Reservoir Detection and Delineation Using Towed Streamer Electromagnetics

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SUMMARY

Following a period of almost a decade, a commercial version of the Towed Streamer EM System was tested over a number of producing fields in the Norwegian and British sectors of the North Sea in October 2012. One of the most challenging tests was over the Alvheim Boa field located 2,100 m below the seafloor. The results demonstrate the system can be used effectively for reservoir detection and delineation.

A new processing technique to enhance the sensitivity of CSEM data to a resistive reservoir anomaly is especially suited to the towed streamer EM system. Known as optimised Synthetic Aperture (SA) processing, when applied to the data acquired at the Alvheim Boa field, it resulted in significantly improved signal strength.

Introduction

Conventional controlled source EM (CSEM) data acquisition is based on stationary nodes emplaced on the seafloor that record the signal emitted from a deep-towed source moving at low speed (Ellingsrud, 2002). The nodes are typically placed in a line or grid patterns on the seafloor approximately 1 km apart, and when the survey is finished they are recalled to the surface, collected, and the data is downloaded for processing and analysis. The obvious drawbacks are low efficiency and sparse sampling, combined with the inability to quality control the data until the survey is finished. The low efficiency is a characteristic of all node-based acquisition methods, and this provided a strong incentive to engineer a more efficient system.

A first generation commercial system for towed streamer electromagnetics (EM) offers greater efficiency of recording and denser data sampling than conventional node based controlled source EM. Because of the high cost of conventional CSEM, it has been used mainly in deep water where the very high well costs motivates additional de-risking of prospects. With the much lower operating cost of the towed streamer system and the very dense sampling, prospects in shallow water Shelf Areas are now considered suitable targets to be evaluated. Existing and assumed fields can be evaluated to demarcate the lateral economic boundary of the hydrocarbon charge, and also to identify satellite deposits next to the main field. A grid of in-line surveys are acquired to build a 3D image; the grid spacing required to create a 3D image is much sparser than a seismic grid due to the much lower spatial resolution of EM.

The towed EM streamer system

The new towed streamer EM system is based on the marine seismic layout as shown in Figure 1. The EM source is an 800 m long bi-pole towed at 10 m transmitting a source signal of 1,500 Amperes. The streamer has effectively 26 offsets with the last one at 7,700m. Signal-to-noise ratio (SNR) is well maintained throughout the length of the streamer by varying the receiver bi-poles in length from 50 m for the nearest offset to 1,100 m for the longest offset. In addition, effective noise reduction processing that takes advantage of the spatially dense data sampling further improves the SNR. The resulting data density is similar to 2D seismic. The system is designed to work in water depths of 400 m or less, and the acquisition speed is 4–5 knots. Deeper waters would decrease the transmitted electric current energy too much for the system to be efficient for deep targets. However, resistivity characterization of targets is still possible in water depths larger than 400 m, provided the target is large, has a high transverse resistance, and is located shallow below mudline. The imaging is very different from seismic though. Shallow targets are optimally imaged with high frequencies and short source – receiver offsets. Deep targets are best imaged with low frequencies and long offsets. The concept is illustrated in Figure 2.

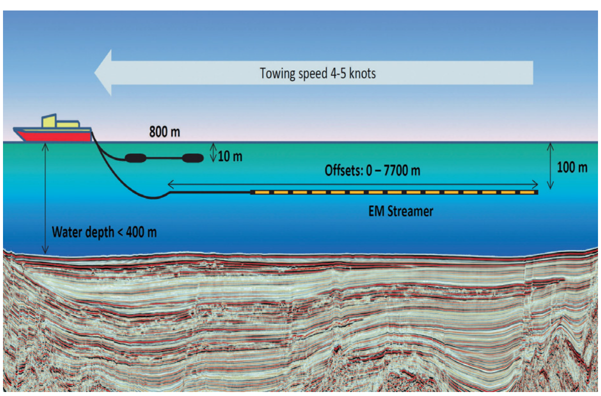

Figure 1 *The Towed Streamer EM acquisition system. The source bi-pole is towed at 10 m and the EM streamer at 100 m or less. The receiver bi-poles are 50–1,100 m long with the length increasing with increasing offset.*

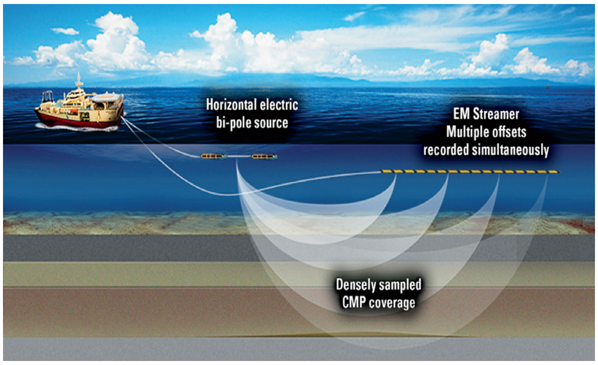

***Figure 2** The source and receiver layout emulates seismic acquisition resulting in dense cmp sampling.*

A challenging test: The Alvheim Boa Field

Located 2,100 m below the seafloor, the Alvheim Boa field (Figure 3) is a medium sized oil and gas field that has been in production for some years, and approximately half of the recoverable oil has been produced, but the gas cap is still intact. The reservoir thickness is shown in colour and the depocentre where the reservoir reaches maximum thickness is the red area immediately west of the survey lines. The suboptimal location of the survey lines was dictated by permitting restrictions and existing platforms in the area.

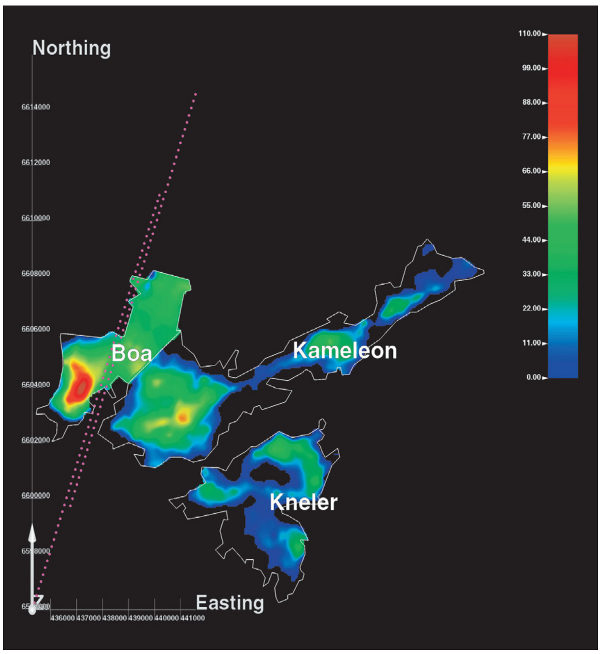

***Figure 3** The reservoir thickness in metres mapped from seismic. The depocentre of the Boa reservoir is seen as the red area immediately west of the two survey lines shown as red dotted lines.*

Synthetic Aperture (SA) processing

A new processing technique to enhance the sensitivity of CSEM data to a resistive reservoir anomaly in shallow waters was published last year by Fan et al. (2012). It is known as synthetic aperture (SA) processing. It can be described as a way to focus the transmitted energy on the target to boost the sensitivity. After evaluation of the technique, we found ways to improve on the original concept that was designed with conventional node-based systems in mind, where the moving source is shooting into stationary receivers. We refer to the improved method as optimised SA, where we take full advantage of the fact that we sort the data into common mid-point for further processing. When it was applied to the data acquired close to the Alvheim Boa reservoir, the nonoptimised SA processing resulted in a signal strength of 7–8 % above background as seen in Figure 4. The optimised SA processing resulted in a sensitivity increase up to 200% above background as shown in Figure 5.

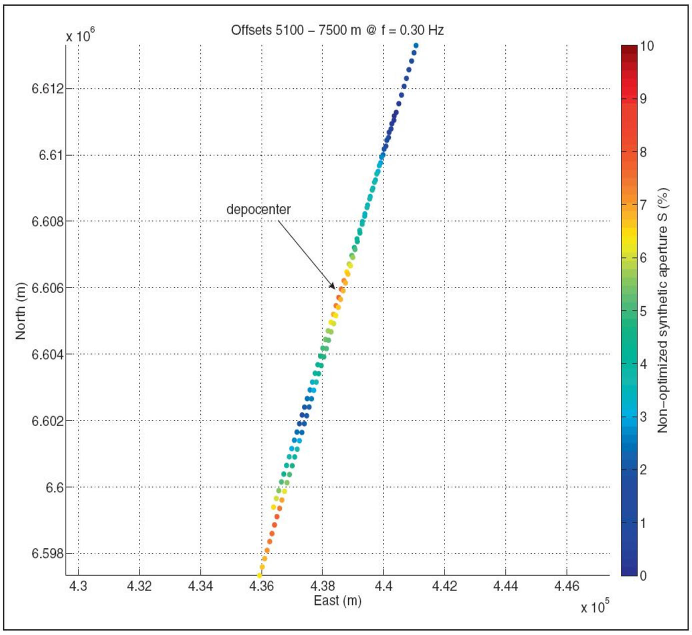

Figure 4 The non-optimised synthetic aperture signal for offsets between 5.0 and 7.5 km along the survey lines results in a maximum anomaly originating in the depocentre that is 7–8 % above background.

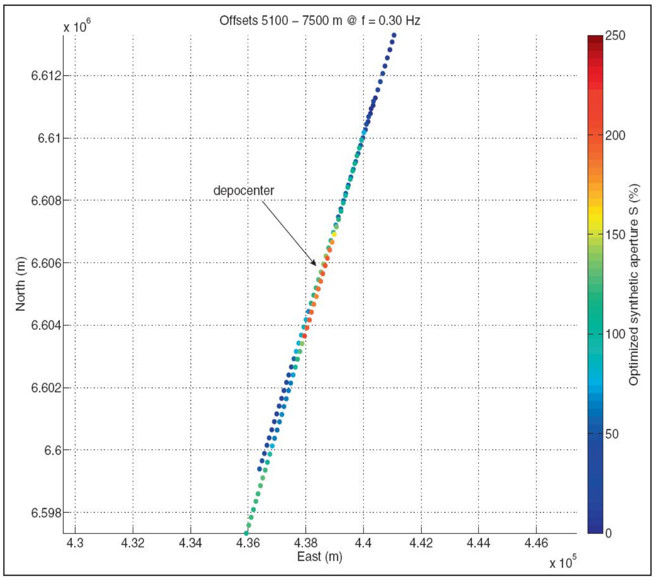

Figure 5 The optimised synthetic aperture signal for offsets between 5.0 and 7.5 km results in a maximum signal that is 200% above the background. Notice also how the red coloured anomaly in the SSW area seen in Figure 5 has been de-emphasised in strength and reduced to green and light blue colours.

An additional advantage with the optimised synthetic aperture is that it de-emphasises other minor anomalies of no interest making the background appear less noisy. The peak signal in both lines is achieved over the depocentre, indicating the signal originates in the reservoir. Also, the optimum frequencies and offsets are consistent with an anomaly at this depth. In addition to boosting the signal from the target, other lesser anomalies in the vicinity are de-emphasised due to the selective target focusing of the optimised SA. This is seen most clearly in the reduced signal variation towards the SW end of the survey lines.

Conclusions

The towed streamer EM system is an evolutionary step change in the acquisition and processing of marine CSEM data. It is a new and more efficient way of conducting surveys that after years of research, development and testing has finally come to fruition as a commercial offering. The ideal markets for this first generation system are the shelf areas where water depth is limited to 400 m, and a target depth that is within 2,500 m below mudline. In addition to evaluating oil and gas fields, monitoring of carbon dioxide injection is a suitable application. The data is acquired inline and 3D images are created by shooting in a grid pattern. Simultaneous acquisition of 2D seismic data from the same vessel is also facilitated in areas where 3D seismic is not available.

The very dense spatial sampling offered by the towed streamer system is ideal both for noise attenuation through stacking, and for synthetic aperture processing that can substantially boost the sensitivity, and also improve spatial resolution.

Acknowledgements

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References

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Fan Y., Snieder R., Slob E., Hunziker J., Singer J., Sheiman J. and Rosenquist M. 2012. Increasing the sensitivity of controlled-source electromagnetics with synthetic aperture. *Geophysics* **77**(2), E135–E145.