high frequencies.
Observations demonstrate that conventional 4ms processing contains a frequency content between 5 and 65 Hz, while 2 ms broadband processing of conventional data expanded bandwidth from 3 to 120 Hz, conventional processing of the 1 ms P-Cable data had frequencies between 20 and 200 Hz and the broadband processing of the 1ms P-Cable data delivered frequencies between 8 and 275 Hz. The extra

bandwidth on the broadband processed P-Cable data provided the geophysicist with considerably more resolution as shown.

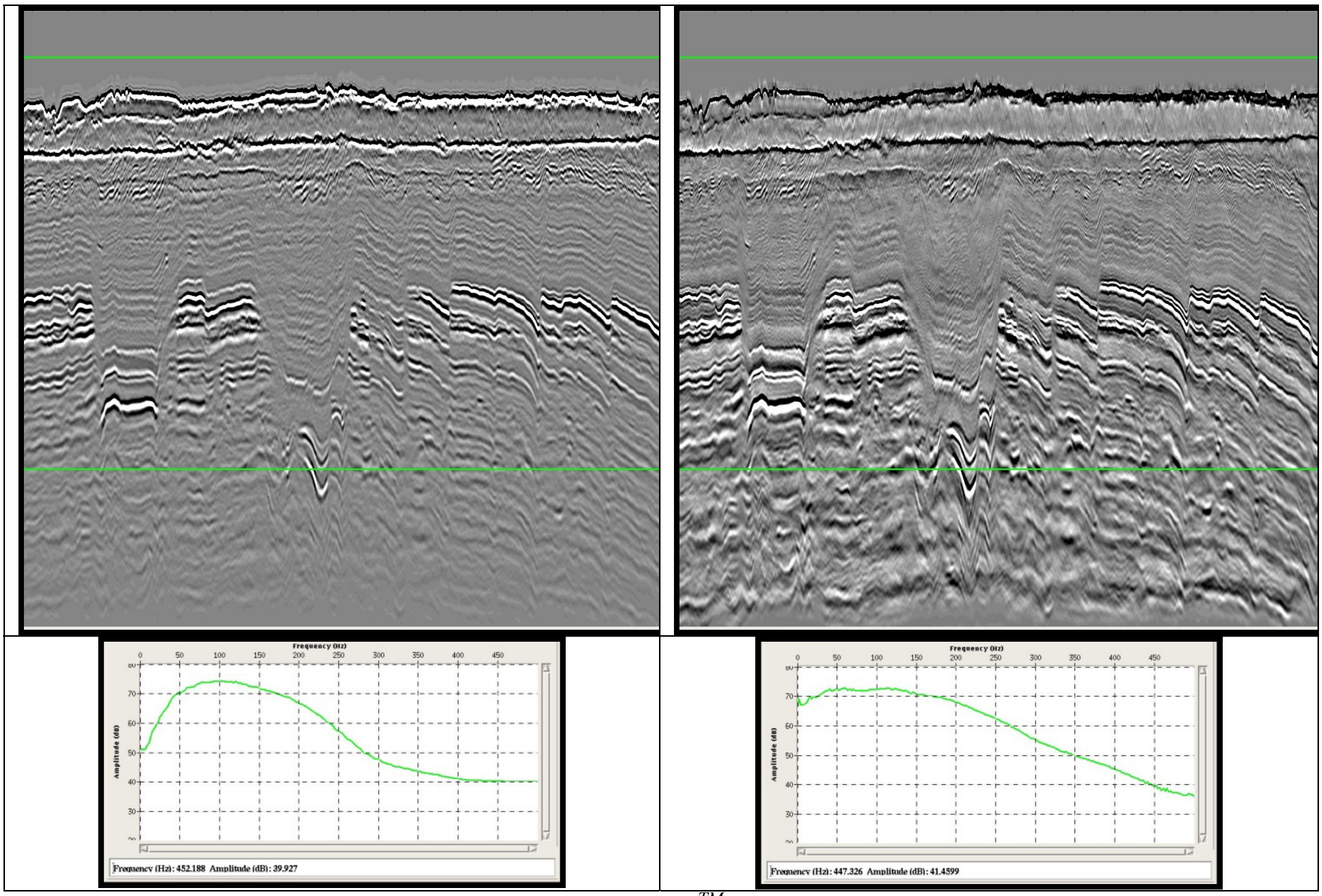

Figure 3 *P-Cable data without (on left) and with Clari-Fi™ (on right) and their respective spectra (data courtesy WGP/TGS).*

Results

The example shows an interpretation of Cretaceous strata in the area towards the Fingerdjupet area (as shown on the insert map in Figure 4). On this western side of the slope the Cretaceous sequence thickens considerably to the west down to Fingerdjupert. To aid the interpretation of the Cretaceous, the top Jurassic has been flattened. The Barremian coastal prograding units can be worked on in greater detail on the high resolution P-Cable data than on previous datasets. The interpreted foresets seen on conventional data (yellow) are in fact only the top layer sets or sequence boundaries. Between these we can interpret the steeper, true foresets (red) and these are the real prograding system.

Another example of the fine detail obtained can be seen when looking at the Snadd formation. The channel systems in Snadd are well known, but the P-Cable data reveals them in greater detail. The greater resolution of the P-Cable data has also allowed interpreters to see what is probably gas hydrates and also free gas below that. The 2ms broadband conventional data shows the gas but not the possible hydrates (Eriksen *et al*., 2014), whereas the P-Cable data shows both.

Conclusion

P-Cable data processed using a deghosting technique such as Clari_Fi™ has been shown to provide the interpretation geophysicist with very high resolution data which can aid in the understanding of the geology.

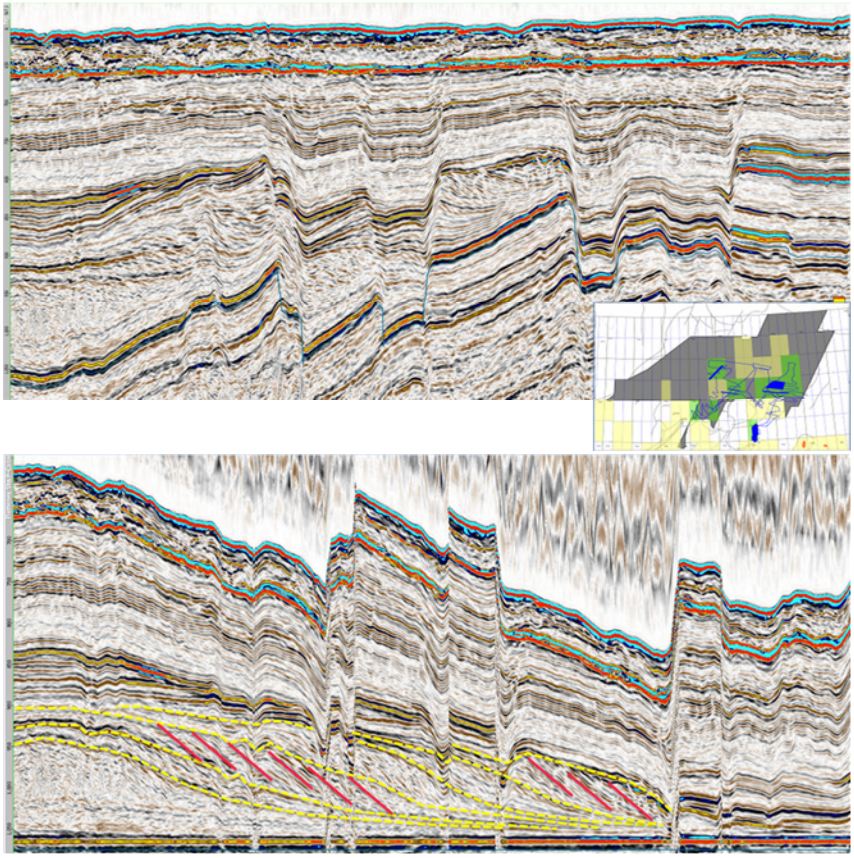

Figure 4 *True Barremian foresets revealed on P-Cable data (data courtesy TGS/WGP) where the data has been flattened to top Jurassic.*

Acknowledgments

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